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THE USE OF COMBINED APPLICATIONS OF LIQUID FERTILISERS AND SELECTIVE WEED KILLERS ON CEREALS

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Summary Little critical evidence relating to the practice of combining the application of herbicides and fertilisers into a single operation appears to exist. Observations based on supervised trials are presented together with an account of the commercial experiences of a number of farmers operating this practice. The conclusions drawn are discussed.

INTRODUCTION

There is no need to stress the considerable advantages to be gained from a farm management point of view if it can be made a practical proposition to combine two farming operations into a single task. The possibility of doing this in the case of liquid fertiliser use and spray chemical application has interested many farmers over the past few years.

As with many newly developing practices there are advantages and disadvantages, and in deciding upon the feasibility of the project, these must be weighed and assessed before proper decisions can be reached.

The advantages of joint fertiliser/herbicide application centre mainly on economic considerations, which involve an examination of factors such as labour saving on a single as opposed to two or more operations. The more economic use of capital equipment is important, and the dovetailing of two time consuming operations during periods of intensive farming activity considerably reduces problems of planning, especially where labour problems are acute.

Technical advantages may also accrue such as the reduction of soil compaction consequent upon one set of wheelings rather than two; neither can the possibility of synergism be completely ruled out as biological systems have growth responses which are closely related and interdependent.

The potential disadvantages are not so clearly defined and in many instances may be more conjectural than real. The necessity for compromise in the timing of a mixed application, when the normal time of application of fertiliser does not coincide with the optimum time for herbicide application, presents a problem. Chemical and physical incompatibilities also may cause alterations to the effectiveness of both fertiliser and herbicide.

Chemical interaction between the two classes of material can be to a large extent predicted, but changes in the physical state of the herbicide, whether it is formulated as a solution, suspension, or emulsion, may be induced by mixing with a solution of high salinity. Effects such as salting out, coagulation, or cracking of emulsions are likely, and these will undoubtedly influence biological activity.

Review of current knowledge

Firm recommendations can only be made with confidence if there is available a fund of real knowledge of all aspects of the problem, and it is a matter of concern that so little attention has been paid to what could be an important technological advancement.

In endeavouring to review the prospects and progress of joint liquid fertiliser/herbicide application in this country there appears to be only one published scientific paper. Thorne (1957), working at Rothamsted compared the effects of top dressing wheat either with solid fertiliser or nitrogen in solution, with and without 2,4-D. She found that the interaction between weed killer and method of applying nitrogen was small, but at the same time observed that the spray applied nitrogen was less efficiently used than top dressed solid nitrogen, and because of this concluded that the spring top dressing of nitrogen with a weedkiller would be undesirable in practice.

Since 1957 it has become clear that the margin of differences in the uptake of nitrogen by a crop when applied either in the form of fertiliser in solution or as a crystalline or granulated solid is not as pronounced as was found by Miss Thorne, and her conclusion is, therefore, not universally valid.

The only other references in this country to the practice of combined applications take the form of journalistic articles in farming or commercial magazines which, in general, suggest that the practice is to be encouraged.

American literature shows the same pattern, with many "reports" or articles which do not attempt to give any quantitative appraisal of comparative yields, with the exception of a paper by Klingman and Stevens (1960) who showed that 2,4-D can be mixed with nitrogen fertiliser solution without detriment to yield. Their experiments were made in weed free plots so as not to confuse the results by weed competition.

In spite of the lack of precise knowledge relating to the potential usefulness of the application of mixtures, the practice amongst farmers appears to be growing. The author is indebted to Messrs. J. W. Chafer Ltd., for permission to examine the records of a number of farm trials carried out during 1967 under their auspices and these are summarised below.

Supervised trials

The pattern of the supervised trials which were carried out on cereal crops with the full co-operation of the farmers concerned was as follows:-

Adjacent plots 100' x 25' separated by a guard strip 3' wide were marked out within fields of winter wheat var. Cappelle. One plot received a nitrogen top dressing in the form of a commercial liquid fertiliser timed in accordance with normal practice. This plot was separately sprayed with herbicide, again in accordance with normal practice. The second plot not having had a prior fertiliser dressing received a combined spray of fertiliser and herbicide at the same time as the herbicide was applied to plot one. The remainder of the field acted as control.

The fertiliser used was a 24% W/W nitrogen solution which incorporates urea and ammonium nitrate. One hundredweight occupies a volume of nine gallons and it was applied through spray jets without dilution.

The herbicides, C.M.P.P. diluted 1 in 40 and dichlorprop + 2,4-D diluted 1 in 54 were applied at rates equivalent to 1 gallon and 4 pints of the commercial products per acre respectively.

The weed populations were assessed by counts made in random quadrats (2' x 2'), average heights and percentage ground cover were estimated and the weed condition was arbitrarily scored for the dominating weed species.

Trial 1

Morton Fen

Fertiliser rate:	60 units N per acre ≡ 22.5 gallons
Herbicide:	C.M.P.P. (35 oz. mecoprop K salt)
Application dates:	April 11 - fertiliser
	April 27 - herbicide
	April 27 - combined
Height of crop at application:	8"
Stage of growth:	Tillered

Weed Assessment:

Treatment

		Separate			Combined			Nil*
Weed	Date	H	GC	S	H	GC	S	H
Cleaver	27.4.67.	7"	10%	6	8"	15%	6	8"
	30.5.67.	12"		3	12"		5	24"
	26.6.67.	12"		1	36"		5	39"
Control			good			slight		
Chickweed	27.4.67.	3"	30%	6	9"	60%	6	9"
	30.5.67.	6"		1	12"		5	15"
	26.6.67.	-		½	18"		3	Sm
Control			good			satis		
Mayweed	27.4.67.	4"	30%	6	4"	20%	6	4"
	30.5.67.	4"		3	5"		6	13"
	26.6.67.	-		½	12"		3	28"
Control			good			satis		

H = height, GC = ground cover, S = score
*Nil = no herbicide; Sm = smothered

Trial 2

Finningley

Fertiliser rate:	72 units N ≡ 27 gallons
Herbicide:	dichlorprop/2,4-D
Application dates:	April 12 - fertiliser
	May 9 - herbicide
	May 9 - combined
Height of crop at application:	9"
Stage of growth:	Tillered

Weed Assessment:

Treatment

		Separate		Combined		Nil*
Weed	Date	H	S	H	S	H
Mayweed	9.5.67.	5"	6	2"	6	5"
	25.5.67.	5"	4	4"	5	8"
	21.6.67.	6"	1	6"	2	25"
	4.8.67.	-	-	9"	2	31"
Control		good		satis		
Wild Pansy	9.5.67.	2"	6	1"	6	2"
	25.5.67.	2"	4	3"	4	-
	21.6.67.	2"	1	9"	3	16"
	4.8.67.	4"	2	13"	3	18"
Control		satis		satis		
Knotgrass	9.5.67.	3"	6	2"	6	
	25.5.67.	3"	3	3"	4	
	21.6.67.	-	0	6"	2	
	4.8.67.	-	0	6"	3	19"
Control		good		satis		

Trial 3 Horncastle

Fertiliser rate: 96 units N ≡ 36 gallons
Herbicide: C.M.P.P.
Application dates: April 11 - fertiliser
April 24 - herbicide
April 24 - combined
Height of crop at application: 14"
Stage of growth: Jointing

Weed Assessment: Treatment

		Separate			Combined			Nil*
Weed	Date	H	GC	S	H	GC	S	H
Cleaver	24.4.67.	19"	40%	6	9"	50%	6	12"
	4.5.67.	14"		4	12"		5	NR
	24.5.67.	15"		4	18"		5	25"
	24.6.67.	14"		2	12"		2	NR
	12.8.68.	17"		1	39"		5	60"
Control			satis			poor*		
Chickweed	24.4.67.	8"	10%	6	8"	5%	6	8"
	4.5.67.	11"		4	12"		5	NR
	24.5.67.	10"		3	13"		5	15"
	24.6.67.	9"		1	NR			NR
	12.8.67.	NR			NR			NR
Control			satis			poor		

NR = not recorded
* rain fell 5 hours after spraying

Incidental to another trial on spring wheat being carried out near Loughborough analagous observations were made on plots which had received 60 units of nitrogen per acre with and without 4 pints dichlorprop + 2,4-D. At the time of application (11.5.67.) the main weeds present were; mayweed (4"), knotgrass (2") and chickweed (5"). 6 wks. after the spraying date the following data was recorded within random quadrats:

	Unsprayed			Sprayed		
Mayweed	36"	score	6	25"	score	5
Knotgrass	14"	"	6	Killed		0
Chickweed	24"	"	6	12"		3

At harvest all the weeds in the sprayed quadrat were dead. The unsprayed plot was very weedy although the weeds were not above the crop, with mayweed 36", knotgrass 17" and chickweed 26". It was noted there was a 2" reduction in crop height in the combined plot, which could possibly be attributed to the herbicides.

DISCUSSION

The observations referred to above provide prima facie evidence that an effective measured weed control can be obtained following combined herbicide/fertiliser applications. Although the efficiency of weed control in these trials was reduced, no noticeable reduction in crop yield or crop deformity was apparent although no measurements were in fact taken.

No comments have been recorded relating to crop scorch following combined applications although in one case fertiliser scorch was noted. Scorch does in fact occur and in this context the experiences of farmer users are of interest.

Specific comments were obtained from twenty-eight farmers on soil types ranging from light to heavy loams and including chalk soils, who were known to have used combined applications for the top dressing of cereals as a normal commercial practice. A total acreage of 3757 was involved in this sample survey. The nitrogen applications ranged from 30 to 72 units per acre, variously combined with M.C.P.A., 2,4-D, dichlorprop, 2,4-D/dichlorprop, C.M.P.P., 2,4-D ester and picloram. In the one case where picloram was used, bad scorch and poor weed control were experienced and in nearly all other cases crop scorch was noted to a greater or lesser degree. There appeared to be a slight correlation between the degree of scorch and the chemical used, but in all cases it was stated that the crop grew away and by harvest no detrimental effects were apparent.

An important factor known to influence crop scorch relates to spray pattern and droplet size and there is some degree of incompatability between the requirements for good fertiliser application and for optimum herbicidal effects. The former calls for a droplet large enough to bounce off the leaf surface and the latter small enough to be retained on the leaf. The ideal compromise remains to be determined but it is a prerequisite that the droplet pattern should be uniform. Non standard spraying is likely to cause variations which can be as great as the differences between mixtures.

CONCLUSIONS

Taking into account the empirical observations of the limited number of trials and the somewhat subjective comments of users, a number of "pointers" emerge which can be summarised under two main headings.

Factors leading to improved weed control:-

1. The use of spray jets capable of delivering a uniformly fine spray pattern with a minimum of coarse droplets.
2. Increase in the quantity of fertiliser applied.
3. Increase in the volume of application.
4. Close spaced drilling.

Factors leading to increased crop scorch:-

1. Increase in the quantity of fertiliser applied.
2. Choice of herbicide; a trend for C.M.P.P. to give greater scorch than 2,4-D/dichlorprop > 2,4-D.P.> M.C.P.A. appears to emerge.
3. Too fine a spray droplet size.
4. Low night temperatures and wind.
5. Too heavy a flag at time of application.

It can be seen that some of these factors are in conflict, but it seems a fair conclusion to suggest that the incorporation of the type of herbicides surveyed with liquid fertiliser does not in itself increase crop damage. This would appear to be the summation of the existing separate scorch effects. Field experiments to confirm this are however urgently needed.

Associated with this is the need for more information regarding critical temperature levels, wind speeds and atmospheric humidity effects.

This paper has considered mixtures of herbicides of the phenoxy type with liquid nitrogen fertilisers used for cereal top dressing, and emphasises the weakness of our real knowledge in quantitative terms of their effectiveness. Reports of other mixtures involving di- and tri- allate herbicides, D.N.O.C., T.C.A. and others used in different contexts appear from time to time and are equally lacking in quantitative analysis.

The establishment of mixed applications as economically sound and agronomically trustworthy field techniques requires a great deal of further research, conducted objectively and preferably within the framework of existing agricultural research institutes and organisations.

In particular there appears to be a need for the resolution of optimum times of application, which on the scanty evidence available appears to be coincident with the recommended timing for the herbicide when used alone.

A further pressing problem is that of spray pattern and droplet size. The compromise required to give a minimum crop scorch must be elucidated and this involves a study of the physical properties of mixtures with particular reference to surface tension changes produced as a result of mixing herbicide and liquid fertilisers.

A redefinition of the spectrum of weed control may be called for.

Many other problems will also arise, and if this review of our lack of knowledge of the subject serves to stimulate interest in further research into a practice which is becoming increasingly popular amongst practising farmers it will have served its purpose.

References

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SPRAY APPLICATION FOR THE CONTINUOUS CEREAL GROWER

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Summary In the absence of precise definitions in physical terms of the required nature of the deposit it is not possible to specify completely the problems to be solved. But it is evident that there is scope for improvement in the standard of uniformity of deposition. Studies have been made of the performance currently being obtained, and the contribution of various factors to the variations observed is under examination. These include individual nozzle performance, effect of combination of nozzles, boom bounce and whip, and wind. The occurrence of drift is another major problem; typical levels of drift deposit and their biological significance have been investigated as a basis for future fundamental studies of the processes involved. The logistics of large-scale, present-day spraying merits some study for possible influences on future sprayer design.

INTRODUCTION

This report refers briefly to some results of experiments carried out in the initial stages of a programme of work at the National Institute of Agricultural Engineering in which the engineering problems in the efficient application of herbicides are being studied. The emphasis at the outset is on the factors which influence the performance of the conventional farm sprayer in the application of herbicides overall to ground crops, typically cereals.

In attempting any comprehensive assessment of the performance currently being achieved in normal practice there is a basic difficulty in the inadequacy of existing information on the requirement, i.e. a definitive specification of the optimum nature of the deposit - or spray leading to that deposit. The determination of such specifications, with limits, must be a major objective of botanists and others engaged in weed control research and for this purpose they must have at their command the means to control and vary the physical parameters of sprays and deposits. Assistance to colleagues of the Weed Research Organisation with the more mechanical aspects of this features in the NIAE programme.

Until tolerances can be laid down, in the context of controlled spray parameters, for the eveness of distribution of material there is scope for improvement in the uniformity of distribution with present-day sprays and the influence of the factors concerned are under study.

With the recent considerable increase in cereal acreage (around 6% per annum,) and the continuing decline in the farm labour force, the farmer is in increasing difficulties to complete his spraying programme within the available period. Thus rate of work of a machine is of paramount importance and this is dependent upon boom width and forward speed whilst in work and on servicing and replenishment time and other factors also. Every possible opportunity to spray must also be taken and the major limiting factor here is probably the weather, and particularly wind, so that data on the occurrence and control of drift is an urgent requirement. The current tendency is to spray in conditions of higher wind speeds than were considered safe a few years ago.

The necessity to utilize every possible spraying opportunity has been accentuated by the closer tolerances on stage of growth imposed by some materials developed for the more difficult crop/weed situations. With the increasing importance of timeliness the influence of the various logistic factors on the proportion of useful spraying time is receiving attention.

Uniformity of distribution

The degree of success which may be achieved in laying down a deposit uniformly across a field with a conventional boom sprayer is subject to several influences and the assessment of this depends upon the sample area used for assessment. For the present purpose it has been assumed that the sample area need not be less than about 4 sq.in. nor should it be greater than 8 sq.in. Assessment of uniformity across smaller areas is in the realm of effect on biological response, about which there is at present insufficient data. The use of 8 sq.in. is commensurate with the area occupied by each weed, on average, weed populations now being commonly under rather than over 20 per sq.ft.

On this scale the uniformity of the deposit will be influenced by the distribution of material across the swath of each nozzle, by the uniformity between nozzles, by the effect of overlap of sprays from adjacent nozzles, by the effect of small wind eddies and gusts between the nozzle and the ground, by the height of the boom and by the forward motion of the boom. Variations on a swath-to-swath basis as for instance due to mis-matching of bouts or through major changes in wind direction or strength may also be detectable on this scale.

Some indication of the standard of performance of which modern sprayers are capable may be obtained from Reports of Tests carried out according to standardised procedures in this and other countries. A Series Test of six sprayers was carried out within the Users Testing Scheme at NIAE in 1963/4. The data given in Table 1 were extracted from the results of these tests. They show lowest and highest sample deposits expressed as percentages of mean deposit, on 4 sq.in. sample areas at ground level, without any crop cover, together with derived values of coefficient of variation.

Table 1

Machine	A	B	C	D	E	F
Lowest, %	41	29	43	45	21	43
Highest, %	159	171	168	162	244	163
Coeff. of variation, %	32	40	22	31	64	31

One may conclude that it is possible to obtain a variation with a new machine, as submitted by the manufacturers and operated by skilled personnel, from one quarter to two and a half times the mean deposit and that it is not uncommon for the deposit to vary from less than one-half to over one and a half times the mean.

Unfortunately no User Experience Survey was carried out on the above machines which might have provided a useful extension from the above results to some indicating the actual performance achieved by the same models of machine under practical farm conditions. However, a small pilot survey of farm sprayer performance was carried out in 1966. This covered six sprayers, not necessarily of the same makes or models as those tested in 1963-4. They were operated by the farm staff in the normal manner without any preparation or attention before the deposit measurements were made. The experimental techniques employed in this pilot survey did not afford a high standard of accuracy but the results summarised in Table 2, may be taken as a useful indication that many farm sprayers may actually be achieving a performance very much below the level of which they are capable. The assessment area for these measurements was 8 sq.in. The lowest values of deposit obtained in this survey were all well below those obtained with new machines and in two cases there were instances of no detectable deposit at all. Overdosing ranged up to 5 times the mean deposit.

Table 2

Machine	1	2	3	4	5	6
Lowest, %	0	22	14	8	0	16
Highest, %	408	405	332	275	498	185
Coeff. of variation, %	98	81	67	58	73	33

Because the sample of machines taken in this survey was small and two or three of the machines were obviously of some considerable age and in poor condition a larger survey was undertaken in 1967. This was arranged in co-operation with the NAAS Crop Husbandry Staff carrying out the NAE 30 survey on the efficiency of herbicide use on cereals. NIAE staff visited a 26-site sample of over 100 sites visited by NAAS and made more detailed measurements relative to the performance of the sprayers.

Throughput of all the individual nozzles were measured and coefficients of variation calculated. The occurrence of these is represented in Fig. 1. The average coefficient of variation was 9.3% and only four sites returned values above 15%. The greatest deviation of a single nozzle was 69% above and 36% below the means of the two machines concerned. The average maximum deviations above and below the means were 19.2% and 13.3% respectively. All the machines examined were operating with nozzles having nominal outputs below 30 gal/h and for these the requirement of the British Standard (B.S.S. 2968:1958) is that output of each nozzle shall be within ± 10% of the stated output. As it was not possible to identify all the nozzles precisely the above tolerances of ± 10% when applied with reference to the mean output obtained shows that on only 8 machines were all nozzles within the limits and on 2 machines there were more than half the nozzles outside the limits. In all, 418 nozzles were within and 67 nozzles outside the limits. For comparison, from the test results obtained with the nozzles of four of the new sprayers which underwent the Users Test, 190 nozzles were within and only 7 outside the requirements of the British Standard as quoted above for uniformity of output. It was not possible to examine the distribution patterns of the nozzles of the machines visited in the field but as an indication of the likely level of variations it may be noted that of the same 197 nozzles examined in the Users Tests, 98 did not conform to the British Standard requirement on distribution pattern.

Because the uniformity of deposit may be affected by many factors apart from nozzle performance, measurements were also made during the survey of deposits at ground level, based on a sample area of 8 sq.in. On each site there were between 125 and 150 samples positioned within one swath width and over about 35 feet of run. These areas were distributed along two transverse and three longitudinal lines of sampling points, relative to line of travel. Examination of the deposit values for the individual lines of sampling points shows that the average coefficient of variation is between 35 and 40% with maximum values between 75 and 92%. The deviations of the highest deposit in each line range between one fifth and about five times the mean. Whereas the greatest mean coefficients of variation were for the transverse lines, the greatest deviations were obtained in the longitudinal strips. The overall coefficients of variation for all samples at each site are depicted on an occuurrence basis in Fig.2. The average coefficient of variation over the 17 sites on which this technique was satisfactorily applied was 46.6%, 5 sites returning values above 70%, with the lowest coefficient of variation 19.3%. The greatest deviation of a single sampling point was 478.3% above and 48.5% below the mean deposits of the appropriate sites. There were no sites on which a nil value of deposit was found, the lowest being 13.3% of the site mean.

An attempt is currently being made to develop means to measure boom bounce and whip for investigation of any correlation with longitudinal variations in deposit. Such a technique will also be valuable in investigating the effect of various design factors on the magnitude of bounce and whip.

Spray Drift

The measurement of the amount of spray drifting away from a sprayer presents extreme difficulties in sampling and in interpretation. The collection and assessment of deposits is less difficult but correlation between deposits on natural surfaces and artificial targets may vary considerably with the shape, size and orientation of the targets and the nature of the surfaces. Previous work of this type has usually been in the context of applications by aircraft and much has been learnt. It has been shown that the subject is considerably more complex than can be covered by a treatment of the free fall of droplets through air moving in streamline fashion at a uniform velocity. Air movements of an unpredictable nature can have a predominant effect upon the motion and eventual fate of spray. The concept of the stability ratio of the atmosphere has been introduced as an aid to understanding the processes which occur. This depends on the difference in temperature and the mean air velocities at two heights above the ground. It helps to explain how drifting spray may be raised and carried for considerable distances to be deposited later by changes in atmospheric conditions or topography. It gives some indication, also, of the scope for studies of the factors giving rise to drift from ground machines.

In a preliminary experiment to determine some basic data on the typical levels of drift deposits resulting from ground spraying and their biological significance, appreciable deposits and plant response were recorded up to 200 yards downwind of a swath along which a conventional sprayer made two passes. Although such deposits did not exceed one three-thousandth of the nominal application rate under the sprayer, the relationships between deposit and distance from the sprayer were such that successive passes of the sprayer along swaths gradually approaching the measuring point could increase the deposit to more than one hundredth of the nominal dose when the sprayer is within 20 yards of the point. These experiments were carried out in conditions of fairly high wind speeds and it would be wrong to assume that such deposits would be proportionately reduced with lower wind speeds. The advice of many who have been called upon to act as assessors of drift damage would be that it is often safer to spray in a slight wind, blowing away from any susceptible crops, rather than when there is very little or no wind at all.

Reduction of drift would appear to depend therefore, not so much upon waiting for "suitable" wind conditions as upon control at the source by the reduction in the amount of spray formed as small particles having low kinetic energy towards their target in comparison with the various air forces which may come to act upon them. Sprays may be coarsened by the use of larger nozzles, by a modest reduction of pressure though this is limited at some stage by the collapse of the liquid sheet, or by alternative design of the nozzle so that it will continue to function satisfactorily at low pressures. However, whilst the basic prosess of spray formation remains the random breakdown of relatively high velocity sheets of liquid in passing through the air there will remain a substantial proportion of the material in fine drops, either as formed initially or by break-away as satellites from larger drops. This feature of the random process can be reduced to some extent by the use of particulating agents in the spray liquid, tending to hold the liquid together in larger drops, or by increasing the viscosity. This may be achieved by the addition of thickeners or possibly with more success by the use of invert emulsions of high water/oil phase ratio.

The best prospect for the elimination of the fine material from a spray may well be by the adoption of a fundamentally different process for dividing a bulk of liquid into drops. Devices to achieve this have already been extensively applied on aircraft, including spinning discs, cages and brushes, which have the characteristic of forming liquid filaments or threads without the earlier process of high velocity sheets. A similar philosophy underlies the development for ground machines of the Vibrajet, derived from the dribble-bar and the Vibro-boom. In these devices the division of the liquid arises through the inherent instability of a fine jet, as first propounded by Lord Rayleigh in 1878. This instability results from disturbances, the wavelength of which is linked to the diameter of the filament such that it breaks up in a regular manner and draws into drops of substantially equal size. In practice, the ideal is not achieved - some satellites may be formed and there is some variation in the main drop size but the proportion of fine drops is very small indeed. In the practical embodiment of the principle the fine holes emitting the filaments of liquid are vibrated laterally to obtain an adequate distribution of the material over the target area but the extent to which this vibration may have an influence on the actual formation of the drops has still to be examined in detail. It would appear that the predominant factor in determining the size of the drops formed is the size of the hole - this would accord with theory.

The reduction of the small material in the spray by use of this process may be illustrated by the results of a brief experiment in which the drop spectrum obtained from a single vibrating hole was compared with that of the coarsest spray previously commercially produced, i.e. by a low-pressure deflector nozzle. The vibrating jet consisted of a 0.025 in diameter hole in the end of a fine stainless steel tube fed at 3 lb/sq.in. and vibrated laterally at 903 cycles/min by a mechanical drive. The mass median diameter of the spray was just under 1200 microns and there was only 1% of the total volume smaller than 500 microns. With the deflector jet the mass median diameters in two tests were about 600 and 800 microns and the volumes below 500 microns were 37 and 24%, with more than 1% below 100 microns.

The premium that must be paid by the adoption of such a process to reduce the drift-proneness of spray is a very much reduced "cover" for a given rate of application - which may be acceptable with adequate translocation - or alternatively the use of a higher application rate to obtain a "cover" equivalent to that traditionally considered necessary - which may also be proved necessary biologically. This latter is contrary to the trend of the last decade towards low volume spraying, the average rate of application in the 1967 survey having been $17\frac{3}{4}$ gal/acre. This points to the urgent need for basic data on the "cover" requirement to meet particular situations. The very considerable effect of drop size on "cover" can be judged from the fact that if 10 gallons is the rate applied on each acre by sprays consisting entirely of drops of 50 micron diameter or 500 micron diameter, the first will result in 17,000 drops on each sq.cm whereas there will be only 17 of the larger drops per sq.cm.

Selectivity

The control of weeds in cereals is probably becoming more dependent upon chemical selectivity than in the past, with the increasing seriousness of grass-type weeds. However, the influence of application parameters on selectivity cannot be overlooked. If for other reasons the distribution of drop size may be changed in the future, it will be essential, as already mentioned, that the biological effect of such changes should have been fully investigated. In the same way, it may be that the maintenance of the correct application rate within closer limits may be of greater importance. In the 1967 survey the actual, measured application rates were compared with the rates the operators claimed to be applying. More operators (71%) were underdosing than were overdosing. The average underdose was 15.7% and the maximum 59%, whilst the average overdose was 18.3% and the maximum 80%. Whether errors of this order constitute adequate evidence to support a case for changes in machine design to afford closer control of application rate will depend upon results coming forward demonstrating their biological significance.

Field Procedures

It is evident that boom bounce and whip must contribute to variations in density of deposit and it may be expected that this errant behaviour of the boom will be exaggerated by higher forward speed and that the effect will be greater with longer booms. In the 1967 survey the average forward speed was 4.6 mile/h and the maximum and minimum speeds 10 and 2.75 mile/h. 14% of the sprayers seen were travelling at speeds over $5\frac{1}{2}$ mile/h.

The most common boom length was 30 feet - accounting for 9 out of 26 machines - with a further three of greater length, one being of 48 feet. The trend towards longer booms will continue but the full benefit will be obtained only if means are developed to assist operators to obtain a high standard of swath matching. This is more difficult to achieve with long booms when the "by eye" method of driving is adopted and there is a tendency for there to be a more generous overlap, to be "on the safe side". On one third of the sites visited on the survey the swaths were actually not being overlapped at all, the greatest error being a 12% missed width. The greatest overlap was 10%; one of two at this value was the 48 foot boom. This would appear to support the pleas so frequently made for the development of improved swath-marking systems. A recent development along these lines is the foam blob system.

Whilst the above factors have a bearing on the actual rate of work achieved whilst spraying, a very considerable factor is the time spent in non-spraying activities. Prominent among these must be the filling and mixing, which, in general, is done in the sprayer tankful by tankful as required. Where considerable areas have to be covered there must be scope for worthwhile reductions in unproductive time by the adoption of bulk mixing in tankers, which may be carried out either before spraying can be commenced for other reasons or by another operator whilst spraying continues. Furthermore, the sprayer may be taken out of work for a refill at the headland rather than in mid-field when the tank is completely empty, so reducing ferrying distances.

A natural development from the concept of bulk mixing is that of metered mixing on the sprayer, the tank of which then has only to be filled with water. The chemical, carried on the sprayer in the container in which it is supplied, is transferred and admitted in the correct proportion in the flow passing to the nozzles. One can foresee some design problems in putting this into effect but advantages in terms of accuracy of application, rate of work and safety should make it worthy of study.

Following on from the reference to the development of swath marking systems it is interesting to speculate on what might be involved in a system which would permit spraying to be done at night - assuming other conditions to be suitable. This would increase the time available very considerably. It presupposes the availability of relief operators prepared to do this and the fact that it could be shown to be economically sound in comparison with the purchase of an additional sprayer for daytime use.

Evaluation of the merits, or otherwise, of these points, whilst dependent upon some engineering effort to make it possible, is an agronomic and economic study rather than engineering research. It also requires the co-operation of some large-scale operators who are prepared to make the necessary departures from current practice.

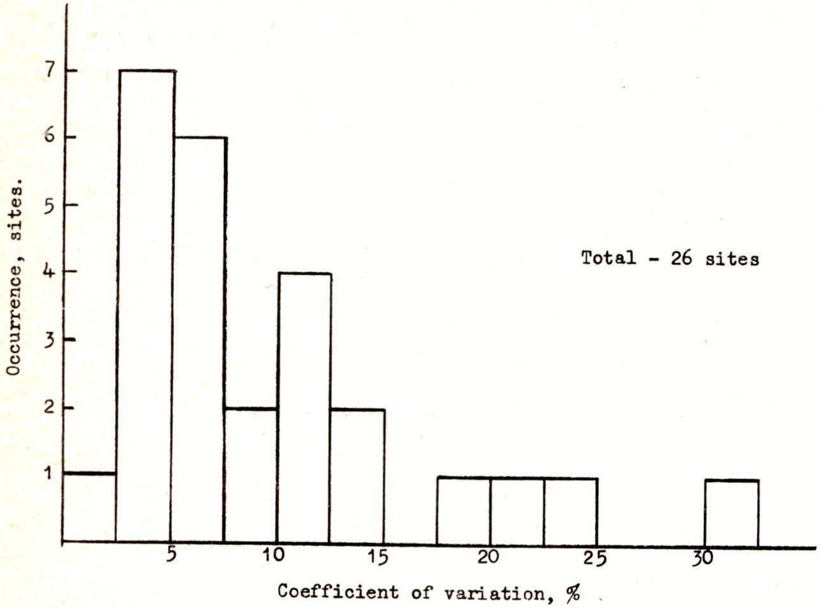

Fig. 1. Coefficient of variation of nozzle throughputs

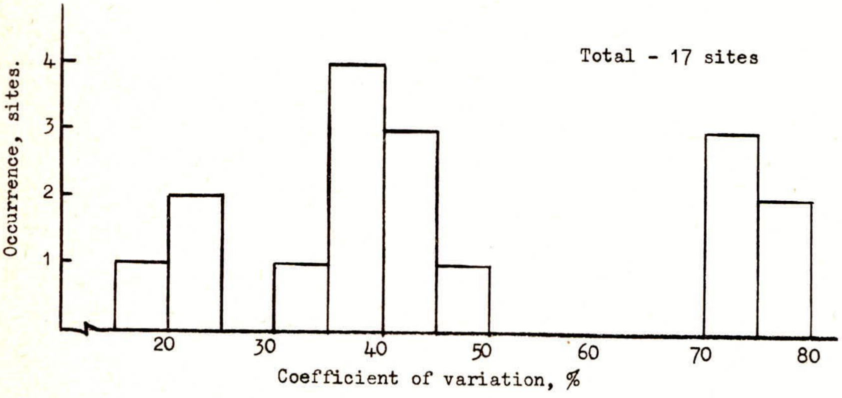

Fig. 2. Coefficient of variation of deposit

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FURTHER DEVELOPMENTS ON THE USE OF THE HYDROXYBENZONITRILES IN SPRING CEREALS

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Summary Trials carried out in the U.K. in the last two years have shown that mixtures of esters of ioxynil and bromoxynil can be used to control a broader spectrum of weeds in spring cereals than equivalent doses of either ioxynil or bromoxynil alone.

In extensive replicated and farm user trials carried out in 1968 it has been shown that a mixture giving 2 oz bromoxynil + 3 oz ioxynil + 6 oz 2,4-DP esters per acre controlled important weeds of spring cereals including Polygonum spp., Mayweeds and Stellaria media and was generally superior to mixtures giving 4 oz bromoxynil + 4 oz MCPA, 2 oz bromoxynil + 3 oz ioxynil + 4 oz MCPA, or 4 oz bromoxynil + 8 oz 2,4-DP per acre.

None of the formulations tested showed signs of phytotoxicity, and at the above doses all can be safely applied from the 3 leaf up to the late tillering stage of spring wheat, oats and barley.

INTRODUCTION

Field work carried out in Canada and the U.K. between 1963-66 had shown that comparatively low doses of mixtures of esters of hydroxybenzonitriles and phenoxyalkanoic acids could be used to control weeds in spring sown cereal crops, (Folland et al, 1966, Clarke and Cook 1964, 1965). Of the various mixtures tested a mixture of 4 oz bromoxynil + 4 oz MCPA has proved to have the most useful range of activity for cereal growers in Western Canada.

In the U.K., this formulation, although providing an economic control of polygonums and mayweeds, could not be claimed to control Stellaria media although in practice this species is usually checked where it occurs in mixed populations. As S. media is the most frequently encountered weed of spring cereals in the U.K., it was obvious that any improvement in a formulation based on hydroxybenzonitrile esters should be directed towards getting positive control of this species.

Work in 1967 showed that mixtures of ioxynil and bromoxynil esters gave a broader spectrum of weed control than equivalent doses of either component. This suggested that improved control of S. media could be achieved by substituting ioxynil for some of the bromoxynil in a bromoxynil/MCPA mixture.

The object of the 1968 experiment was to choose, on the basis of both efficiency and cost, the most suitable mixture for control of Polygonum spp., S. media and mayweeds in spring cereals.

METHODS

Materials and Formulations

	Common Name	Formulations
1967	Bromoxynil octanoate/ioxynil octanoate 1:1 mixture	Emulsifiable concentrate containing the equivalent of 20% w/v bromoxynil and 20% w/v ioxynil
	Bromoxynil octanoate/ioxynil octanoate/2,4-DP 1:1:4 mixture	Emulsifiable concentrate containing the equivalent of 10% w/v bromoxynil, 10% w/v ioxynil and 40% w/v 2,4-DP iso-octyl ester a.e.
1968	Bromoxynil octanoate/ioxynil octanoate/MCPA 1:1$\frac{1}{2}$:2 mixture	Emulsifiable concentrate containing the equivalent of 10% w/v bromoxynil, 15% w/v ioxynil and 20% MCPA iso-octyl ester a.e.
	Bromoxynil octanoate/2,4-DP 1:2 mixture	Emulsifiable concentrate containing the equivalent of 20% w/v bromoxynil and 40% w/v 2,4-DP iso-octyl ester a.e.
	Bromoxynil octanoate/ioxynil octanoate/2,4-DP 1:1$\frac{1}{2}$:3 mixture	Emulsifiable concentrate containing the equivalent of 10% w/v bromoxynil, 15% w/v ioxynil, 30% w/v 2;4-DP iso-octyl ester a.e
	2,4-DP	Emulsifiable concentrate containing the equivalent of 40% w/v 2,4-DP iso-octyl ester a.e.
1967/68	Bromoxynil octanoate/MCPA 1:1 mixture	Emulsifiable concentrate containing the equivalent of 20% w/v bromoxynil and 20% w/v MCPA, iso-octyl ester a.e.

Spraying and assessment

Weed control experiments

1967 All sites sprayed at 20 g.p.a. with small-plot precision sprayer, plots 7' x 20'. Simple randomised layout with three replicate plots per treatment. At all sites weed counts were made in 2 x $\frac{1}{2}$ sq yd quadrats in each plot, 4-6 weeks after spraying. Both plant numbers and bulk (number x mean height) were recorded.

1968 Twenty-four sites were sprayed at 20 g.p.a. with small plot precision sprayer, plot size 9' x 100'. Seven sites were sprayed by Land-rover at 20 g.p.a plot size 18' x 200'. Simple randomised block layout with two replicate plots per treatment.

At all sites weed counts were made in 2 x $\frac{1}{2}$ sq yd quadrats in each plot, 4-6 weeks after spraying. Both plant numbers and bulk were recorded.

Cereal tolerance experiments

Four experiments in spring barley, 3 in spring wheat and 2 in spring oats were designed to provide information on the effect on yield of cereals in crops with very little or no weed competition. A randomised block layout was used, split for 2 times of application; individual plots were 9' x 150', with 4 replicates per treatment. Yields were obtained with a 6' cut self-propelled combine.

Three experiments were carried out to check the tolerance of the following varieties of spring cereals:

BARLEY:	Proctor, Zephyr, Impala, Sultan, Vada, Deba Abed, Maris Badger
WHEAT:	Kloka, Koga II, Kolibri, Opal, Rothwell Sprite
OATS:	Astor, Condor, Manod

All three were sprayed at three growth stages, which were:

- (i) 3-leaves
- (ii) 5-6 leaves
- (iii) just before jointing

The experiments were examined at 3 and 10 day intervals after spraying for leaf scorch, and later for effect on crop height; following ear emergence, 100 ear samples per variety treatment were examined for the incidence of ear malformation. Individual plot size was 8' x 12' per variety/treatment replicate, with 3 replicate plots per treatment.

In both the above series of experiments, the hydroxybenzonitrile/phenoxyalkanoic mixtures were applied at x1, x1½ and x2 the ratio used for weed control. In addition, the 2:4-DP ester component of one of the mixtures was applied separately at the rates at which it was used in the mixture.

RESULTS

Table 1.

Mean % control of plant numbers: 1967 trials

Species and number of sites at which each occurred		Compound and dose rate (a.i. oz/acre) Bromoxynil & Ioxynil esters			Bromoxynil ester	Ioxynil+ 2,4-DP esters	Bromoxynil+ MCPA esters
		3 + 3	4 + 4	5 + 5	3+3+12	4+4+16	4+4
Chenopodium album	8	99	100	100	100	99	99
Chrysanthemum segetum	2	42	33	67	33	43	5
Galeopsis spp.	3	82	94	85	86	86	79
Lamium purpureum	2	84	86	94	96	98	43
Myosotis arvensis	5	99	99	99	97	98	94
Polygonum aviculare	6	88±9.4	88±13.6	97±9.2	84±12.8	93±12.3	93±15.9
Polygonum convolvulus	7	98	98	98	99	99	98
Polygonum persicaria	8	98	99	99	98	99	94
Spergula arvensis	2	41	35	57	54	53	34
Stellaria media	10	75±15.1	77±11.3	67±18.3	97±5.8	98±7.5	37±16.2
Tripleurospermum maritimum	5	94	94	98	94	96	87
Urtica urens	3	60	59	51	95	98	82
Veronica persica	3	98	99	99	96	96	28
Viola spp.	9	69±11.0	71±9.9	75±7.2	91±9.9	96±8.1	38±14.3
Total Weeds - Nos:	12	80±7.1	83±9.1	85±12.8	86±8.3	91±7.1	70±8.7
" " - Bulk:	12	85±8.0	88±9.5	90±9.6	91±10.1	93±8.0	77±9.6

95% Confidence limits given for 6 or more occurrences.

Table 2.

Mean % control of plant numbers: 1968 trials

Species and number of sites at which each occurs		Compound and dose rate (a.e. oz/acre)			
		Bromoxynil+ MCPA esters 4 + 4	Bromoxynil+ ioxynil + MCPA esters 2 + 3 + 4	Bromoxynil+ 2,4-DP esters 4 + 8	Bromoxynil ioxynil 2,4-DP esters 2 + 3 + 6
Aethusa synapium	5	97	97	95	99
Amsinkia spp.	2	99	99	99	98
Anchusa arvensis	2	100	100	100	100
Chenopodium album	7	99	100	99	99
Fumaria officinalis	2	90	83	99	100
Galeopsis spp.	8	89±9.6	88±18.0	67±3.6	66±3.9
Lamium purpureum	4	50±50.0	93±23.0	52±48.0	99±3.9
Lapsana communis	2	91	97	91	95
Mayweed spp.	3	99	94	100	99
Myosotis arvensis	3	85	95	89	93
Polygonum aviculare	13	92±0.9	91±0.1	92±0.1	90±0.2
Polygonum convolvulus	16	99±0.9	99±1.0	99±3.5	99±4.5
Polygonum lapathifolium	2	99	99	99	99
Polygonum persicaria	7	97±3.0	97±2.8	88±2.1	99±0.8
Ranunculus repens	4	73	67	64	75
Silene alba	3	53	71	65	78
Sinapis arvensis	3	100	100	100	100
Stellaria media	18	18±2.9	71±1.6	63±2.3	85±1.2
Veronica spp.	9	78±6.4	96±3.0	94±2.4	92±0.5
Viola spp.	8	33±12.9	85±6.5	71±7.4	90±3.8
Total weeds Nos:	32	82±0.3	89±0.4	88±0.6	89±0.5
Bulk:	32	92±0.2	95±0.3	94±0.4	94±0.5

95% confidence limits given for 4 or more occurrences

Table 3.

Effect of yields of cereals with small weed populations of mixtures of the esters of hydroxybenzonitrile and phenoxyalkanoic acids

Yields in cwt/ac at a calculated 15% moisture

Crop, Variety & growth stage & control weed pop. Nos. per sq yd		Treatment & doses in oz/ac	Bromoxynil/ioxynil MCPA			Bromoxynil/ioxynil 2,4-DP			Bromoxynil 2,4-DP			2,4-DP			Bromoxynil MCPA	Un-sprayed	
			2+3+4	3+4½+6	4+6+8	2+3+6	3+4½+9	4+6+12	4+8	6+12	8+16	8	12	16	4+4		
S. BARLEY																	
Sultan	12	2-4 lvs	32.3	32.3	32.5	32.1	28.8	32.1	30.7	32.6	32.6	30.2	31.7	31.7	33.9	29.1	NS
	24	5-7 lvs	32.8	32.5	33.7	30.8	31.5	30.8	32.6	32.8	32.5	33.3	33.1	32.2	32.6	32.5	NS
Zephyr	37	3-4 lvs	29.6	29.0	30.2	30.1	30.6	30.6	31.1	30.7	29.6	29.4	29.4	29.6	30.2	29.6	NS
	24	6-7 lvs	31.4	30.9	30.9	29.0	31.3	30.2	30.6	29.8	29.4	31.2	31.2	30.3	32.6	30.3	NS
Zephyr	14	3-4 lvs	31.5	32.0	31.6	31.8	29.6	30.4	31.7	30.6	31.2	31.9	31.9	31.1	31.9	33.1	NS
	16	6-7 lvs	31.6	30.8	32.5	29.5	31.1	31.1	31.0	29.5	30.8	32.2	33.1	31.8	32.2	31.8	NS
Proctor	155	3-5 lvs	31.1	31.8	30.4	30.4	30.1	30.9	32.2	30.3	31.2	31.9	32.2	31.0	29.0	30.7	NS
	182	5-6 lvs	30.9	30.1	30.1	31.3	29.4	29.1	31.1	32.2	30.5	32.5	33.0	33.0	32.2	33.1	NS
			a	d	d	c	de	e	c	c	c	ab	a	a	b	a	
S. WHEAT																	
R. Sprite	65	2-3 lvs	24.6	25.6	25.9	24.8	25.5	25.1	25.6	25.5	26.3	23.3	24.1	25.2	25.7	22.1	NS
	85	4-6 lvs	23.8	24.5	23.6	22.9	23.9	22.5	22.9	23.6	23.6	24.5	24.1	23.6	22.5	23.3	NS
Kloka	65	3 lvs	29.0	29.8	29.5	29.7	26.9	29.3	27.7	28.7	31.3	26.7	29.7	29.7	28.3	29.7	NS
	70	5-6 lvs	29.8	30.6	27.7	29.3	26.9	27.1	26.9	28.4	25.2	31.3	30.4	30.4	30.8	28.8	NS
Kloka	14	2-4 lvs	29.4	27.4	28.8	29.6	27.1	27.1	28.1	28.1	27.2	27.7	28.1	26.0	27.8	28.4	NS
	24	5-7 lvs	27.5	27.8	28.4	29.8	29.4	29.0	28.8	29.4	28.6	28.6	27.4	30.8	29.5	22.9	NS
S. OATS																	
Condor	74	3 lvs	29.4	35.4	31.8	33.5	33.5	29.8	31.8	33.0	33.1	33.8	32.0	31.1	32.5	32.3	NS
	64	4-5 lvs	29.6	30.2	29.4	31.1	30.7	30.7	32.5	29.5	30.1	30.6	31.2	29.9	31.8	28.8	NS
	40	3-4 lvs	44.4	48.2	47.5	46.2	44.3	47.5	48.6	46.5	46.1	47.0	46.6	46.6	46.1	47.3	NS
	38	5-6 lvs	46.2	46.5	42.5	47.0	42.8	42.5	48.7	45.8	44.5	44.7	45.6	45.6	44.3	45.8	NS

NS - No significant differences

Proctor barley 5-6 lvs. Means followed by the same subscript letter are not significantly different

DISCUSSION

Weed control experiments - 1967

Table 1. illustrates the advantages of 6 oz/acre mixed ioxynil + bromoxynil esters, the lowest rate tested, over 4 oz/acre bromoxynil + 4 oz/acre MCPA, particularly on Stellaria media, Galeopsis spp., Lamium purpureum, Veronica persica and Viola spp. and that there was little or no response to dosage increased above 6 oz/acre. Improved reliability of weed control resulted from the addition of 2,4-DP esters to the mixture of ioxynil and bromoxynil esters, though the amounts of 2,4-DP used in the mixtures tested were higher than would be commercially feasible.

Choice of mixtures for the 1968 experiments

If equivalent ioxynil were substituted for half the bromoxynil in the established 4 oz/acre bromoxynil + 4 oz/acre MCPA mixture, activity against S. media would be improved, though not enough; 3 oz/acre, however, might be successful and this amount would balance the loss of activity against Polygonum spp. and mayweeds resulting from the removal of 2 oz/acre bromoxynil. The resultant mixture chosen was therefore 2 oz/acre bromoxynil + 3 oz/acre ioxynil + 4 oz/acre MCPA as esters. Because of the importance of S. media control, an alternative 3-way mixture with the same bromoxynil/ioxynil ratio, and 6 oz/acre of 2,4-DP ester instead of 4 oz/acre MCPA, was also designed. It was logical also to consider a straightforward substitution of 2,4-DP for the MCPA in the 4 + 4 oz/acre mixture. The third mixture tested, therefore, was of 4 oz bromoxynil + 8 oz 2,4-DP/acre.

Weed control experiments - 1968

In Table 2. it can be seen that 2 oz bromoxynil + 3 oz ioxynil + 4 oz MCPA/acre, 4 oz bromoxynil + 8 oz 2,4-DP/acre, and 2 oz bromoxynil + 3 oz ioxynil + 6 oz 2,4-DP/acre all gave equivalent and very satisfactory control of the total weed populations at sites and all were better than 4 oz bromoxynil + 4 oz MCPA/acre. On Stellaria media however, there is a clear order of superiority - bromoxynil + ioxynil + 2,4-DP giving commercially acceptable control, bromoxynil + ioxynil + MCPA somewhat less efficient, and bromoxynil + 2,4-DP giving moderate control. Control with bromoxynil/MCPA was negligible. Excellent control of Polygonum spp. and mayweed was maintained with all the mixtures. Lamium purpureum, Veronica and Viola spp. were controlled by both of the 3-way mixtures, though bromoxynil + ioxynil + 2,4-DP was the more reliable of the two in each case. Galeopsis tetrahit was the one species in the experiments against which the compounds containing MCPA were clearly superior to those containing 2,4-DP.

Cereal tolerance

(a) Visible crop effects

Though the formal counts and assessments described were completed, no tables of results are given, as there were no effects to be seen. The absence of any cereal leaf scorch, height reduction, or ear malformation in the experiments confirms the crop safety of hydroxybenzonitrile based mixtures, though it is acknowledged that the amount of crop damage attributable generally to herbicide application in the 1968 season was less than normal. No interaction between herbicides and cereal disease was detected.

(b) Effect on grain yield

At most of the sites, the aim of conducting the experiment in a relatively weed free crop was achieved, so that in these cases, the absence of any significant differences in yield between treatments and control establishes the absence of any crop toxicity, as measured by yield effect. In the Proctor barley, sprayed at 5-6 leaves, the reductions in yield can be related to two particular weed effects:

(i) a late emerging infestation of Convolvulus arvensis which tended to develop more strongly where annual weeds had been removed by spraying,

(ii) an infestation of Equisetum palustre which flourished in patches where drainage was poor and which happened to provide a bias favouring the control.

CONCLUSIONS

The substitution of 3 oz/acre of ioxynil ester for 2 oz/acre of the bromoxynil ester in a 4 oz/acre bromoxynil + 4 oz/acre MCPA ester mixture increases the herbicidal activity particularly on Stellaria media, and maintains the effect on Polygonum spp. and mayweeds. The further substitution of 6 oz/acre of 2,4-DP ester for 4 oz/acre MCPA increases the control of Stellaria media to the level of commercial acceptability. A mixture of 2 oz/acre bromoxynil + 3 oz/acre ioxynil + 6 oz/acre 2,4-DP esters also has the advantage over 4 oz/acre bromoxynil + 4 oz per acre MCPA esters of controlling Lamium purpureum, Viola spp., Veronica spp.

The crop safety of 2 oz/acre bromoxynil + 3 oz/acre ioxynil + 6 oz/acre 2,4-DP conforms with that established for other hydroxybenzonitrile based mixtures, and such a mixture may safely be applied in spring barley, wheat and oats from the three leaf stage, for the optimum control of weeds in very young stages, to beyond the normal practical limit of herbicide application in the field, i.e. just before jointing.

Acknowledgements

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Proc. 9th Brit. Weed Control Conf.(1968)

WORK ON A NEW HERBICIDAL MIXTURE BASED ON MCPA, DICAMBA AND BENAZOLIN

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Summary

The paper describes the work carried out to broaden the herbicidal spectrum of MCPA/dicamba by the addition of benazolin which was added specifically in order to improve control of *Stellaria media* (chickweed) and *Galium aparine* (cleavers). In fact it was found that when using a clearly definable optimum concentration of benazolin, in addition to controlling the above weeds, the mixture also exerted a considerable measure of control on the mayweeds found in cereals in the United Kingdom e.g. *Matricaria recutita*, *M. matricarioides*, *Anthemis cotula*, *Tripleurospermum maritimum ssp. inodorum*.

INTRODUCTION

The properties of MCPA/dicamba formulations for the control of weeds in cereals are well known in the U.K. and in other countries where intensive cereal growing is practised. Such products in addition to controlling a wide range of MCPA susceptible weeds are particularly effective against members of the *Polygonaceae*, especially *Polygonum aviculare* (knotgrass) against which they are appreciably more active than are herbicides based on 2,4-D, MCPA, mecoprop and dichlorprop. Two common weeds of cereals, however, viz. *Stellaria media* (chickweed) and *Galium aparine* (cleavers) are not as well controlled as they are by mecoprop and dichlorprop based herbicides. It was considered worthwhile to attempt to rectify this deficiency by the addition of mecoprop or benazolin, herbicides well known for their ability to control these two weeds. Leafe (1964) and Lush et al. (1965). The work that this involved during 1967-68 is reported in this paper.

METHODS AND MATERIALS

Trials were of two main types, detailed and user, standard experimental procedures being followed. Detailed trials involved replicated layouts of either finite dose or logarithmically treated plots, the size of which varied according to function but all of which fell within the range 1/160 to 1/40 acre. Detailed trials were designed to investigate weed control efficacy and crop safety. For the latter, yield and cereal variety experiments were conducted. Application was in all cases made by the Lenton Small Plot Sprayer with or without logarithmic attachment. User trials involved comparison in adjacent 2 acre plots of trial material and proprietary standards. In all cases farmers' spraying machines were calibrated before use.

Initially, a formulation containing MCPA/dicamba (22.5% w/v and 1.6% w/v respectively) was prepared and evaluated in detailed trials with and without the superimposition of logarithmically decreasing dosages of benazolin or mecoprop. Later a formulation containing MCPA 25%, dicamba 1.6%, and benazolin 2.5% (all w/v) was prepared for further trial work. In the user trials this formulation was compared against MCPA/dicamba, mecoprop/dicamba and MCPA/dicamba/mecoprop formulations. In the text that follows reference to use of MCPA/dicamba always implies normal rate of use viz. 18 oz + 1.3 oz/ac respectively.

RESULTS

The addition of either benazolin or mecoprop to MCPA/dicamba broadened the spectrum of weed control to include Stellaria media (chickweed) and Galium aparine (cleavers) as would be expected from a knowledge of the properties of these compounds. A completely unexpected result of adding benazolin to MCPA/dicamba was the very good control of mayweeds that occurred, not only of Tripleurospermum maritimum ssp. inodorum but also of the more resistant species Matricaria recutita, M.matricarioides and Anthemis cotula. This is shown for M. recutita in Table 1 and for A. cotula in Table 2. Direct comparisons were made of treatments at the seedling and also the young plant stage. At both stages the mayweeds were equally well controlled. The addition to MCPA/dicamba of mecoprop at certain rates sufficient to confer good control of S. media and good suppression of G. aparine did not result in as effective control of the mayweed species. Table 3.

Work on Matricaria recutita showed that the rate of benazolin to be added to MCPA/dicamba to produce optimum herbicidal effect is critical as seen in Table 1. Effect increased with increasing rate of benazolin up to 2 oz/ac but diminished after this rate until at 4 oz/ac of added benazolin the effect on M. recutita was less than that with MCPA/dicamba alone.

Certain other weeds responded more to MCPA/dicamba/benazolin than to MCPA/dicamba alone. These included Polygonum aviculare, P. convolvulus, P. persicaria, Lamium spp. and Veronica spp. Table 5 shows the frequency with which this superiority was observed in the 1967 trial series.

The addition of benazolin to MCPA/dicamba did not increase the phytotoxic hazard to cereal crops. In fact the reverse was the case in a number of trials in both years. In one of six cereal yield trials conducted in 1967, MCPA/dicamba at normal rate on wheat var. "Sprite", caused abnormal head effects together with statistically significant yield depression. These effects did not occur with the MCPA/dicamba/benazolin treatment. Four cases also occurred in user trials in 1967 and one in 1968 where MCPA/dicamba treatment gave rise to crop height depression and abnormal heads of the type known to be associated with late application of dicamba. Adjacent plots treated with MCPA/dicamba/benazolin did not show these effects. Yield figures were not obtainable from these trials.

DISCUSSION

Undoubtedly the most interesting feature of the work reported is the very marked effect on mayweed species of adding benazolin at 2 oz/ac to MCPA/dicamba when used at the normal rates of 18 oz and 1.3 oz per acre respectively. This is all the more surprising in view of the fact that benazolin alone at this rate has no effect on mayweeds and MCPA/dicamba at the above rates has only a moderate effect. Tables 1 and 4.

Particularly interesting is the fact that, after increasing to an optimum at 2 oz added benazolin per acre, control of Matricaria recutita rapidly falls off until at 4 oz/ac of added benazolin, control becomes inferior to that given by MCPA/dicamba which suggests the onset of antagonism at that rate. This antagonistic effect occurs only in relation to the respective proportions of the three ingredients and does not occur when the rate of the whole product is increased.

Table 1.

Effect on Matricaria recutita of adding various rates of benazolin to MCPA/dicamba (mean of eight detailed trials each at two stages*)

Treatment	Rate/acre in oz	Effect on *Matricaria recutita*
MCPA/dicamba	18 + 1.3	6
MCPA/dicamba/benazolin	18 + 1.3 + 1.5	7
MCPA/dicamba/benazolin	18 + 1.3 + 2	9
MCPA/dicamba/benazolin	18 + 1.3 + 3	7
MCPA/dicamba/benazolin	18 + 1.3 + 4	5
MCPA/dicamba/benazolin	18 + 1.3 + 6	4
Benazolin	2	0
Benazolin	4	<2
Benazolin	6	3

Assessment scale 0 = No effect
10 = Complete kill

* Weed stage: comparisons made at the seedling and young plant stage showed no differences and the scoring is derived from both stages.

Table 2.

Control of Anthemis cotula

Location	Crop and variety	Date sprayed	Assessment	
			MCPA/dicamba/benazolin	MCPA/dicamba
Yorks 1	Barley Vada	1.6.67	9	7
Yorks 2	Barley (Spring)	9.5.67	8	6
S. Wales	Barley Proctor	1.6.67	8	6
Kent	Wheat Cappelle	14.5.68	9	6
Dorset	Barley Zephyr	12.5.68	9	6
Yorks 1	Barley Zephyr	End May 1968	9	-*
Yorks 2	Barley Rika	22.5.68	9	-*

* MCPA/dicamba not present

Assessment scale 0 = No effect
10 = Complete kill

Weed stage: *Anthemis cotula* varied from seedlings to young plants.

Table 3.

Comparison of benazolin and mecoprop as additives to MCPA/dicamba (mean of four trials each at two stages*)

Treatment	Rate/acre in oz	Effect on Matricaria recutita	Effect on Tripleurospermum maritimum ssp inodorum
MCPA/dicamba	18 + 1.3	6	8
MCPA/dicamba/benazolin	18 + 1.3 + 2	9	9
MCPA/dicamba/mecoprop	18 + 1.3 + 19	7	9
MCPA/dicamba/mecoprop	18 + 1.3 + 24	8	9
Mecoprop	38.5	2	9

Assessment scale 0 = No effect
10 = Complete kill

* Weed stage: comparisons made at the seedling and young plant stage showed no differences and the scoring is derived from both stages.

Table 4.

Response of a number of annual weeds to benazolin at 2 oz/acre (Summarised from the results of ten trials)

Stellaria media	9
Galium aparine	5
Polygonum aviculare	1
Polygonum persicaria	1
Polygonum convolvulus	1
Matricaria recutita	0
Anthemis cotula	0

Assessment scale 0 = No response
10 = Complete kill

Weed stage: **seedling and young plant stages.**

Table 5.

Showing herbicidal superiority of MCPA/dicamba/benazolin over MCPA/dicamba on weeds other than mayweeds

Weed	No. of trials in which occurring	% no. of trials in which benazolin mixture superior
Polygonum aviculare	64	28
Polygonum convolvulus	30	23
Polygonum persicaria	17	18
Lamium spp	12	42
Veronica spp	21	43

Weed stage: seedling and young plant stages.

At the rates included in the trials mecoprop added to MCPA/dicamba resulted in a lesser effect against mayweeds than benazolin except in the case of *Tripleurospermum maritimum ssp. inodorum* which is susceptible to mecoprop and, to a lesser extent, also to MCPA/dicamba.

It is very encouraging that the enhanced effect of MCPA/dicamba/benazolin was observed on all mayweed species occurring in the trials, including the traditionally more resistant species *Anthemis cotula*. This weed was found to occur much less frequently than popularly supposed but where it occurred it was always very successfully controlled.

Of the other weeds controlled more effectively by the formulation containing benazolin, the most suprising is *Polygonum aviculare* a weed that is very susceptible to MCPA/dicamba and virtually unaffected by benazolin at 2 oz/ac. One would have expected that control of this weed by MCPA/dicamba would always have been of such a high order that there was little room for improvement by the addition of such an additive. In fact marked superiority was shown in 28% of the trials carried out in 1967. Improvement was less frequent in the case of the other two important *Polygonaceous* weeds of cereals (*Polygonum convolvulus* and *P. persicaria*), but occurred most frequently of all with *Lamium* and *Veronica spp*. Whilst these weeds are not amongst the most important their improved control is very acceptable.

The results of the cereal safety work show that the addition of benazolin far from reducing the safety margin of MCPA/dicamba, in fact tends to increase that margin under circumstances where late application of MCPA/dicamba causes adverse crop effects.

This safening influence of benazolin observed on every occasion that adverse effects followed the use of MCPA/dicamba in this trial series, is an interesting phenomenon that is still under investigation.

Thus it can be seen that the addition of benazolin at a rate of 2 oz/ac to MCPA/dicamba at 18 oz and 1.3 oz per acre respectively, results in improved herbicidal activity and wider spectrum with a tendency towards greater rather than reduced cereal safety.

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WEED CONTROL IN SPRING CEREALS WITH PRE-EMERGENCE HERBICIDES

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Summary Trials to investigate the effect on cereal yields of pre-emergence herbicide treatments compared with post-emergence treatments produced only very limited evidence that better yields can be expected from pre-emergence treatments.

INTRODUCTION

Spring cereal crops are normally sprayed for weed control from the 3-leaf stage until the start of the "jointing" stage. The earlier the spraying within this period the less the depressing effect the weeds should have on crop yield. This was first demonstrated on spring oats by Elliott (1956) and it is also true of other spring cereal crops (Evans, 1961). To obtain the maximum advantage of weed control it would seem logical to use a residual herbicide at planting time to maintain the crop free of weeds from the beginning.

Work at the Weed Research Organisation (Holroyd, 1962a) had indicated that some herbicides might be suitable for pre-emergence use in barley and one of these (propazine) was first elected for use in a series of N.A.A.S. trials. Later, when propazine became unavailable, terbutryne (GS 14260) was substituted although it was known to be generally less selective than propazine in barley. The trials were meant to show whether a selective pre-emergence residual herbicide would lead to better yields than an appropriate post-emergence herbicide.

The activity of the soil-applied herbicides was known to be influenced by soil type but, in the absence of precise information, a range of doses was used in each trial in the hope that one dose would give satisfactory weed control without toxicity to the crop.

METHOD AND MATERIALS

In 1964 and 1965 propazine was applied at 3 upper or 3 lower doses in the range 4,8,12, and 16 oz/ac. In 1966 and 1967 terbutryne was also used at 3 doses in a range of 12 to 48 oz/ac. The herbicides were applied to the soil within a few days following drilling.

The post-emergence applications varied according to the weed situation but they were all applied at or between the times when the crop was at the 3-leaf and 5-leaf stages.

Assessments consisted of:-

(a) scores for weed control and

(b) grain yields obtained with combine harvesters.

RESULTS

The control of weeds obtained at each site is summarised in the Tables. The weed control achieved by propazine (Table 1) was generally much better than that from terbutryne (Table 2) and, at the highest dose, was usually good. Terbutryne gave a good control at the highest dose in only two of the four trials where assessments were made.

The yields of barley (12 trials) or wheat (2 trials) are also shown in the Tables. Spring wheat was sensitive to propazine and yields were depressed by all doses at both sites.

The general trend of yields of barley treated with propazine was a reduction in yield with increasing dose of herbicide. Some barley sites where propazine was used can, however, be disregarded in relation to this series of trials because either crop yields were not taken (trials 4 and 7) or the crop was free of weeds (trial 3). In the remaining trials the lowest dose of propazine led to good weed control and as good or better grain yields compared to plots treated post-emergence, i.e. trials 2,5, and 8.

Terbutryne seemed less selective. The general tendency was for yields to improve with increasing doses and, consequently, better weed control; but the highest dose seemed to be harmful to the crop in a few instances and, even so, often gave poor weed control. Only trial 14 produced good weed control at the middle and high dose and the best crop yields were obtained from these treatments. In the only other site, number 9, where weed control from the highest dose of terbutryne was good, the crop was harmed.

DISCUSSION

It is clear that neither propazine nor terbutryne were adequately selective to give regularly a good weed control without also sometimes affecting the crop. By particular consideration of trials 2,5,8, and 14 however it can be argued that a satisfactory pre-emergence treatment gave as good or better barley yields than an appropriate post-emergence treatment. Other trials can be considered as irrelevant to the aims of the programme because:-

(a) crop yields were not taken

<u>or</u> (b) the crop was free of weeds

<u>or</u> (c) weed control was inadequate

<u>or</u> (d) the crop was wheat and too sensitive to the herbicide treatment.

There is then a clear suggestion that, as would be expected, pre-emergence spraying can give at least as good yields as post-emergence spraying; but the evidence suggesting that any appreciable improvement in yield can be expected from pre-emergence as compared to post-emergence spraying is limited. There are other reasons for wishing to use pre-emergence herbicides in cereals and these have already been discussed by Holroyd (1962b).

Table 1 Weed Control and Crop Yield - Propazine

Weeds: Mean scores on scale 0 to 10; 0 = no weeds, 10 = maximum density.
Crop: Yield as percent of control - figures shown in brackets.

Year	1964					1965		
County	Wilts	Worcs	Northumberland	West Riding	Oxon	Hereford	Salop	Hants
Crop	Wheat	Barley	Barley	Barley	Barley	Wheat	Barley	Barley
Soil Type	Greenland	Sandy loam	Medium loam	Heavy loam	Fine Sandy loam	Medium loam	Sandy clay loam	Chalk
Weeds	Fat hen, Knotgrass, Shepherd's purse	Chickweed Scentless mayweed, Fat hen, Spurrey, Shepherd's purse	None	Runch, Fat hen, Redshank	Scentless mayweed, Fat hen, Charlock	Chickweed, Fat hen, Cleavers, Polygonum spp.	Charlock, Speedwell, Fat hen, Chickweed	Chickweed, Polygonum spp.
Weeds per sq. ft.	23	28	0	-	27	11	10	13
Propazine - low dose	4.2 (92)	2.8 (102)	- (98)	4.3 (No yields)	1.2 (109)	4.7 (91)	6.5 (No yields)	4.0 (107)
" - middle dose	3.2 (85)	1.5 (98)	- (96)	3.3	- -	3.0 (93)	4.2	2.0 (109)
" - high dose	1.5 (69)	0.9 (97)	- (91)	2.8	0.2 (103)	2.8 (91)	3.7	1.0 (101)
Post-emergence	1.5 (97)	* (93)	- (96)	2.5	0.3 (107)	* (94)	1.5	2.0 (108)
Control	9.5 (100)	8.3 (100)	- (100)	5.7	9.4 (100)	9.5 (100)	8.7	8.0 (100)
Mean yield on control plots as cwt/ac at 15% moisture	40	42	46	-	37	33	-	33

* Density of crop prevented adequate assessment but observation was that a good weed control was achieved.

Table 2

Weed Control and Crop Yield - Terbutryne

Weeds: Mean scores on scale 0 to 10; 0 = no weeds, 10 = maximum density.
Crop: Yield as percent of control - figures shown in brackets.

Year	1966			1967		
County	Worcs	Oxon	Cambs	Salop	Staffs	Essex
Crop	Barley	Barley	Barley	Barley	Barley	Barley
Soil Type	Clay loam	Light	Clay loam	Silty loam	Sandy loam	Silty clay loam
Weeds	Pale persicaria Chickweed, Fat hen, Pennycress Mayweed Speedwell	Corn marigold, Spurrey, Chickweed, Pansy, etc.	Cleavers, Charlock, Speedwell,	Chickweed, Spurrey, Knotgrass, etc.	Redshank, Spurrey, Charlock, etc.	Black bindweed, Scarlet pimpernel, Fat hen, etc.
Weeds per sq. ft.	39	20	5	19	66	6
Terbutryne - low dose	7.8 (103)	6.7 (105)	No weed scores available (90)	9.0 (98)	Pre-emergnece application largely ineffective on weeds (101)	5.0 (91)
" - middle dose	6.8 (102)	4.3 (119)	(105)	8.0 (102)	(102)	2.0 (107)
" - high dose	1.5 (94)	5.0 (126)	(107)	5.0 (116)	(98)	1.0 (106)
Post-emergence	0 (100)	1.3 (187)	(97)	2.0 (91)	(100)	2.0 (100)
Control	10.0 (100)	10.0 (100)	(100)	10.0 (100)	-	10.0 (100)
Mean yield on control plots as cwt/ac at 15% moisture	39	22	27	19	43	29

Acknowledgements

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THE TRANSLOCATION AND PERSISTENCE OF CCC (CHLORMEQUAT) IN VARIETIES OF WHEAT AND BARLEY

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Summary The reason for the difference in response of wheat and barley to applications of CCC was investigated by examining translocation of C^{-14} CCC in 6 varieties of wheat and 6 varieties of barley. Further evidence was also obtained of the disappearance of CCC in field grown wheat and barley from the time of application to final harvest. Limited export of C^{-14} CCC from treated leaves in barley was correlated with the poor response in this crop.

INTRODUCTION

In a series of experiments, Alcock et al (1966, 1967) have described the response of wheat and barley to application of CCC. This work has shown that barley is in no way as responsive as wheat to the shortening action of CCC although under certain conditions, CCC can control lodging in barley to a considerable extent. Preliminary observations on the translocation of C^{-14} labelled CCC in Opal wheat and Proctor barley suggested that the relatively restricted translocation from treated leaves in Proctor may explain the poor responses obtained with barley. In order to obtain further information on this subject two experiments were performed and are reported here. Experiment (I) consisted of a quantitative examination of the translocation of C^{-14} labelled CCC in six varieties of wheat and six varieties of barley and Experiment (II) involved the analysis of residual CCC in sequential samples of treated Opal wheat and Proctor barley taken during the growth of the crop in the field.

METHOD AND MATERIALS

Experiment I

Six varieties of spring wheat and six varieties of spring barley were grown in sand culture in the glasshouse during Spring 1967. Three plants were grown in each 10" pot and the whole were given complete nutrient solutions following the technique of Hewitt (1966). Supplementary illumination from 400 watt mercury vapour lamps was given with a 16 hour photo-period.

VARIETIES

Spring Wheat	Spring Barley
Svenno	Union
Atle	Proctor
Koga II	Impala
Opal	Europa
Jufy I	Pallas
Kloka	Deba Abed

When the 5th leaf on the main shoot was fully expanded an application was made to this leaf of either 1 or $4 \mu c$ of aqueous chlorocholine -1,2-C^{14} chloride (specific activity 4.8 millicuries per millimole - $30.5 \mu c$/mg). The application was made as a droplet of 0.01 ml or 0.04 ml, the latter being applied to plants destined to be harvested last. Plants were harvested with three replications per variety at 1, 4, 7, 14 and 21 days after treatment. The plants were freeze dried and representative plants mounted on paper and autoradiographs prepared using the techniques described by Crafts et al (1964). After a visual examination of the autoradiographs all plants were dissected into the following fractions:

1. Treated leaf.
2. Treated tiller minus the treated leaf.
3. Non-treated tillers.
4. Roots.

The different fractions were extracted with methanol and both extract and residue were subjected to determination of radioactivity. The procedures adopted were those described by Blinn (1967). The chemical identification of the source of radioactivity in some of the extracts was made by chromatography followed by autoradiography again following the techniques of Blinn (1967).

Experiment II

This formed part of a field experiment reported by Alcock et al (1967).

Proctor barley was sown on 17th March, 1966 at the rate of 135 lb/ac. and Opal wheat at the rate of 150 lb/ac. 80 units each of phosphate and potash /ac. was applied to the seed bed and 100 units of nitrogen per acre was applied on the 25 April. Treatments consisted of different times of applying CCC as an aqueous spray (NIL (0), 4 lbs. a.i./ac. at growth stage 5* (C1), 4 lbs. a.i./ac. at growth stage 9 (C2) and 2 lbs. a.i./ac. at growth stage 5 with 2 lbs. a.i./ac. at growth stage 9 (C3).

* Growth stage refers to Feeke's Scale - Large (1964).

Samples of entire plants were taken regularly during the growth of the crop, dried in a forced-draught oven and milled using a screen of 1-mm diameter openings. Replicate samples were bulked for analysis since the analytical techniques proved both costly and time consuming. The samples were then analysed for CCC residues using the techniques described by Mooney and Pasarela (1967).

This experiment was repeated in 1967 with treatments modified as follows:
(Nil application of CCC (0), 4 lbs. a.i./ac.at growth stage 5 (C1), 4 lbs. a.i./ac. at growth stage 9 (C2), in combination with no nitrogen applied (No) or 60 Units nitrogen/ac. (N_1).

CCC residues were determined in the grain and straw and are reported here.

RESULTS

Experiment I

The considerable data obtained in this experiment has been condensed for presentation in this paper, Table 1. Generally speaking all wheat varieties behaved similarly as did all barley varieties and such variation that did exist was not consistent with time. Thus a true species difference is demonstrated in the table. Given is (a) the amount of radioactivity exported from the treated leaf together with the variety standard deviation and (b) the percentage distribution of exported radioactivity in the remaining plant parts. The basic differences are not so much in the distribution of exported radioactivity but in the extent of export from the treated leaf which is approximately halved in barley.

Chromatographic identification verified that the radioactivity measured was present as radioactive CCC.

In a previous paper Alcock et al (1967) noted the accumulation of radioactivity in the mature ears of Opal wheat but not in the ears of Proctor barley. This striking difference in distribution could not be verified in the present experiment since unforseen circumstances prevented the continuation of the experiment beyond the stage of ear emergence. However CCC residue analysis supports the original observation.

Experiment II

CCC residues are presented as ppm in the total plant dry matter and as lb per acre, Table 2. The values have been corrected for the lower limit of detectability as described by Sutherland (1965).

The residues (as ppm) declined with time which initially was a dilution effect as growth increased but then was a definite disappearance from the plant. Late

Table 1

Quantitative measurement of the export of C^{-14} labelled CCC from a treated leaf and subsequent distribution in plants of wheat and barley. Values given are the average for 6 varieties of wheat and 6 varieties of barley. (See text for details).

			days from treatment				
			1	4	7	14	21
% radioactivity exported from treated leaf	WHEAT	mean	17	25	39	60	55-
		standard deviation	28.7	20.5	10.9	18.2	10.1
	BARLEY	mean	8	11	19	32	28
		standard deviation	3.5	4.9	12.7	17.6	8.4
% distribution of exported radioactivity	(1)	WHEAT	56	62	41	65	46
		BARLEY	34	50	54	26	30
	(2)	WHEAT	21	26	39	28	47
		BARLEY	29	33	28	58	51
	(3)	WHEAT	23	12	20	7	7
		BARLEY	37	17	18	16	19

(1) treated tiller minus treated leaf. (2) non-treated tillers. (3) roots.

Table 2

The effect of different times of applying CCC to Opal wheat and Procter barley on CCC residues. (Experiment 1966).

Sampling date	C_1				C_2				C_3			
	OPAL		PROCTOR		OPAL		PROCTOR		OPAL		PROCTOR	
	ppm	lb/ac	ppm	lb/ac	ppm	lb/ac	ppm	lb/ac	ppm	lb/ac	ppm	lb/ac
May 27	86.3	0.27	76.1	0.23	-	-	-	-	79.5	0.22	68.0	0.22
June 13	39.3	0.23	39.0	0.26	-	-	-	-	19.4	0.11	9.6	0.07
June 24	13.8	0.11	22.5	0.20	43.2	0.38	36.6	0.35	37.2	0.31	56.9	0.54
July 11	12.5	0.14	7.1	0.10	27.2	0.32	39.5	0.55	16.9	0.20	45.8	0.61
July 28	5.8	0.09	5.7	0.09	15.8	0.23	18.8	0.32	14.5	0.24	9.4	0.14
August 15	2.4	0.03	N.D.	N.D.	7.9	0.12	7.9	0.11	8.6	0.12	5.4	0.07
September 6	N.D.	N.D.	-	-	5.2	0.07	-	-	4.6	0.06	-	-

C_1 : 4 lb a.i. CCC/ac. on 26 May C_2 : 4 lb a.i. CCC/ac. on 15 June

C_3 : 2 lb a.i. CCC/ac. on 26 May and 2 lb a.i. CCC/ac. on 15 June. N.D. : not detected.

Table 3

The effect of time of application and nitrogen supply on residual CCC in the grain and straw of Opal wheat and Procter barley (Experiment 1967)

TREATMENT		corrected values of CCC : ppm in dry matter			
		GRAIN		STRAW	
		N_0	N_1	N_0	N_1
OPAL	C_1	0.93	0.97	5.65	5.53
	C_2	1.37	1.99	23.51	23.99
PROCTOR	C_1	N.D.	N.D.	2.68	0.75
	C_2	N.D.	N.D.	16.44	11.68

N.D. : not detected.

applications either single (C2) or split (C3) resulted in higher residues at harvest. The amount of CCC recovered one day after application (C1) was small (0.23 - 0.27 lbs/ac.) in relation to the amount applied (4 lbs a.i./ac.).

On a basis of measurements in ppm the biological half life estimated for C_1 and C_3 after the earliest application averaged 12 days for wheat and 12.5 days for barley. This compares with a value of 13 days for wheat quoted by Mooney and Pasarela (1967). A similar calculation using estimations in lb/ac. results in a biological half-life of 20 days in wheat and 25 days in barley.

CCC residues in the grain and straw from the 1967 Experiment are in Table 3. The main differences are (a) the lack of CCC in barley grain and (b) the lower levels present in barley straw. Late applications (C2) increase residues when they are present and there is an indication that nitrogen reduced the level of residues in both grain and straw of barley.

DISCUSSION

It is now generally reported that the effect of CCC in producing morphological change in barley is by no means as pronounced as in wheat. The work of Larter (1967) in Canada and Barrett et al (1967) in this country provide examples of this difference in response. However these workers and Alcock et al (1967) have all shown that variation in response occurs and that under certain varietal and field conditions, lodging can be reduced in barley with often an increase in grain yield. The fact that complete resistance is not observed in barley makes it worthwhile continuing to investigate the mechanisms of the varied response with the ultimate object of being able to exercise control over the process. The experiments reported here provide some initial evidence of the basis of species difference in response to CCC.

It is clear from the first experiment that a major difference occurs between wheat and barley in the amount of C^{-14} labelled CCC exported from the treated leaf. The reduced export in barley is not a result of differences in uptake from the treated leaf since visual observations of autoradiographs reveal radioactivity in the whole leaf soon after application with no indication of radioactivity being localised around the spot of application.

A parallel can be drawn between the above phenomena and the resistance mechanism observed in other plants to applications of herbicides. For example, Peterson (1966) has shown that resistance of cereals to applications of 2,4-D - which varies between cereal species and stage of growth - is related to the lack of translocation of the compound in the plant. Why CCC does not translocate readily in barley is not as yet understood. Our evidence is that free C^{-14} - CCC can be extracted from the treated leaf 21 days following application and that apparently it is not degraded to compounds remaining in the leaf and possessing the labelled carbon atom. The failure to observe metabolites in extracts from labelled plants is at variance with the work of Jung et al (1966) who provide evidence of degradation of CCC to cholinchlorid. This work, however, was carried out 'in-vitro' and it is therefore possible that the lack of identification in our experiments is a result of a further utilisation of cholinchlorid in the plant thus preventing accumulation. Alternatively further degradation may lead to the disappearance of radioactivity with the evolution of C^{-14} carbon dioxide. It should be noted that Blinn (1967) using C^{-14} CCC from the same source as that used in our experiments also failed to detect any significant metabolism of CCC in wheat.

The residue analysis clearly points to the degradation or elimination of CCC from the cereal plant. Biological half-life has been calculated by two methods and varies from 12.0-20.0 days and 12.5-25 days for wheat and barley respectively. In this respect there is very little difference between wheat and barley. The hypothesis postulated by Jung et al (1966) that differential reaction of plants to CCC may be correlated with the rate by which plants degrade this compound does not appear to apply in the case of wheat and barley.

Future progress with utilisation of CCC for the barley crop may well depend on discovering why it is not exported readily from the treated leaf and on being able to influence this.

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THE EFFECTS OF COMBINED APPLICATIONS OF CHLORMEQUAT AND HERBICIDES TO CEREALS

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Summary Trials are described in which, over a four year period, a number of herbicides were applied to cereals, chiefly wheat, both alone and in combination with chlormequat. Chlormequat was compatible with all the herbicides tested. The weedkilling properties of the herbicides were not affected. If the herbicide scorched the crop, this scorch was sometimes increased by the addition of chlormequat, but the effect was not serious or permanent. Chlormequat significantly reduced stem length. Some herbicides also reduced stem length but rarely significantly. The reduction of lodging due to chlormequat was sometimes improved by the addition of a herbicide. Crop yields were not adversely affected by chlormequat or herbicides, alone or in combination.

INTRODUCTION

Chlormequat was introduced onto the market in the United Kingdom in 1967 under the name of CYCOCEL* Plant Growth Regulator to reduce lodging in wheat. Diversely referred to as CCC, chlorocholine chloride and 2-chloroethyltrimethyl ammonium chloride, its use on cereals has been reviewed by Humphries (1968). The timing of the application of chlormequat to wheat closely approximates to the time of application of most commonly used herbicides to cereals. This poses the question to the farmer whether it is safe or desirable to mix chlormequat with herbicides in the same spray tank, thus avoiding the necessity of two spraying operations to the same crop. The subject has already been explored by Frohner (1965), Stryckers and Van Himme (1966), Jung and Sturm (1966), Hubbard (1968) and Hughes (1968). This paper describes trials carried out between 1965 and 1968 by Cyanamid of Great Britain Limited on spray tank mixtures of herbicides and chlormequat for applications to wheat and oats.

METHODS AND MATERIALS

Trials were carried out on commercial crops. Sprayed plots were 50 yd^2 each in the first three years and 200 yd^2 in 1968. Trials were laid out as randomised blocks of two or three replicates. Spray was applied by small boom sprayer at 20 gal of diluted wash per acre. Chlormequat was applied at the rate of 2.5 lb a.i./acre in 1965, at 1.5 lb a.i./acre to winter wheat and 1.0 lb a.i./acre to spring wheat in 1966 and 1967 and at 1.5 lb a.i./acre to winter wheat and 0.75 lb a.i./acre to spring wheat in 1968. The application to spring oats in 1967 was at 2.0 lb a.i./acre. All the herbicides used were proprietry brands and the highest rates of use recommended by the manufacturers were applied in all cases. In every trial each herbicide tested was used alone and in combination with chlormequat; untreated plots and plots treated with chlormequat alone were included. Assessments were made of compatibility, crop damage (scorch), stem length, lodging, herbicidal activity (1966 only) and yield (1968 only). Lodging percentages were calculated from index values which took into account both extent and severity of lodging.

Wheat 1965 - One trial on Cappelle winter wheat - applications at Growth Stage 6 (Large, 1954). Herbicides used: MCPA, mecoprop, 2,4-D, dicamba + MCPA.

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* Trademark of American Cyanamid Company

Wheat 1966 - One trial on Cappelle winter wheat - applications at Growth Stage 5/6. One trial on Koga II spring wheat - applications at Growth Stage 5/6. Herbicides used: MCPA, mecoprop, 2,4-D, dicamba + MCPA, dichlorprop, ioxynil + mecoprop, dicamba + MCPA + 2,3,6-TBA + mecoprop, 2,3,6-TBA + MCPA, 2,4-DB, benazolin + MCPA + 2,4-DB.

Wheat 1967 - One trial on Cappelle winter wheat - applications at Growth Stage 4. One trial on Kloka spring wheat - applications at Growth Stage 5/6. Herbicides used: dichlorprop + 2,4-D, dichlorprop + MCPA, MCPB, 2,4-DB + MCPA + 2,4-D, mecoprop + 2,4-D, 2,4-D ester, ioxynil + dichlorprop + MCPA, mecoprop + fenoprop, 2,4-DB + MCPA, MCPB + MCPA, MCPA amine, picloram + dichlorprop.

Wheat 1968 - One trial on Cappelle winter wheat - applications at Growth Stage 5/6. Herbicides used: 2,4-D ester, dicamba + MCPA + 2,3,6-TBA + mecoprop. One trial on Kloka spring wheat - applications at Growth Stage 6. Herbicides used: ioxynil + dichlorprop + MCPA, dicamba + MCPA + 2,3,6-TBA + mecoprop.

Oats 1967 - One trial on Condor spring oats - applications at Growth Stage 6. Herbicides used: 2,4-D, dicamba + MCPA, dichlorprop, ioxynil + mecoprop, 2,3,6-TBA + MCPA, 2,4-DB, MCPB, mecoprop + fenoprop, picloram + dichlorprop.

RESULTS

Compatibility

All the herbicides used in the four years of field trials were compatible with chlormequat. In most cases, there was slightly more frothing in the spray tank when chlormequat was included than with herbicides alone.

Crop damage

Over the four-year test period in many cases herbicides used alone were found to cause some yellowing (scorch) to the leaves present at the time of application. Chlormequat alone also sometimes caused slight yellowing. The addition of chlormequat to the herbicide in some cases increased this yellowing effect, but in no case did it do so seriously. Specific observations were as follows:

1965: Mixtures caused slightly more yellowing than chlormequat or herbicide sprays applied alone.

1966: The following four herbicides caused some yellowing to Cappelle when sprayed alone: dichlorprop, dicamba + 2,3,6-TBA + mecoprop, 2,3,6-TBA + MCPA and benazolin + MCPA + 2,4-DB. The addition of chlormequat slightly increased the yellowing effect of three of these herbicides, but not of dichlorprop. All the herbicides caused some initial yellowing on the spring wheat trial, but with only 2,3,6-TBA + MCPA was it at all severe. The addition of chlormequat did not increase these effects. All signs of yellowing disappeared after four weeks.

1967: In the winter wheat trial, initial yellowing largely disappeared by 19 days. No increase was associated with chlormequat treatment. On the spring wheat, yellowing was recorded on most treatments after nine days and was most severe following treatment with dichlorprop + 2,4-D, dichlorprop + MCPA, mecoprop + 2,4-D and ioxynil + dichlorprop + MCPA. Mixing chlormequat with these herbicides slightly increased the yellowing effect. However, little yellowing was seen 29 days after treatment. On the spring oat trial, some initial yellowing was caused by dichlorprop and ioxynil + mecoprop. This was not increased by the addition of chlormequat and had largely disappeared by 21 days.

1968: No yellowing was recorded on either trial.

Plant height

1965: Chlormequat significantly reduced plant height by a mean of 14% (P = 0.01). There was no effect on plant height due to herbicide treatment.

1966: A components analysis was carried out on the stem lengths of both trials, and these showed that significant height reductions (P = 0.001) were effected in all cases when chlormequat was added to the herbicide spray solution. In the absence of chlormequat, the mixture of dicamba + MCPA significantly reduced stem length of Cappelle by 7% (P = 0.05) but was the only herbicide to do so. When mixed with chlormequat, the dicamba + MCPA just failed to reduce stem length of Cappelle significantly over chlormequat alone, whereas the two mixtures with chlormequat of dicamba + MCPA + TBA + mecoprop and benazolin + MCPA + 2,4-DB did significantly further reduce stem length (P = 0.01 and P = 0.001, respectively). None of the herbicides had any significant effect on stem length of Koga II spring wheat.

1967: Treatment with chlormequat caused significant stem length reductions in the wheat trials. Most herbicides marginally reduced stem length, but not significantly so. Stem length measurements were not carried out on oats.

1968: Treatment with chlormequat caused significant stem length reductions on both Cappelle and Kloka. The herbicides tended to have a shortening effect when used alone or in combination with chlormequat. On Cappelle the herbicide 2,4-D ester reduced stem length by 13% (sig. at P = 0.001) and increased the effect of chlormequat from 22% to 26%. A 5% reduction (sig. at P = 0.05) was caused by dicamba + MCPA + 2,3,6-TBA + mecoprop.

Lodging

In all trials where it occurred, lodging was reduced or prevented by chlormequat treatments. In the 1966 spring wheat trial and the 1967 winter wheat trial, there was a suggestion that herbicide treatments had a slight effect in reducing lodging both alone and in combination with chlormequat. However, this was not confirmed by statistical analysis. Late lodging occurred in the 1968 winter wheat trial and a figure of 40% was recorded on untreated plots. None of the plots treated with chlormequat lodged. The mean lodging figure for 2,3,6-TBA + dicamba + MCPA + mecoprop alone was 13%, while on the 2,4-D ester plots only 2% lodging occurred.

Herbicidal activity

Observations were made on weed control on the spring wheat site in 1966. No obvious differences in weed population or vigour were recorded when plots sprayed with herbicide alone were compared with plots sprayed with mixtures of herbicides with chlormequat.

Yield

Yields of grain recorded in the two 1968 trials showed no significant differences between treatments.

DISCUSSION

All the herbicides tested in this series of trials were compatible with chlormequat. Jung and Sturm (1966) reported incompatibility with DNOC. The mixing of chlormequat with dinitro compounds such as DNOC and DNBP is not recommended.

Chlormequat used alone sometimes caused a slight yellowing in leaves present at the time of spraying. This effect was also observed to a greater or lesser degree with certain herbicides, particularly those containing mecoprop, dichlorprop or 2,3,6-TBA. When chlormequat was mixed with these herbicides, the yellowing was often slightly increased. In no case did this yellowing persist for more than four weeks, and it is unlikely to have had an adverse effect on yield. Similar observations were made by Frohner (1965) and Mayr and Primost (1963).

Chlormequat caused significant stem length reductions in all of the trials. The effects of herbicide treatments on stem length were variable. In many cases there was a suggestion that some of the herbicides reduced stem length, either when used on their own or in combination with chlormequat. This effect was significant only in isolated cases. Notable amongst these were dicamba/MCPA/2,3,6-TBA mixtures on Cappelle in 1966 and 2,4-D ester in 1968. Frohner (1965) reported no significant effect of herbicides on stem length, although there was a suggestion of shortening by five herbicides both with and without chlormequat. Stryckers and Van Himme (1966) found that the addition of DNOC-NH_4 increased the shortening effect of chlormequat on winter wheat. MCPA-Na had a similar effect on spring wheat. Jung and Sturm (1966) recorded a greater shortening effect when chlormequat was applied in mixture with seven different herbicides compared to an application of chlormequat alone. The differences in heights recorded amounted to only 2-4 cm, but it was suggested that in combination with certain herbicides of the hormone type reductions in doses of chlormequat by 0.5 lb a.i. over normal field rates was possible.

Where lodging occurred in the trials, it was prevented or reduced by chlormequat treatments. There was a suggestion in some trials that treatments with herbicides alone had reduced lodging, but this could not be confirmed by statistical analysis. In the 1968 trial on winter wheat practically no lodging occurred on plots treated with 2,4-D ester alone, while a figure of 38% was recorded on untreated plots. Frohner (1965) recorded complete absence of lodging on plots treated with mecoprop alone compared with 75% lodging on the untreated. Hubbard (1968) found that MCPA, mecoprop, MCPA + 2,3,6-TBA and ioxynil + mecoprop reduced lodging on their own and increased the effects of chlormequat when mixtures were applied.

Weed control observations confirmed the results of Frohner (1965) who reported that chlormequat did not affect the efficiency of herbicides. Stryckers and Van Himme (1966) found that on adding herbicides to chlormequat some weeds were controlled better than with herbicides alone, but others were less well controlled. Hughes (1968) and Hubbard (1968) both reported that the addition of chlormequat had no effect on the weed control efficiency of any of the herbicides tested in their trials.

No significant effect on yield of wheat grain followed any of the treatments in the 1968 trials. Likewise, Frohner (1965) found no adverse effect of treatment on grain yield. Hubbard (1968) recorded an increase of yield in all treatments over control. This was associated with the reduction of lodging effected by all chlormequat treatments and also by the herbicides alone. Hughes (1968) found no adverse effects of chlormequat/herbicide treatments on yield in the absence of lodging.

The optimum stage of wheat growth for the application of chlormequat is Growth Stage 6 on the Feekes Large Scale (Caldicott 1967a and 1967b). On oats it is Growth Stage 7. Manufacturers instructions for the use of most cereal herbicides advise application when the crop is in the fifth-leaf stage (or earlier).

This approximates to Growth Stage 4 to 5. Chlormequat applied to wheat at this earlier stage will reduce stem length and strengthen stems; but, the effects can be reduced or lost, particularly if cold weather and slow growth intervenes before stem elongation commences. Early application to oats is ineffective. Herbicides should not normally be applied after the jointing stage (Growth Stage 6) as such applications may reduce weed control or grain yield. Some herbicides, such as 2,3,6-TBA and dicamba, can be particularly damaging if applied late (Fryer and Evans 1968).

In the work referred to in this paper, applications of chlormequat in mixture with a wide range of herbicides were made to wheat at various growth stages of the crop from 4 to 6. The results were satisfactory from the point of view of herbicidal and growth regulating activity and of absence of crop damage and yield loss. Mixtures of herbicides and chlormequat can be sprayed onto wheat up to the jointing stage with reasonable safety, but the optimum stages of application for each are not necessarily the same.

The range of herbicides sprayed onto oats caused no damage when combined with chlormequat and applied at Growth Stage 6. However, as the recommended stage for application of chlormequat to oats is 7, it is not advisable to spray mixtures of herbicides and chlormequat to oats.

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THE INTERACTION OF CHLORMEQUAT, HERBICIDES AND NITROGEN APPLIED TO CEREALS

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Summary Initial work showed that foliar application was superior to seed dressings or soil applications but results on timing of the application were inconclusive. Later work has produced promising results from mixtures of growth regulating herbicides with Chlormequat applied between the five leaf stage and the shooting stage of spring and winter wheat. There appears to be a trend towards increased activity, such mixtures showing adequate responses at the lower dosage rates, the early applications only resulting in slight loss of efficiency. There was no evidence of increased incidence of mildew but ear diseases - Septoria sp., Fusarium sp. and Cladosporium sp. - were more prevalent. However, this did not affect yield. The lodging resistance was improved by addition of chlormequat over control but increasing the rate applied produced little further improvement.

INTRODUCTION

Owing to limitations of space it has only been possible to include results of work carried out in 1968 in this paper. Earlier work starting in 1963 compared different methods of application. Chlormequat applied as a seed dressing was ineffective except at very high dosages which were uneconomic whilst mixtures with fertilisers in the seedbed proved unsatisfactory owing to the hygroscopic properties of chlormequat. Spray treatments proved the most effective method of application and later trials were carried out to determine optimum dosages and times of application. The best results were recorded in winter wheat and a considerable number of trials indicated that a satisfactory resistance to lodging and statistical increases in yield could be obtained. The effects on winter and spring oats and on spring wheat were rather more variable and barley showed no response. The main objectives of the work more fully reported in this paper were to determine whether chlormequat could be applied in mixtures with growth regulator herbicides at earlier stages of crop growth than had previously been thought desirable for chlormequat application.

METHODS AND MATERIALS

In 1968 11 trials were laid down on 9 sites from the South Coast to the Humber. Trials 1-7 were all carried out at farm sites. The extra nitrogen being superimposed on the farm fertiliser practice to bring the level to 100 units of N. A formulation containing 40% wt/vol chlormequat as an aqueous solution (1) was applied at 3 rates 0, 1 and 1.5 lb/ac on winter wheat and winter oats and at 0, 0.5 and 0.75 lb/ac on spring wheat. When herbicides were applied, they were selected as appropriate to the weed flora from mecoprop, dichlorprop, 2,4-D/dichloprop mixture (2), ioxynil /MCPA/ dichlorprop mixture (3). Applications of herbicides and growth regulant were made by Land Rover in 30 gal/ac using spraying system tips 6504 at 30 psi.

(1) Cycocel
(2) Tetralex
(3) Certrol P.A.

The plot size sprayed was 3½ yd x 54 yds and 2 yds x 50 yds harvested. There were 4 replicates of each treatment. The timing of the early and late applications was planned for the two extremes of the safe period for the herbicides (i.e. the 5 leaf stage and jointing) but in view of the difficult spraying conditions encountered this was not always possible. Crop height was recorded twice, 14 measurements per plot being taken at random.

Trials nos. 8 & 9 were designed to determine different rates of nitrogen and rates and times of application of chlormequat and herbicides on 3 varieties of spring wheat. Nitrogen at 42 units/ac was applied in the seedbed and a further 40 or 80 units/ac as a top dressing. Chlormequat was sprayed at 0, 0.5 and 1.0 lb/ac at the shooting stage. A dichlorprop/2,4-D herbicide was applied as a proprietary mixture at 4 pts/ac at the 5 leaf stage. Spring wheat varieties were Rothwell Sprite, Kolibri and Troll. Each treatment was replicated 4 times. Assessments were carried out for crop height at ear emergence, resistance to lodging, incidence of mildew (Erysiphe gramminis)infestation, ear diseases and effect on maturity. Crop yields were recorded.

Trial no. 10 tested the response of chlormequat on 16 varieties of spring wheat and trial no.11 on 20 varieties of spring barley. Chlormequat was applied to unreplicated plots at 1.5 and 3 lb/ac at the shooting stage of crop growth. Assessments were carried out for incidence of disease, effect on maturity and height of crop at ear emergence.

RESULTS

(i) Weed Control

Chlormequat was compatible with all the herbicides tested and the weed control obtained was in line with that on those plots where chlormequat was not included.

(ii) Lodging

Assessments for degree of lodging in 3 varieties of spring wheat are given in Table 1.

Table 1

MEAN SCORES FOR CROP LODGING
(1 = no lodging 9 = severe lodging)

Chlormequat rate/ac	Variety/extra nitrogen								
	Sprite			Kolibri			Troll		
Units N	40	80	Mean	40	80	Mean	40	80	Mean
0 lb/ac	4.0	3.5	3.75	4.0	6.0	5.0	5.5	5.5	5.5
0.5 lb/ac	3.0	3.0	3.0	2.5	4.0	3.25	2.5	3.5	3.0
0.75 lb/ac	2.5	3.0	2.75	3.0	3.5	3.25	2.5	3.0	2.75

The higher rate of chlormequat gave a slight increase in the resistance to logding in varieties Sprite and Troll. Observations in Trials nos.1-7 indicated that late applications of chlormequat at the jointing stage were marginally more effective than treatments applied at earlier stages of crop growth. In all trials chlormequat gave considerably increased resistance to lodging and was particularly successful in preventing early lodging which sometimes resulted in secondary germination of grain in the controls. There was a noticeable trend for reduction in crop height to be accompanied by an increased resistance to lodging but owing to the small number of sites where lodging occured there was no statistical correlation between these factors.

(iii) Crop Height

Mean reduction in crop height following applications of chlormequat at 1.5 and 1 lb/ac are shown in Table 2.

Table 2

REDUCTION IN CROP HEIGHT ACCORDING TO TIME OF APPLICATION
(Results expressed in inches)

Trial No.	Time of Application / Crop	June assessment		August assessment	
		5 leaf	Shooting	5 leaf	Shooting
1.	Winter oats	4.2	2.8	2.7	6.6
2.	Winter oats	4.4	3.4	0	2.4
5.	Spring wheat	4.8	6.5	4.8	7.9
6.	Spring wheat	2.9	3.7	2.5	3.3
8.	Spring wheat	-	-	5.8	8.0

In trial no.1 on Peniarth winter oats the chlormequat application at the shooting stage was applied very late (Feekes-Large Scale 9); this resulted in a marked reduction in crop height. In trial no.2 on the same variety the shooting stage treatment was applied earlier and the reduction in crop height at the late assessment was less.

Early assessments showed that application of chlormequat at the 5 leaf stage generally gave a greater reduction in straw height but when assessed again just prior to harvest this trend was reversed.

The effects of different rates of application of chlormequat are given in Table 3.

Table 3

THE EFFECT ON CROP HEIGHT OF DIFFERENT RATES OF APPLICATION
(Results expressed in inches)

Trial No.	Crop	Chlormequat rates per ac					Extra height reduction of higher rate
		1.5 lb	1.1b	0.75 lb	0.51b	Nil	
1.	Winter oats	46.9	48.3			52.3	1.4
2.	Winter oats	48.5	49.0			49.5	0.5
3.	Winter wheat	42.2	42.3			44.7	0.1
4.	Winter wheat	44.8	45.1			50.5	0.3
5.	Spring wheat			34.9	35.0	41.3	0.1
6.	Spring wheat			32.5	33.1	35.7	0.6
7.	Spring wheat			29.7	30.6	38.6	0.9
8.	Spring wheat			36.2	37.0	43.2	0.8

The higher rate of application of chlormequat gave a greater reduction in crop height in all trials but this difference was again slight with the exception of trial no.1

In trial no.9 the addition of a herbicide to chlormequat gave a mean reduction in height of 5% compared with chlormequat alone.

(iv) Effect on crop maturity

Chlormequat delayed maturity of 15 varieties of spring wheat by 1-3 days, the higher rate had the more pronounced effect. Svenno was the only variety which was not affected.

(v) Incidence of fungal diseases

Chlormequat at rates up to 3 lb/ac had no significant effect upon the incidence of mildew (*Erysiphe gramminis*) on 16 spring wheat varieties. In trial 8 there was an increased incidence of ear diseases, *Fusarium* spp., *Septoria* spp. and secondary *Cladosporium* infections but this had no effect on yield.

(vii) Varietal response

In trial no. 10 chlormequat applied at 1.5 lb/ac to 16 varieties of spring wheat at the shooting stage gave the following mean reductions in crop height:

Svenno	0.8 in.	Atle	1.1 in.	Kolibri	1.4 in.	Pompe	1.7 in.
Toro	0.9 in.	Koga II	1.3 in.	Kloka	1.5 in.	Hpg 2772/60	1.7 in.
Trident	1.1 in.	W11276	1.4 in.	Clarion	1.5 in.	Opal	1.9 in.
Hpg 2656	1.1 in.	Pet 71/64	1.4 in.	Sprite	1.6 in.	Troll	2.7 in.

There were no significant differences in crop height between 3 and 1.5 lb/ac of chlormequat.

Chlormequat at the same rates was applied to 20 varieties of Spring barley. There was severe lodging and no varietal differences were detectable.

(viii) Effect on yields

Results are given in Table 4.

Table 4

CROP YIELDS
(Cwts/ac at 15% moisture)

Treatment per ac				Winter Oats		Winter wheat		Spring Wheat		
Rate of Chlor-mequat	Time of Appli-cation	+ or - weed-killer	Total Units of N.	Trial No.1	Trial No.2	Trial No.3	Trial No. 4	Trial No.5	Trial No.6	Trial No.7
High	5 leaf	+	100	35.3	35.7**					
High	5 leaf	+	100					35.6**	25.4**	30.8**
Low	5 leaf	+	100	36.1	35.2**					
Low	5 leaf	+	100					33.7**	25.8**	30.6**
High	Shooting	+	100	36.8	37.2**	26.9	43.0*			
High	Shooting	+	100					33.5**	24.3*	
Low	Shooting	+	100	36.4	34.6**	27.3	42.6*			
Low	Shooting	+	100					34.1**	24.6*	
High	Shooting	-	100			27.1				
Low	Shooting	-	100			26.1				
Nil		+	100	36.6	28.6			30.7*		29.5*
Nil		+	Nil		36.0**	26.6	38.0	28.6		24.8
Least sign. diff.			P = 0.01	N.S	5.5	N.S.	-	2.6	4.1	5.8
			P = 0.05	N.S.	4.0	N.S.	4.3	1.9	3.0	4.2

In trial no.2 nitrogen top dressing significantly depressed the yield by 7.4 cwt/ac in the absence of chlormequat owing to the inherently high fertility of the soil as a result of many years of poultry folding. Significant increases in yield were obtained from the use of chlormequat in trials nos. 4, 5, 6 and 7.

Crop yields at different rates of application are given in Table 5.

Table 5

MEAN CROP YIELDS AT DIFFERENT DOSAGES OF CHLORMEQUAT
(Cwts/ac at 15% moisture)

Trial No.	Crop	Rate of Chlormequat				
		1.5 lb/ac	1 lb/ac	0.75 lb/ac	0.50 lb/ac	0 lb/ac
1	Winter oats	36.1	36.2			36.6
2	Winter oats	36.4	34.9			-
3	Winter wheat	27.0	26.7			24.2
4	Winter wheat	42.6	42.4			-
5	Spring wheat			34.6	33.9	30.7
6	Spring wheat			24.8	25.2	-
7	Spring wheat			30.8	30.6	29.5

There were no significant differences in yield between chlormequat at the upper or lower rates of application.

The effect of time of application on crop yield is shown in Table 6. Early applications at or near to the jointing stage.

Table 6

CROP YIELD AT DIFFERENT TIMES OF APPLICATION
(Cwts/ac at 15% moisture)

Trial No.	Crop	Early	Late	
1	Winter oats	35.7	36.6	No significant differences
2	Winter oats	35.4	35.9	
5	Spring wheat	34.7	33.8	
6	Spring wheat	25.6	24.4	

DISCUSSION

The results show that whilst there is a very slight loss of efficiency from early applications of chlormequat combined with a herbicide, commercially satisfactory results are obtained in winter and spring wheat with adequate resistance to lodging. In winter oats the effect from the recommended late application (Caldicott 1966) was outstanding and there is insufficient evidence from the earlier applications of combined herbicide mixtures to suggest these would be commercially satisfactory. The late application would be outside the safe period for the herbicide component.

There are indications that the rate of chlormequat can be reduced by 30% when mixed with herbicides for applications to winter and spring wheat (Table 2). It is probable that the enhanced effect is due to the wetting agents in the herbicides improving absorbtion of chlormequat by the crop. Further work is however required before recommendations for general use can be made.

Acknowledgements.

The authors wish to express their gratitude to the many farmers who co-operated and allowed this work to be carried out on their farms.

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CHEMICAL WEED CONTROL IN OIL SEED RAPE

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Summary. Of seventeen herbicides tested for selectivity in oil seed rape in a preliminary screening trial in 1967, six retained for further studies in 1968 were : CP 50144 (2-chloro-N-2,6-diethylphenyl-N-methoxymethyl-acetamide), UC 22463 (3,4-dichlorobenzyl N-methylcarbamate), R 7465 (2-(-naphthoxy)-N,N-dimethylpropionamide), C 7019 (2-azido-4-isopropylamino-6-methylthio-1,3,5-triazine), propachlor and nitrofen. All were applied before crop emergence and C 7019 was also tested in post-emergence applications. At the highest doses used, all herbicides except nitrofen gave good control of *Stellaria media*, the predominant weed species, and nitrofen at 8 lb/ac a.i. satisfactorily controlled *Polygonum aviculare* and *Veronica* spp. The effect of treatments on crop yield (shoot dry material) was not significant statistically. Symptoms of toxicity were observed on rapeseed plants following pre-emergence applications of 4 lb/ac a.i. UC 22463 or C 7019, and following post-emergence treatment with 2 lb/ac a.i. C 7019, and this was reflected in a slight depression in crop productivity. No other treatments had any apparent deleterious effect on crop growth.

INTRODUCTION

Oil seed rape is of potential importance in Britain as a break crop in systems of intensive cereal production (Bunting, 1967). Prospects for rapeseed cultivation would be enhanced if a safe and effective method of weed control were available.

Investigations on the subject at the University Field Station, Wytham, Oxford began with a herbicide screening trial in 1967, when the effects of seventeen herbicides on two species of oil seed rape (*Brassica napus* and *Brassica campestris*) were examined. The six herbicides giving promising results were used in further studies in 1968. Three of these herbicides, CP 50144, propachlor and R 7465 had no apparent adverse effects on growth of either species of rapeseed in 1967, while the other three, namely, UC 22463, C 7019 and nitrofen had only a slight effect on crop growth, and this was largely confined to the higher doses and to the species *B. napus*. The remaining eleven chemicals tested in 1967 obviously affected crop growth deleteriously (see Table of results) and were subsequently discarded from the programme. It was feasible to grow only one variety of rapeseed in the 1968 experiment. A variety of *B. napus* was chosen because this species is much more widely grown in Europe than *B. campestris*, and, moreover, as data from the screening trial indicated that *B. napus* was more susceptible to herbicidal injury than *B. campestris*, assessments of crop tolerance to herbicidal treatments are likely to be more critically determined with *B. napus*.

METHOD AND MATERIALS

Screening trial 1967

Two varieties, Rigo and Nida, representing the two species of oil seed rape, *Brassica napus* and *Brassica campestris* respectively, were sown on alluvial loam soil in plots 3 ft wide and 64 ft long on April 19th. Herbicide treatments were applied with a logarithmic sprayer, the four 16 ft long sections within each plot receiving a diminishing dose in the following succession :

Section	(1) 0-16 ft	(2) 16-32 ft	(3) 32-48 ft	(4) 48-64 ft
Dose	100% -50%	50% -25%	25% -12.5%	12.5% -6.25%

Seventeen herbicides were tested, and treatments were randomized within two blocks, giving a total of 34 sprayed plots. A similar number of untreated plots was included in the design in order to separate all sprayed plots, and to provide an adjacent control plot for comparison of the effects of each treatment.

The times and method of application were as follows :

(1) Six herbicides were applied and incorporated into the soil with a rotavator on April 19th, immediately before the crop was sown.

(2) Nine herbicides were applied on April 19th immediately after sowing.

(3) Two herbicides were applied on May 23rd, after emergence, and when crop plants were at the 2 - 3 true leaf stage.

Details of treatments are presented in the results, together with a description of the effects of herbicides on the crops and on the weeds.

Experiment 1968

A Brassica napus type of oil seed rape (erucic acid free variety SZ 62-11) was drilled on April 5th, on freely drained clay loam soil overlying limestone gravel, in plots of four rows, 12 ft long, 18 in. apart. Six herbicides, each at three doses, were applied on April 9th, before crop emergence. One of these herbicides (C 7019), was applied also post-emergence, at 2-3 true leaf stage of growth of the crop, on May 22nd. Three untreated controls were included in each block, and as the treatments were replicated three times, the total number of plots was 72. Details of treatments are presented in the results. Herbicides were applied with the Oxford Precision Sprayer at a pressure of 30 lb/in^2 and a volume of 20 gal/ac. Weed counts were made early in June. As bird damage to the rape siliquas was beginning, plants were harvested on August 21st, before the seed was ripe, and the yield of dry shoot material was determined.

The highest doses used in the main experiment were applied also in a separate experiment on the same site, to give an indication of any effects of herbicides on the crop. Treatments in this experiment were also replicated three times, but any surviving weeds were removed by hand, to maintain a weed free environment.

RESULTS

Screening trial 1967

At the time of emergence it was already apparent that treatments toxic to the crop affected Brassica napus (var. Rigo) more than Brassica campestris (var. Nida). Emerging seedlings of Rigo on affected plots showed much more discoloration in the form of bleached or yellow-blotchy cotyledons.

The site was heavily infested with Stellaria media, and reference to the weed killing performance of treatments, assessed on June 1st, effectively applies to this species only. The results of the assessments may be summarized as follows :

Treatment No.	Chemical	Top Dose lb/ac a.i.	Effects
Pre-emergence applications			
1	C 7019	4	Slight effect on crop growth at the highest doses (2 - 4 lb/ac). Weed control moderate.

Treatment			Effects
No.	Chemical	Top Dose lb/ac a.i.	
Pre-emergence applications (cont.)			
2)	GS 11357 (2-methylthio-4-methylamino-6-n-propylamino-1,3,5-triazine)	8	B. napus: at the higher doses (4 - 8 lb/ac) some reduction and considerable delay in emergence; above 1 lb/ac chlorosis in veins and stunted growth, both effects becoming gradually less apparent as herbicide dose decreased. B. campestris: similar symptoms, although less intense. Weed control above 2 lb/ac very good.
3)	CP 50144	4	No apparent effect on crop development. Weed control moderate.
4)	R 7465	4	No apparent effect on crop development. Weed control good.
5)	Sindone "B" (1,1,4-trimethyl-6-isopropyl-5-indanyl ethyl ketone)	8	B. napus: At 4 - 8 lb/ac delayed emergence, stunted growth, deformed plants, chlorosis in veins. B. campestris: similar effects and almost as severe. The effects on crop growth persisted down to 1 lb/ac, gradually becoming less marked and disappearing at the dose somewhat above 0.5 lb/ac. Weed control good.
6)	OCS 21799 (2-(4-chloro-*o*-tolyloxy)-N-methoxyacetamide)	4	Both species killed at higher doses. Weed control poor.
7)	UC 22463	4	At 2 - 4 lb/ac slight effect on crop growth, especially of B. napus. Weed control moderate.
8)	Propachlor	8	No apparent effect on crop development. Weed control at 4 - 8 lb/ac moderate.
9)	Nitrofen	8	Slight effect on crop growth, especially on B. napus at doses of 4 - 8 lb/ac. Weed control poor.
Post-emergence treatments			
10)	Dicamba	0.5	B. napus: at 0.25 - 0.5 lb/ac severe leaf deformity; less marked at lower doses but persisting down to 0.06 lb/ac and disappearing only in the section of lowest dose (0.03 - 0.06 lb/ac). B. campestris: Hardly any visible effects of treatment. Weed control good.
11)	Desmetryne	2	Most plants of both species killed at doses of 1 - 2 lb/ac, and the few remaining alive badly scorched. Scorching of plants of both species continued down to the dose of 0.25 lb/ac, where approximately 30% of plants of each species were affected. Weed control very good.
Incorporated into the soil			
12)	R 4574 (NN-hexamethylene-S-isopropyl-(thiocarbamate))	4	Plants of both species reduced in vigour at all doses. Weed control moderate.

Treatment			Effects
No.	Chemical	Top Dose lb/ac a.i.	
Incorporated into the soil (cont.)			
13)	R 2063 (N-cycloheryl-N-ethyl S-ethyl-(thiocarbamate))	4	Both crop species equally affected and considerably diminished in vigour. Weed control good.
14)	R 1910 (S-ethyl NN-diisobutyl(thiocarbamate))	4	Both crop species showed reduced growth. Significant chlorophyll deficiency in plants of B. napus. Weed control very good.
15)	Planavin	2	Both species reduced in growth at all doses. Weed control good.
16)	Benefin	2	B. napus: some inhibition of emergence and considerably retarded development at the higher dose (1 - 2 lb/ac), and growth reduced also at all lower levels. B. campestris: effects similar to those observed on B. napus. Weed control very good.
17)	Trifluralin	2	Marked effect on development of both crop species at all doses. Weed control very good.

Experiment 1968

The data presented in Table 1 summarize the effects of treatments on weed survival and on crop yield.

Table 1

Summary of performance of herbicides

Herbicide treatment			Surviving weeds as % of control			Crop yield
Chemical	lb/ac a.i.	applied	Stellaria media	Other	Total	Dry shoot tons/ac
CP 50144	1	pre-em.	80	58	71*	3.43
CP 50144	2	pre-em.	32	77	49***	3.08
CP 50144	4	pre-em.	6	29	14***	3.01
UC 22463	1	pre-em.	79	91	83	3.30
UC 22463	2	pre-em.	37	55	44***	3.83
UC 22463	4	pre-em.	3	28	12***	2.98
Propachlor	2	pre-em.	79	104	88	3.31
Propachlor	4	pre-em.	60	102	75*	3.07
Propachlor	8	pre-em.	22	42	29***	3.21
R 7465	0.5	pre-em.	59	81	67**	3.31
R 7465	1	pre-em.	54	63	58***	3.19
R 7465	2	pre-em.	26	63	40***	3.17
C 7019	1	pre-em.	59	94	72*	3.20
C 7019	2	pre-em.	18	67	36***	3.35
C 7019	4	pre-em.	5	11	12***	3.09
Nitrofen	2	pre-em.	76	45	64**	2.96
Nitrofen	4	pre-em.	104	23	74*	3.02
Nitrofen	8	pre-em.	113	34	84	3.77
C 7019	0.5	post-em.	78	106	88	4.31
C 7019	1	post-em.	40	88	58***	3.22
C 7019	2	post-em.	11	38	20***	2.82
Untreated control; weeds/yd^2			35	20	55	3.06
Coefficient of variation %					12.8	14.9

Total weeds sign. diff. from control: *at P=0.05 **at P=0.01 ***at P=0.001

Stellaria media, the dominant weed species, was almost completely controlled by pre-emergence application of 4 lb/ac a.i. CP 50144, UC 22463 or C 7019 and nearly as well by post-emergence treatments with 2 lb/ac a.i. C 7019. Pre-emergence treatments with propachlor at 8 lb/ac a.i. and R 7465 at 2 lb/ac a.i. reduced the number of S. media plants by about 80% , but nitrofen was ineffective against S. media at doses up to 8 lb/ac a.i. At 4 lb/ac and 8 lb/ac a.i., however, nitrofen controlled Polygonum aviculare, Polygonum convolvulus and Veronica spp. satisfactorily. CP 50144 was also effective against Veronica spp. and at 4 lb/ac a.i. against P. aviculare and P. convolvulus.

Some discoloration of emerging seedlings of rape and an apparent reduction in early growth of the crop followed pre-emergence applications at 4 lb/ac a.i. of C 7019 and, more markedly, of UC 22463. Foliar applications of C 7019 at 2 lb/ac a.i. also caused slight chlorophyll deficiency in many crop plants and these remained for a fortnight noticeably lighter in colour than unaffected plants. Although the effect of treatments on yield of dry shoot material was statistically non-significant, some depression in yield following these treatments was recorded (Table 1), and comparable results were obtained from the adjacent trial under weed-free conditions.

DISCUSSION

Eleven of the herbicides used in the 1967 screening trial seriously affected crop development. The effects were usually more detrimental to Brassica napus (var. Rigo) than to Brassica campestris (var. Nida). Of the remaining six herbicides three, CP 50144, R 7465 and propachlor had no effect on either crop species in 1967, and in the other three, namely, UC 22463, C 7019 and nitrofen, the effects were largely confined to plants of B. napus subjected to the higher doses.

The symptoms of toxicity on seedlings following application of UC 22463 and C 7019 in 1968 were somewhat more serious than those observed in 1967. These observations may be accountable to differences in soil type (alluvial loam 1967, clay 1968) or variety of B. napus (Rigo 1967, SZ 62-11 1968). The other four chemicals, R 7465, CP 50144, propachlor and nitrofen had no apparent effects on emerging seedlings or subsequent crop growth.

The absence of any yield response to herbicide treatment in the 1968 experiment probably reflects the combination of moderate level of weed competition with favourable conditions for crop growth.

Acknowledgments

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EVALUATION OF HERBICIDES FOR WEED CONTROL IN OIL SEED RAPE -

N.A.A.S. EXPERIMENTS 1967-68

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Summary Six N.A.A.S. experiments were carried out in 1967-68 to evaluate herbicides for annual weed control in oil seed rape. In three experiments in 1967, nitrofen, propachlor, 2 - azido - 4 - isopropylamino - 6 - methylthio - S - triazine (C 7019) and desmetryne were investigated as pre emergence and post emergence treatments where appropriate. Three experiments in 1968 investigated nitrofen, propachlor, 2 - chloro - 2, 6 - diethyl - N - (methoxy methyl) acetanilide (CP 50144), trifluralin and C 7019 again as pre emergence and post emergence treatments. The paper presents observations on crop tolerance and weed susceptibility for each herbicide at different rates and times of application from all of these trials. Of the treatments investigated only CP 50144 at 24 oz./ac a.i. and nitrofen post emergence at the 2 leaf stage gave a worthwhile control of a sufficiently wide range of annual weeds without severely affecting the vigour and density of the crop.

INTRODUCTION

The increasing interest in oil seed rape as a break crop for cereals has led to a demand for chemical weed control in the crop. In the later stages of growth the crop is most effective in smothering weeds but it can suffer from competition in the early stages, particularly in cold dry conditions on May. The yield and return from the crop in Britain is not sufficient to warrant much expenditure on either herbicides or cultural means of weed control so that candidate chemicals need to be inexpensive. Most of those tested in this series of trials have been developed for use in related vegetable crops and may not meet this requirement.

Table 1

Location of Trials, Soil Types and Main Weeds Present

Year	County	Soil Type	Main Weeds (no./ft^2)
1967	Cambridgeshire	Loam	Stellaria media, Polygonum aviculare, Silene album.
1967	Hampshire	Silty Loam	Stellaria media (13), Polygonum aviculare (4.5), Polygonum convolvulus (1.2), Veronica agrestis (1).
1967	Shropshire	Sandy Loam	Polygonum aviculare (12), Capsella bursa-pastoris (11), Poa sp (3) Tripleurospermum maritimum ssp. inodorum (2).
1968	Berkshire	Sandy Loam	Stellaria media (7.3), Lepidium campestre (1.9), Chenopodium album (1.3), Polygonum aviculare (3).
1968	Worcestershire	Sandy Clay Loam	Occasional Stellaria media, Senecio vulgaris.
1968	Shropshire	Sandy Loam	Polygonum aviculare (33), Poa annua (6), Stellaria media (5), Sinapis arvense (4), Chenopodium album (2).

METHODS AND MATERIALS

Details of the trials and of the treatments are given in Tables 1 and 2. Each trial was of randomised block design with three or four replicates.The plot size was 20 - 24 yd^2 and the treatments were sprayed with Oxford Precision Sprayer at 20 gal/ac. All doses are given as oz./ac a.i. Crop damage was assessed by visual scoring for vigour and density on a scale 0 - 10 where 10 represents the full crop. Weed kill was assessed in the same way for each of the main weed species present at each centre and a composite score given for all weeds.

The doses and times of application of nitrofen, propachlor, C 7019, CP 50144 and desmetryne are shown in Table 2. In addition, trifluralin at 16 and 32 oz/ac was applied in Shropshire as a pre sowing incorporated treatment in 1968. Barban, applied at 5 oz./ac at the 4-leaf stage, was included in Hampshire trial in order to examine crop tolerance.

RESULTS

Pre-sowing treatment

Trifluralin

At the one centre at which trifluralin was incorporated pre-sowing there was severe stunting and retardation of the crop seedlings but numbers were only slightly reduced. There was complete control of a wide spectrum of annual weeds with the exception of Sinapis aversis and Capsella bursa-pastoris. The effects of the initial stunting of growth could be seen through to the seeding of the crop and at these rates crop damage was too great for this chemical to be a likely candidate.

Pre-emergence treatments

Nitrofen

Crop vigour and crop plant numbers were only slightly affected at two centres by all rates of application of nitrofen. Weed growth was only partially controlled, the higher rates of application being marginally better at all centres. There was poor control of Stellaria media and Sinapis arvensis at all centres but Polygonum aviculare was severely reduced in numbers and vigour. Other annual weed species were slightly reduced in vigour.

Propachlor

Crop vigour and density was only marginally affected at all rates and at all centres by this chemical. Overall weed control was poor at three centres, but good reduction of Stellaria media, Lapidium campestre and Chenopodium album was achieved in Berkshire. There was reasonable control of Polygonum aviculare and Stellaria media in Shropshire (1968), but little control of Sinapis arvensis.

C 7019

This chemical severely reduced vigour and density of crop stand at all centres at all rates of application, but there was evidence of reasonable recovery 10 weeks after sowing at two centres. Excellent weed control resulted from all rates of application at all centres with the exception of Polygonum aviculare in Hampshire. Control of Stellaria media was particularly effective.

Table 2

Effect of herbicides on oil seed rape and weeds

Score 0 - 10 10 = crop and weed at full vigour 0 = complete kill

Treatments (oz./ac a.i.)			Cambridge		Hampshire		Shropshire 1967		Berkshire		Worcester		Shropshire 1968	
			Crop	Weeds	Crop	Weeds	Crop	Weeds	Crop	Weeds	Crop	Weeds	Crop	Weeds
Pre-emergence														
Nitrofen	32		8.5	3.5	-	-	-	-	7.7	4.0	9.7	-	8.5	4.6
	50		8.5	2.0	9.2	8.0	-	-	-	-	-	-	-	-
	64		8.0	2.0	-	-	-	-	7.0	2.5	9.7	-	8.3	4.6
Propachlor	64		9.5	5.0	-	-	-	-	-	-	-	-	-	-
	85		9.5	5.0	9.2	8.0	-	-	8.5	2.0	9.3	-	8.0	6.3
	128		-	-	-	-	-	-	7.2	1.4	7.0	-	-	-
C 7019	24		-	-	-	-	-	-	-	-	5.3	-	6	3.3
CP 50144	24		-	-	-	-	-	-	8.2	1.1	-	-	-	-
	26		-	-	-	-	-	-	-	-	4.7	-	4.3	3.6
	48		-	-	-	-	-	-	5.2	0.4	3.3	-	3	1.3
Post-emergence														
Nitrofen	16)	2-leaf	9.5	2.0	-	-	6.5	3.5	-	-	6.7	-	6.6	4
	32)	stage	9.0	1.5	-	-	6.0	5.5	-	-	6.7	-	6.0	3.6
Nitrofen	16)	4-leaf	7.0	3.5	8.2	8.2	8.5	5.0	8.2	8.2	-	-	-	-
	32)	stage	6.0	2.0	7.9	8.5	9.0	5.0	7.9	8.5	-	-	-	-
C 7019	16)		4	1.5	-	-	-	-	-	-	-	-	-	-
	24)		-	-	7.2	9.4	-	-	5.2	7.5	-	-	-	-
	32)	4-leaf	4	1.5	-	-	-	-	-	-	-	-	-	-
	40)	stage	-	-	5.6	3.7	10	9.0	-	-	-	-	-	-
	48)		3	0.5	-	-	-	-	-	-	2.3	-	2.6	2.3
	64)		-	-	-	-	10	6.5	-	-	-	-	-	-
C 7019	40)	2-leaf	-	-	-	-	8.5	5.5	-	-	-	-	-	-
	64)	stage	-	-	-	-	8.5	1.5	-	-	-	-	-	-
Desmetryne	4)	4-leaf	3.0	0.6	5.9	5.4	-	-	-	-	-	-	-	-
	6)	stage	2.0	0.9	1.6	1.7	-	-	-	-	-	-	-	-

CP 50144

The 24 oz./ac a.i. rate of application only slightly affected vigour and density of crop but higher rates progressively reduced vigour and plant numbers at all centres. There was good control of Stellaria media, Polygonum aviculare, Chenopodium album, Lepidium campestre and Poa sp at all rates of application at all centres where these weeds were present. Control of Sinapis arvensis was not effective.

Post-emergence treatments

Nitrofen

Applications at the 2 true leaf stage of the crop gave a severe scorch to those leaves, increasing in intensity with dose rate at all centres. The growing points were unaffected and recovery was fairly rapid so that only slight retardation in growth was detectable four weeks after application. Leaf scorch was also severe at the 4-leaf stage of application but although the proportion of green leaf remaining was greater the check to the crop seemed to be greater than when the same doses were applied at the 2-leaf stage. Crop plant density was relatively unaffected by either time or rate of application.

Weed control was considerably better at the earlier stage of application particularly at the higher rate, but was satisfactory at one centre only. The larger plants of Stellaria media and Tripleurospermum maritimum ssp. inodorum were particularly resistant to the chemical but a reasonable control of Polygonum aviculare, Chenopodium album and Polygonum convolvulus was achieved with 32 oz./ac. Poa sp were unaffected.

C 7019

At two centres in 1967 up to 40 oz./ac had very little effect on the crop and crop vigour was only slightly reduced at one centre (Berkshire) in 1968 by 24 oz./ac of C 7019. At one centre (Cambridge) in 1967 and two centres (Shropshire and Worcester) in 1968 the crop was completely devastated by all rates of chemical up to 48 oz./ac at both the 2-leaf and 4-leaf stages of application. Weed control was also very variable, with excellent control of all weeds at all rates in Cambridge and Shropshire (1968) and good control at 40 oz./ac in Hampshire, but poor control with 24 oz./ac. At the Shropshire 1967 centre weed control was good with 32 oz./ac but only moderate at 24 oz./ac rate when applied at the 2-leaf stage and poor at both rates when applied at the 4-leaf stage of the crop.

Desmetryne

This chemical was used in 1967 only at two centres (Cambridge and Hampshire) and caused severe yellowing of all crop plants with necrosis of many leaves at 6 oz./ac but slightly less severe symptoms at the lower rate of application. The crop made no effective recovery from the severe check at the Cambridge centre but there was reasonable recovery from the lower rate of application at the Hampshire centre. Weed control was excellent at all rates at the Cambridge centre and with 6 oz./ac in Hampshire but only moderate with 4 oz./ac.

Barban

This chemical was applied at 5 oz./ac in Hampshire (1967) only to test crop reaction. Only occasional wild oats in the 2 - 3-leaf stage were present. Barban had no effect on crop vigour and density.

DISCUSSION

Selective control of a broad spectrum of annual weeds in oil seed rape is proving to be quite difficult as it is in other direct drilled Brassicae. A reasonable suppression of unrelated species such as Stellaria media, Polygonum aviculare seems possible with some of the chemicals tested, i.e. CP 50144 and propachlor, but related aggressive species such as Sinapis arvensis are very difficult to control.

The crop was obviously not sufficiently tolerant of C 7019, either pre or post-emergence, and desmetryne at dose rates which are effective on weeds. Nitrofen post-emergence was quite effective within its weed spectrum and often gave a slight check to such weeds as Stellaria media which was sufficient to enable subsequent crop growth to effectively smother them. The initial check of post-emergence application of nitrofen to the crop seemed to be quite drastic but in most of the trials scoring was carried out within 4 weeks of this post-emergence spraying. There was some evidence from the Worcester and Shropshire (1968) trials that later recovery was complete although there are no yields to confirm this.

CP 50144 showed some promise as a soil acting selective herbicide in rape even on the heavier soil type in Worcester. The results in Berkshire suggest that lower rates even than 24 oz./ac could give reasonable weed control with greater safety to the crop.

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