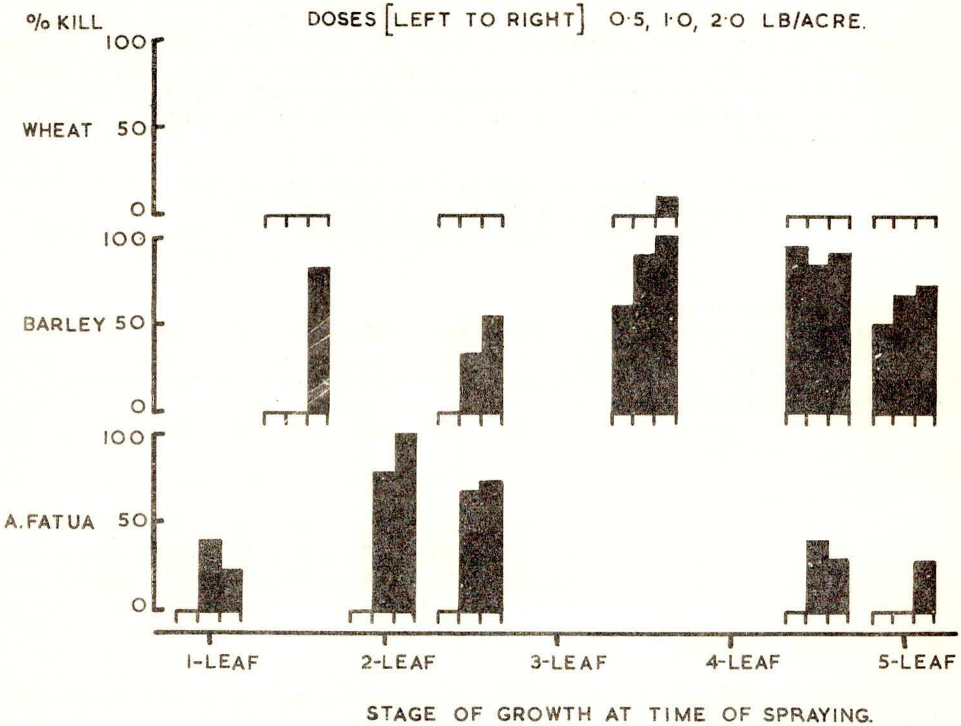

Fig. 3. Percentage kill of wheat, barley and A.fatua treated with barban at various stages of growth.

(55-70 per cent) but at a sowing depth of 2 inches there was only 30 per cent reduction. These results were not readily explicable in terms of the depth of the growing point as measured in this experiment.

Crop competition

Various suggestions have been made that competition from a vigorous crop increases the control of A.fatua by barban. Accordingly an experiment was conducted to determine whether light intensity, one of the major factors involved in competition, influenced susceptibility of A.fatua to barban. Light was reduced to 24 per cent and 50 per cent of full daylight by the use of perforated metal screens placed over the pots from the time of seedling emergence to spraying, at the $1\frac{1}{2}$-$1\frac{3}{4}$ leaf stage, and from spraying to final assessment 4 weeks later. There was an appreciable increase in spray retention, particularly on the leaf blades, by plants in full daylight prior to spraying compared with those receiving only 24 per cent light. This difference was almost proportional to the difference in dry weight of shoots between the two sets of plants.

The initial check to growth from the highest dose of 0.75 lb/ac was greatest where plants had received only 24 per cent light before and after spraying but there was little difference between the other combinations of light treatments. Data illustrating the ultimate effect on fresh weight after 4 weeks are presented in Table I. Each percentage is based on the control receiving the same combination of light treatments. These results indicate that a reduced light intensity for the whole period from emergence to assessment increases inhibition, but that reducing light for the post-spraying period only does not enhance the effect.

TABLE I. PERCENTAGE REDUCTION IN FRESH WEIGHT PER PLANT OF A.FATUA, 4 WEEKS AFTER SPRAYING WITH BARBAN UNDER VARIOUS LIGHT CONDITIONS

Light intensity prior to spraying, as per cent of full day light	100	100	100	50	50	24	24
Light intensity after spraying, as per cent of full day light	100	50	24	100	50	100	24
Dose in lb/ac							
0.19	80	89	125	70	56	63	44
0.38	53	36	60	20	30	44	37
0.75	10	11	28	10	10	14	14

Site of spray retention

An attempt was made to investigate the relative importance of retention at various points in the shoot of A.fatua. The plants were at the early 2-leaf stage growing in a modified Hoagland's culture solution. Five 0.002 ml drops of pure barban in alchhol were applied at various points with an Agla microsyringe. Dry weights of shoot and roots were determined separately after two weeks. The picture presented by the effect of a dose of 0.1 mg per plant on shoot growth is typical. There was a reduction of 15 per cent and 36 per cent if this dose was applied to the tip of the second and first leaf blades respectively. Much greater reductions of 62 per cent and 61 per cent were given by application to the base of the first leaf blade and to the outside of the sheath of the first leaf respectively.

A similar technique using plants growing in solution culture was used to study the time-course of effect of barban on A.fatua. This demonstrated that, with application to either the tip or the base of the first leaf blade, the shoot was inhibited in growth first, an effect being apparent after 8 days. It was not until after 12 days that root growth was reduced.

Susceptibility of other species

The possibility of undersowing clovers and grasses in cereal crops treated with barban was investigated. Doses of 0.19, 0.38 and 0.75 lb/ac were applied to the soil surface immediately after sowing S124 red clover, S100 white clover, French Provence lucerne, S47 Cocksfoot and S22 Italian ryegrass. Overhead watering equivalent to 0.17 in. of rain was supplied on the following day. There were no effects on growth of any species.

2,3-dichloroallyl diisopropylthiolcarbamate

In the first experiment with this herbicide doses of 0.25, 0.5, 1.0 and 2.0 lb/ac were sprayed on the soil surface, and incorporated in a 3 inch depth of soil on the following day. The pots were then sown immediately with Atle and Koga II wheat, Proctor and Rika barley, A.fatua and A.ludoviciana. There was little or no reduction of emergence of wheat and barley but a marked reduction in numbers of both Avena spp. Wild oats which did emerge were very much restricted in their subsequent growth as indicated by the data in Table II.

TABLE II. THE EFFECT OF 2,3-DICHLOROALLYL DIISOPROPYLTHIOLCARBAMATE ON THE GROWTH OF CEREALS AND WILD OATS: FRESH WEIGHTS OF SHOOTS ABOVE GROUND LEVEL AS A PERCENTAGE OF CONTROL

Dose lb/ac	Proctor barley	Rika barley	Atle wheat	Koga II wheat	Avena ludoviciana	Avena fatua	Avena fatua in open
0.25	101	99	101	91	9	9	27
0.5	94	98	70	85	2	1	4
1.0	68	95	18	40	0	0	1
2.0	41	30	1	4	0	0	0

This assessment was made when the controls had reached the 2½-3 leaf stage. Both species of wild oats were virtually identical in response. With the cereals there was a greater difference between species than between varieties. Wheat was much more susceptible than barley. Proctor showed more adverse effect than Rika as did Atle compared with Koga II but these differences were only evident at the 1 lb/ac rate. The selectivity between A.fatua and cereals seemed greater than with 3-amino-2,5-dichlorobenzoic acid which was investigated at the same time. The main experiment was kept in the greenhouse, at a minimum temperature of 53°F. A second set of A.fatua was maintained outside with overheat protection from rain but with free air circulation over the pots. These were at a much lower temperature, which fell to freezing point on occasion. The last column of Table II shows that the effect of the herbicide was rather less under these circumstances. Also one set of pots was kept moist but unsown in the greenhouse for 3½ weeks, then re-mixed and sown with A.fatua. There was still sufficient herbicide remaining from original applications of 0.5 lb/ac and above to produce a very severe toxicity.

A further experiment was designed to indicate whether change of soil type influenced initial toxicity and persistence. 1:1 mixtures by volume of our standard loam with sharp sand and with granulated peat were compared with the standard loam alone and with a clay soil (containing about 20 per cent clay). The effect on wheat and A.fatua sown at the time of incorporation on the day following spraying was greatest in the sand-soil mixture and least in the clay soil. Pots kept moist in the greenhouse for 4 weeks before sowing lost some of their activity but the proportion lost did not appear to vary appreciably between the soils. Sufficient remained from an initial dose of 0.56 lb/ac to restrict growth of A.fatua to less than 10 per cent of control growth in all cases.

Visual observation indicated some differences in leaf characteristics of plants receiving 2,3-dichloroallyl diisopropylthiolcarbamate prior to sowing, as compared with control plants. Therefore wheat which had received 0.31 and 0.47 lb/ac of this herbicide as a pre-sowing incorporation treatment was sprayed with 2,4-D or dinoseb or tartrazine for retention measurement at the 2-leaf stage. This preliminary experiment indicated a slight increase in spray retention and in damage from dinoseb where there had been pretreatment with the thiolcarbamate.

Experiments on other species indicate most dicots to be resistant to this herbicide. Sugar beet, kale, peas, field bean, maize, lucerne, white clover, red clover all withstood up to 2 lb/ac incorporated in the soil immediately prior to sowing. Dicotyledonous weeds such as Stellaria media and Brassica alba also appeared resistant. Most grasses tested were susceptible and may be roughly ranked in the following order of decreasing resistance: Poa annua, cocksfoot, Alopecurus myosuroides, timothy, Avena fatua, Italian ryegrass.

DISCUSSION

The experiments described have demonstrated that both barban and 2,3-dichloroallyl diisopropylthiolcarbamate have potentially useful selectivity between wild oats and cereal crops. However they also indicate that successful use will depend on compliance with restrictions regarding many of the conditions of the application.

With barban, barley was often as susceptible as A.fatua (as in Figure 2) but this was because the variety Proctor was used. This variety is particularly susceptible as is shown by Pfeiffer et al (1960); Rika showed a much higher resistance when included in one experiment. Differences in spray retention between wheat, barley and A.fatua do not favour the selective action required; on the contrary selectivity should be much greater if equal doses could be deposited on crop and wild oat plants. Reducing the spray volume increases retention and ultimate effect on both barley and A.fatua; thus low volume application should give greater economy of herbicide. The results indicate that an application method which increased retention by the leaf sheath and at the bases of the leaf blades would improve the control of A.fatua. The importance of stage of growth of both crop and weed at the time of spraying was verified, and the very short period of maximum susceptibility of A.fatua is an obvious practical disadvantage of this herbicide. Selectivity in Proctor barley cannot be improved by deep drilling, though some increased safety was imparted to wheat by sowing 2 inches deep. This would however be unacceptable agriculturally.

The results of the experiments with 2,3-dichloroallyl diisopropylthiolcarbamate indicate that, as with most soil-acting herbicides, the environment may be particularly important. Thus there appear to be variations in performance with changes in soil type and perhaps with temperature. On the other hand there was not the major change in resistance between Proctor and Rika barley that occurs with barban. The period of persistence of toxic residues in the soil is a major advantage in that control of wild oats germinating some time after drilling of the crop can be expected. It is a disadvantage insofar as cultivated grasses are susceptible and undersowing of treated crops is precluded, whereas this is probably possible with barban. The safety of applying post-emergence herbicides to crops treated with 2,3-dichloroallyl diisopropylthiolcarbamate requires further investigation. Promising indications were obtained that this herbicide would be worth experimenting with for the control of Avena spp. in dicotyledonous crops such as beet, peas and beans.

Acknowledgments

Thanks are due to C. Parker, C. Donaldson and Mrs. G. Benfield for much assistance with these experiments. Spencer Chemical Co. and Monsanto Chemical Co. kindly supplied the herbicides used.

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Discussion on preceding nine papers on wild oats

Mr. G. B. Lush. I deprecate as much as anyone the reading of papers from the floor but, unfortunately, peculiar circumstances have made it impossible for us to contribute to this session in the usual way. We regret this enormously and are extremely grateful to the Chairman and Session Organiser for allowing us the opportunity of recording a very few words on our work this year on the control of wild oats with 2,3-dichloroallyl di-isopropylthiolcarbamate (X). We have in the past season carried out an extensive series of both replicated and farmer trials, distributed throughout the wild oat problem areas, the trials lying in the territory to the east of a line drawn between Yorkshire and Devonshire. In the replicated trials, 'X' was applied at a range of doses from ¾ to 3 lb/ac and investigations included method of incorporation, effect of soil type, timing, varietal susceptibility and persistence in the soil. In this season we have concentrated on spring barley, in order that we might have available sufficient wealth of information of performance under U.K. conditions to enable us to market for this crop in 1961. At the same time, more limited work in spring wheat, sugar beet and peas indicates the potential use of 'X' in these crops. The results of this programme of work show quite clearly that 'X', used as we propose to recommend it, in spring barley at 1½ lb active ingredient per acre well incorporated into the soil before drilling, will give an extremely good control of both Avena fatua and Avena ludoviciana. I entirely agree with Dr. Sanders when, earlier in this Conference, he made the point that 90 per cent control of wild oats was insufficient. In our trials the poorest results we have had, have been of that order and in every case we have been able to explain the failure in terms of incorrect application. In the main, our control of wild oats has varied between 95 per cent and 98 per cent with the occasional 100 per cent. It has been notable that the wild oats that do emerge from treated plots, i.e. the odd 2-5 per cent, grow to the same height as in the untreated plots and can readily been seen and rogued. Provided the recommended technique is employed, there is negligible hazard to barley with considerable latitude in application. All the commonly grown barley varieties included in our trials were found to be equally resistant. This is, of course, including Proctor, which occurred in 97 per cent of our farmer trials. Removal of wild oats by the use of 'X' in these trials has given increases in barley yield of up to 50 per cent. The following of applications of 'X' by post emergence sprays of MCPA, 2,4-D and mecoprop has been carried out without any deleterious effect on the crop or on wild oat control.

Miss J. M. Thurston. The results of my experiments on competition between the crop and wild oats in pots and in naturally infested fields agree well with the results obtained by Miss Holmes and Dr. Pfeiffer using cultivated oats. The number of wild oat seeds per plant can be reduced considerably by increasing competition from the crop. This can be done by any method which does not also benefit the wild oats e.g. by increasing the sowing-rate, by sowing early to ensure that the crop is well established by the time the wild oats germinate, or by changing to a more vigorous and free-tillering variety. Additions of nitrogenous fertilizer does not increase competition from the crop as it also increases the vigour of the wild oat plants. Wild oats are most susceptible to competition in the early seedling stage, when their leaves are small and narrow and there is not so much food-reserve available from the smaller seed of wild oats compared with the seed of a cultivated cereal. The young seedlings of wild oats have a higher nett assimilation rate than corresponding crop plants or older wild oat plants; this enables them to grow faster than the crop plants and catch them up in size. Overshadowing by the crop can prevent them from taking advantage of this difference.

It is possible that the sensitivity of young wild oat plants to barban applied at the 1½-2½ leaf stage, decreasing as the plants get older and bigger, is connected in some way with the physiological activity of the seedling, and this would seem to be worth investigation.

It might also be worth considering whether the sensitivity of wild oats to 2,3-dichloroallyl di-isopropylthiolcarbamate is connected with the depth at which the wild oat seeds are buried in the soil and the effect of this on the part of the plant which penetrated the treated layer of soil. If the seeds are more than 3 to 4 in. below the surface of the soil it is the first leaf, and not the coleoptile, which appears at the surface and perhaps this is more sensitive than the coleoptile to the herbicide. The crop, on the other hand, is sown at such a depth that the emerging shoot is protected by its coleoptile. Wild oats can emerge from seeds buries at 6 to 9 in. below the soil and often do so. The seeds are commonly mixed with the soil down to or below the depth to which it was ploughed.

Mr. R. W. E. Ball. We carried out some field experiments, in 1959, with barban, and one of these was in a crop of Koga II spring wheat. The results confirmed the observation of Mr. Holroyd that this variety is sensitive to barban after the 2-3 leaf stage. In our experiment it appeared to be as susceptible as Proctor at doses of 8 oz/ac and above. I should like to ask Dr. Pfeiffer whether spring wheats show as great a variation in varietal susceptibility as do the spring barleys.

Dr. R. K. Pfeiffer. In the majority of our experiments we had Koga II and we encountered no difficulty. Our own spring wheat variety trials failed due to drought but N.I.A.B. should in future have information on this.

Regarding crop competition, Miss Holmes and I have submitted a paper on this matter to the Editor of the new Weed Research Journal. This is a study of the competition between oats and barley as influenced by fertiliser and seed rate. We confirm observations that nitrogen does not help, for wild oats and barley benefit to the same degree, but increase in barley seed-rate led to a reduction of the oats. Additional reduction was produced by barban.

Mr. J. Holroyd. When Koga II was sprayed at the 3-leaf stage in our field trial there was no depression in yield but there was a reduction when it was sprayed at the 5-leaf stage.

Mr. T. E. Miller. March was mentioned specifically, but March in Yorkshire is not the same as March in the South. This is very important if it is a matter of spraying at exactly the right stage.

Dr. R. K. Pfeiffer. So far as the effect during March is concerned, we do not understand it yet. A lot more work is needed on this and trials have actually started.

Professor A. H. Bunting. Have you followed the pattern of development of tillers during this period, and the effect of treatment thereon, for this may be critical in determining ultimate yield?

Dr. R. K. Pfeiffer. We observed the effect for the first time this year; we did not expect it and therefore unfortunately did not take the necessary observations. We have to start from the beginning to study the problem.

Mr. A. L. Abel. Dr. Dubrovin of Spencer Chemical Co. is now engaged on detailed study of that particular point, and in due course this will appear in the American Journal 'Weeds'.

With the subject we are dealing with it is important we do not have too many unnamed off-spring. It is desirable to have a family and christian name for herbicides - barban has been christened and its name is 'Carbyne'. Could we please have a name for the thiolcarbamate?

Mr. G. B. Lush. Before long we shall be able to produce the appropriate name.

Mr. R. F. Norman. To what depth should 'X' be incorporated into the soil and how is this depth to be measured? Is it as a loose or firm tilth and how critical is this factor? There is little indication as to whether it is possible to use other herbicides, for example MCPA or mecoprop, on crops growing in land treated with 'X'. It would appear from Dr. Holly's work that materials such as DNOC and dinoseb might well cause scorch to crops growing in land treated with 'X'. It is possible to provide more information on this matter?

Dr. L. H. Hannah. When we say incorporate in the top 1 to 2 in. we mean stirring not more than the top 1 or 2 in. of soil, whether firm or loose. We maintain that the closer to the surface we keep the herbicide the better wild oat control will be. I did not have time to present information from the U.S.A. on concentrating the chemical, with a special piece of equipment, about ½ in. below the surface in loose soil. This gave an excellent control of wild oat; Chenopodium and Amaranthus were also controlled.

About the use of MCPA, we could cite experience in Canada this year in which many thousands of acres of flax, barley and wheat were treated. About 95 per cent of the crops that were treated with 'X' were also treated with 2,4-D and there was no injury.

Mr. G. B. Lush. When 'X' application to barley was followed by post emergence application of MCPA, 2,4-D or mecoprop, no deleterious effect occurred.

Mr. G. A. Toulson. Towards the end of his paper, Dr. Holly dealt with the effect of barban on species other than the cereals and appeared to give the impression that this herbicide does not adversely affect grasses, clovers, etc. I suggest that this statement requires qualifying. In a particular trial conducted in Wales, in the absence of wild oats, barley varieties were sprayed with barban (11 oz/ac) at two stages during early development. The barley had been undersown with a general purpose seed mixture at the time of drilling the crop and grasses and clover were in their first and second true leaf stage respectively, at the time of spraying. The application of barban at both stages considerably reduced the stand of grasses, but the clovers remained unharmed.

Dr. K. Holly. I should point out that in my paper I was dealing with the susceptibility of grasses and legumes sown into soil treated with barban, i.e. visualising the situation where the crop was sprayed very early for wild oat control and the 'seeds mixture' drilled subsequently. The results of

Mr. Toulson and myself are therefore not at variance. If one was spraying barban after the emergence of cultivated grass seedlings some damage to grasses might be expected, but surely in most instances we would not be doing this because by then the wild oats are too advanced in growth.

On the point of spray damage from other herbicides after treatment with the thiolcarbamate (X): where wheat has been very slightly damaged by thiolcarbamate the situation is very similar to that with TCA treatment of peas where dinitro herbicides can not be applied subsequently with safety because the wax on the leaf surface is affected.

Dr. R. K. Pfeiffer. I interpreted Dr. Holly's paper in the sense that the grass would be undersown after barban was sprayed and would not be present at the time of spraying. I would expect that ryegrass would be damaged if in the 1-2 leaf stage when sprayed with barban but there would not be much damage to clover. Our limited information shows that ryegrass sown a day after spraying with barban did not show any damage provided no more than the recommended dose was used. Twice the recommended rate caused very little damage. Barban is almost inactive on A.fatua if applied to the soil as a pre-emergence treatment unless 10-20 lb/ac are used.

SESSION 9

Chairman: Mr. J. V. Spalding

WEEDS OF WATERWAYS

CHEMICAL CONTROL OF WEEDS IN AND ALONG WATERWAYS

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Watercourses are meant to take care of a ready transport of water for draining or for irrigation. Consequently in all situations in which no optimal flow is obtained remedial measures have to be taken. In the regular maintenance of watercourses the removal of aquatic and ditch bank weeds is one of the most important aspects. In former years this was usually done by hand, but nowadays due to the decreasing availability of hand labour a great diversity of ditch cleaning machinery is available to drainage authorities, contractors and farmers. A more recent development in Europe is the application of herbicides against aquatic weeds. Although still in an initial stage in some area's it is already playing a part next to mechanical ditch cleaning.

I have been invited to discuss recent developments in the control of water weeds. In this discussion I shall not deal with ditch cleaning machines, however important they may be, but confine to the possibilities of herbicides in this field. By many people the use of chemicals in aquatic weed control is rightly considered with a certain distrust. Accordingly a careful consideration of all factors involved is highly desirable. Therefore I greatly appreciate having this opportunity to review the various problems.

It seems to me, that in the chemical control of aquatic weeds the secondary consequences of the application are more important than in any other use of herbicides. The reports presented to previous British Weed Control Conferences by Alabaster (1956, 1958) covering the toxicity to fish of several pesticides only touch upon one (although a very important one) of the problems connected to the application of herbicides in waterways. Other points that may not be neglected are the influence of the chemical on the quality of the water for drinking by cattle, for irrigation and for spraying, on the biological purification normally taking place, etc. Especially, the use of auxin herbicides in watercourses used for irrigation and for spraying horticultural crops and orchards, is very risky as extremly small quantities may cause damage to the crop.

Considering the function of waterways to transport water, the aims of chemical aquatic weed control can best be compared with those of total weed control on industrial areas. In both cases a considerable reduction or entire removal or prevention of plant growth is required. Still there are great differences between the two fields both as to the herbicides that can be used and as to the way in which they must be applied. In industrial weed control, many times herbicides are used which are taken up through the roots. Now the root system of aquatic plants is hard to get at. In addition the water environment of submerged aquatic weeds differs considerably from the atmosphere in which terrestrial plants are growing, and consequently the techniques of application must be different. The problems involved will form the background of the first part of my discussion.

In the control of emergent graminaceous weeds, systemic herbicides, transported from the leaves to the root system, have been widely investigated and they are already used in practice. Among these products dalapon takes an outstanding position. TCP (trichloropropionic acid) is much less active (Kramer, 1960). Expressed in molecular concentration the general herbicidal activity of dichlorobutyric acid seems to be about the same as that of dalapon, although it seems to be less effective against Sparganium racemosum. For practical applications the price of the commercial formulations and their availability may determine which of them will be used.

For an optimal effect dalapon, as most other herbicides, must be applied at a rather high relative air humidity (not less than 70 per cent), in low to medium volumes of water and in rather small droplets. A wetting of all leaves is necessary, so in dense vegetation a penetrating air stream or the use of a high pressure spray gun is needed. The effect of wetting agents on the effect of dalapon is partly a controversial topic. Most investigators agree that wetting agents generally increase the initial kill and die-back of the vegetation. This may be important because of an earlier decay, but it is not clear whether the final effect is also improved. Of course the proportions of the leaf area above and in the water must effect the dosage required for an effective treatment. However in our experiments in the Netherlands Glyceria maxima, Phragmites and Typha have been successfully controlled by 15 kg/ha (16.5 lb/ac) of dalapon under varying conditions of water table and treated leaf area.

Aminotriazole is another chemical effective against emergent ditch weeds. At sufficiently high rates of application (about 10 lb/ac) the activity of this herbicide is sufficient to make it of practical importance. In mixtures with dalapon, amino triazole is given the function of "assisting herbicide". We have found that a mixture of 10 lb of dalapon and 2 lb of amino triazole/ac has the same herbicidal activity as 15 lb of dalapon alone. In the mixture, amino triazole considerably speeds the effect of the application and the rate of decomposition of the dead organic material. After spring applications, the results may be clean or more or less clogged watercourses during the summer. The importance of the way of formulating amino triazole, in particular the addition of ammonium thiocyanate, is under study in several countries. It seems to me too early to come to general conclusions as to the effect of this addition on the rate of chemical to be applied and the initial and final kill of the vegetation. After the publicity amino triazole has received in the U.S.A. as a result of residue determinations in food products and subsequent governmental action on contaminated cranberries, the chemical is the subject of great public suspicion. There are indications, however, that a reconsideration of the available toxicological data in some countries may lead to official recommendation of its use in aquatic weed control.

In the control of broad leaved emergent weeds no special difficulties are met. Generally speaking satisfactory control is obtained with the auxin herbicides MCPA and 2,4-D at twice the doses used in cereals and grass-lands. In mixed vegetation we prefer the amine salt of 2, 4-D to MCPA, because of its activity against a broader range of weeds. Against the typical low peat vegetation, where Stratiotes aloides and Sium species are the main weeds, the cheaper MCPA is acting as well. As a rule two applications are required against Stratiotes. In early spring this is a submerged weed, the rosettes of which become floating and partly emergent in early summer, often covering the whole surface of the ditches. As the herbicide is only effective when sprayed on the emerged parts of the leaves and not all rosettes always emerge at the same time, a second treatment about three weeks after the first may be necessary for a complete control.

In most cases grasslike and broad-leaved weeds may be satisfactorily controlled by one single spraying of a mixture of dalapon, an auxin type herbicide and amino triazole. In the Netherlands we have good experimental results with a combination of about 7½ lb of dalapon, 2 lb of 2,4-D-amine salt and 2 lb of amino triazole.

Next to the stage of development of the weeds, the time of spraying has to be based on the specific maintenance requirements of the watercourses. In Holland spraying in the middle of May has the advantage that the treated weeds decay rather quickly. Thus watercourses sprayed at that time remain clean until at least the beginning of August. Then some regrowth may start from some not completely killed rhizomes of Glyceria maxima and Phragmites. This new vegetation may, however, be definitely killed by a second treatment with a lower dose, e.g. two thirds of the first application. If the first spraying is postponed until the middle of June or later, one single treatment will generally give a satisfactory control, but the treated ditch will not be clean during the summer because the dead lignified plant material decays too slowly and obstructs the flow of the water.

The vegetation of temporarily dry ditches is usually very similar to the emergent vegetation dealt with before. For the control of weeds under these circumstances, however, in addition to the herbicides mentioned other products have to be considered. First of all TCA, a grass-herbicide, cheaper in use than dalapon and successfully applied in e.g. temporarily dry fish ponds. TCA is only effective through the roots whereas dalapon effects the plant both through the roots and leaves. So for temporarily dry water ways that may become refilled with water at any unexpected moment, TCA is not to be recommended instead of dalapon. In Germany and the Netherlands commercial mixture of TCA, amino triazole and auxin herbicides are being studied. In my opinion mixtures of dalapon, amino triazole and auxin herbicide as mentioned earlier are more important, however.

If a ditch is free of water for considerable time periods and without of deep-rooted plants, e.g. due to treatments with dalapon and auxins, applications of total herbicides of low solubility with long residual action become attractive. A long residual effect against germinating plants can only be expected, however, if the chemicals can penetrate in the top-layer of the ditch bottom. Therefore, some rain is required, but not so much that the ditch bottom will be again covered with flowing water. In experiments, good results were obtained with monuron and diuron, with mixtures of monuron and diuron with amino triazole and with simazin plus amino triazole. In the Netherlands monuron and diuron are used for these applications on a practical scale.

The exceptionally dry summer of 1959 caused the drying up of watercourses carrying large volumes of water under normal weather conditions. This actually offered opportunities for chemical weed control, but unfortunately could not be taken advantage of. Sufficient experience was not available then to justify large-scale practical recommendations. In future, however, such opportunities may be better utilized.

Passing on to the control of submerged weeds, in these plants the interrelations between leaves, stems and roots may be in many respects different from those in land plants. In Ceratophyllum, which has no roots at all, it is clear that water and minerals may only be taken up by the leaves and stems. In other submerged weeds the only function of the roots might be to attach the plants in the ditch bottom.

As there is no transpiration stream, an intensive transport of water through the xylem is not probable. Consequently herbicides that act on land plants after absorption by the roots and subsequent translocation by the transpiration stream to the shoot system should be of no value in the control of submerged weeds. It appears, however, that some of these products, as e.g. monuron, diuron and simazine, although they are poorly or not at all absorbed by the leaves of land plants, act quite well on submerged leaves through absorption from the surrounding water. Here we must realise, that the anatomy of the leaves of submerged water weeds is different from that of most land plants. In contrast to the leaves of submerged aquatics the leaves of land plants generally have morphological features which restrict transpiration and uptake of chemicals as e.g. a pronounced cuticule, sunken stomata and a waxlayer. As these are wanting in submerged weeds, the uptake of substances dissolved in the water will be much easier than in immersed (normal) leaves of land plants.

In treating submerged weeds with herbicides we have to consider the concentration of the product in the water and not the dose to be applied to the treated area. This goes for stagnant as well as for flowing water. In the latter case, however, where the time of exposure is limited, the concentrations to be applied must be much higher than in stagnant water. This is particularly true for the application of contact herbicides. Here it can be said, that above a certain threshold value, typical for each chemical, the concentration as well as the time of exposure determined the effect. In flowing water the continuously occurring dilution of the herbicide limits optimal effects to a certain distance from the place of injection.

In systemic herbicides, as monuron, simazine and auxin herbicides probably a different relationship exists between concentration and time of exposure. Although our insight in this point is far from complete it has been established for auxins (Blackman, 1956), monuron (Tedd, priv. comm.) and simazine (Van Steekelenburg, priv. comm.) that after short time exposures a loss of the chemicals from the treated plant parts can be observed if the plants are returned to untreated water. Because of this submerged plants may completely recover from temporary growth inhibitions. However, this does not mean that plants treated with the same chemicals in very high concentrations will also recover. A trend in the investigations in our institute is the study of such treatments with concentrations of 30 - 1000 ppm with short exposure times.

It is too early to say, however, whether the investigations will lead to any practical method of control.

One way to achieve a higher concentration of chemical near the leaves and stems of submerged plants is by using pellets, which sink to the ditch bottom or settle on the vegetation. In completely stagnant water in this way a rather high concentration can be achieved in the water-layer close to the ditch-bottom and in various cases with this method positive results are mentioned, especially with pellets containing esters of 2, 4-D or 2,4,5-TP. On the basis of surface area treated the doses to be applied are very high, viz. 10 to 20 times those for land plants. But here we must realise that in land plants after an application of e.g. only 1 lb /ac of MCPA in 50 gal of water the herbicide is taken up from an initial concentration of the spray of about 2000 ppm, which concentration even rises during drying-up.

Dusts have also been investigated for the control of submerged weeds. When using dusts the leaves may be covered by many small particles from which the herbicide diffuses into the leaves, a situation more or less similar to that in sprayed land plants. The formulation of the product and particularly those factors that determine the tendency of the dusts to become attached to the submerged vegetation are probably of great importance. As far as I know the method has not yet led to extensive practical applications, and where dusts were applied apparently the doses of active ingredient used were similar to those where the products were formulated as pellets.

After these general considerations some comments can be given on specific products. In the irrigation districts of the western United States contact herbicides are generally used, in the first place aromatic solvents, nowadays also acrolein., The last named product has been introduced to you at the 4th British Weed Control Conference (Van Overbeek, 1958). The application difficulties of this very unpleasant product seem to have been sufficiently mastered to allow safe handling. Its most important advantages seems to be that acrolein is flowing much more evenly through the submerged vegetation than any other product and that in a short time the plants desintegrate to small pieces, which do not have to be removed. In Western Europe the very high toxicity of the product for all organic life in the water prevents its application in most cases. The same goes for aromatic solvents.

Although I understand that diquat may also be of some use in the control of submerged weeds, its use is apparently unsufficiently studied to allow practical recommendations.

It must be emphasized that on submerged weeds the effect of contact herbicides is a kind of chemical mowing, without any effect on roots and rhizomes in the bottom, so regrowth takes place.

Attention continues to be drawn to copper sulphate, used as algicide. The product has also some value against some dicotyledonous weeds too, as has been shown e.g. by Chancellor et al (1958).

From the auxin herbicides studied, 2,4,5-TP has to be specially mentioned. The chemical is recommended for use in the control of submerged weeds in the PGBE formulation commonly used in applications against terrestrial weeds. In stagnant water or where the flow of water can be prevented for some days the product is effective against weeds like Myriophyllum and Elodea (Dow 1959). The toxicity of the product to fish will be discussed later.

A group of lower plants which I should like to mention briefly are the filamentous algae. In some parts of the Netherlands occasionally they are very harmful, because such growths of algae are so tough and felty that they cannot be removed by machines. Filamentous algae do not occur in some ditches in polders north of Amsterdam. This absence is caused by an intensive treatment of the ditch banks with monuron, a herbicide to which filamentous algae are more sensitive than submerged weeds. The practice of killing all vegetation on ditch banks is certainly not recommended by us, because it exposes the banks to erosion. The only reason that I mention this is that the treatment causes the ditches to be practically free from algae. At Wageningen we have discontinued our investigations on the control of filamentous algae because we have observed in preliminary tests that these organisms are much more susceptible to herbicides than Elodea canadensis, which is our most common and serious submerged weed and one of the major test weeds in the experiments.

The use of chemicals in weed control on ditch banks is no problem on its own. In Holland we prefer a closed vegetation with grasses and this can be easily achieved by spraying auxin herbicides. This is also an important measure for the general farm sanitation, because ditch banks are as a rule important sources of weed seeds for the farm.

In several countries studies are made on growth inhibition of grasses in order to cut down mowing costs. A treatment with 4 - 6 lb/ac of maleic hydrazide combined with an auxin herbicide in order to prevent domination of broadleaf weeds proved to be successful, but generally was insufficiently reliable. The fact is, that the margin between growth inhibition and partial kill has proved to be very narrow and besides grasses most important for a closed sward are the most susceptible. Also with high doses of 2,4,5-TP growth inhibition may be obtained. Also treatments for inhibiting grass growth are rather expensive. Therefore at the moment in my experience spraying auxin herbicides is the most suitable. It results in a good and valuable sward, that can easily be mowed mechanically or by hand.

Control of water weeds means interfering in a natural succession of plant growth. The removal of the emergent vegetation, as can take place with chemicals, will inevitably result in a stronger development of the submerged plants. This is the reason that in our opinion the study of the control of submerged weeds and algae deserves highest priority.

In my opening remarks I mentioned that there are several consequences of the application of herbicides in watercourses. From all problems indicated I should like to discuss in some detail only one, viz. the influence of the chemicals on the water as the environment of fish life. The presence of waterplants may be either beneficial or troublesome to fish. The determining factor is to what intensity the plant growth is developed. Only few plants, like Lemna and Azolla, are always considered to be harmful for fishes. For all other waterplants, waterweed control can be looked upon from the viewpoint of fisheries, as selective checking of plant growth favourable to the maintenance or improvement of water environments required for optimal fish life. In this respect control of aquatic weeds is more or less comparable to control of grassland weeds; a selective checking of many plants is there preferred to a complete eradication, because of the function of dicotyledonous plants in determining the herbage value of the sward. From the point of view of fisheries a careful maintenance of waterways is highly desirable. This explains the interest of fishery specialists for simplified methods of maintaining waterways. The urgency of improved vegetation control is well illustrated by Hofstede (1960) who states that in Holland in 1957 in 30 per cent of all cases of severe death of fish exceptional growth of Lemna or other plants could be established as the probable cause.

In checking aquatic vegetation the maintenance of the ditch profile is of great importance. In many ditches dredging is so long postponed that the removal of all material means a strong interference in the biological environment. Due to mechanical cleaning the parts of most water plants present in the ditch bottom are removed (rhizomes, and other hibernating organs). In practice a complete removal seldom occurs and then quite soon regrowth starts.

Those waterways of major importance for the drainage conditions in a district are usually regularly cleaned. From spring to autumn the conditions in these waterways, where the plant-growth is frequently mowed or cut down near the bottom, are quite different from those in the uncleaned smaller ditches. This means, that various types of environment are available, each with its specific importance for adult fishes, fish-brood and fish-food organisms. In most cases exuberant plant-growth means decrease and consequently loss of environment suited to fish-life. On the other hand a great quantity of intensively decaying plant material may result in oxygen shortage and other toxicity phenomena in the water.

Taking into consideration all aspects mentioned, the use of herbicides in waterways may not result in an undesirable influence upon the water environment for fish. Preceeding any approval, products must be investigated as to their possible toxic action on fish species in any stage of development, on fish-food and on other organisms of importance in the food-chains in water.

The available time does not allow me to discuss all problems in detail. Therefore, I shall restrict myself to some comments.

In the first place a comment on the method of assessing toxicity to fishes and fish-brood. In reading publications on this topic (Alabaster, 1956, 1958; Bandt, 1959; Davis and Hardcastle, 1959; Edson, 1958) one observes a diversity in methodology which leads us to express the desirability of having a more standardized technique. Considering the work carried out already, it should be possible to come to an agreement on the methodology of one or some toxicity determinations, the results of which could also be used for an international exchange of data. In aquarium experiments fishes are usually exposed for several days to definite concentrations of herbicides. In our opinion it should also be recommended to investigate the effect of short temporary exposures to higher concentrations.

Secondly a comment on the way of interpreting the results of the determinations. Generally speaking in toxicity studies concentrations of herbicides are being investigated, calculated to be present after field applications in waterways of a specific not too great depth. In Holland, until now, we have accepted the standard that a tenfold concentration of the calculated one shall not influence test animals. Of course somewhere a line must be drawn but still a discussion on this factor seems desirable. In Austria Neururer and Slanina (1960) accept a safety quotient of 20. Only if the relation between the lowest tolerated concentration by fish and fish-food and the concentration calculated to be present after practical applications exceeds 20, Neururer and Slanina approve the application.

Finally a comment on the importance of the formulation of the herbicide in these toxicity studies. Although from a scientific point of view insight into the toxicity of the active ingredient is necessary, from data available it appears that the formulated products also have to be investigated. It is known, that the addition to the product of a wetting agent increases the toxicity of dalapon. In other cases we must believe that concentrating active substances in solvents and applying the products as emulsions greatly influences their toxicity.

According to Edson (1958) there is a general correlation, although not a precise one, between toxicity of pesticides to fish and toxicity to mammals, influenced in some cases by the water stability of the chemical. The correlation is too weak, however, to be of decisive importance in the discussion on the approval of herbicides for water weed control. We can roughly state, that herbicides easily soluble in lipoidal material are more toxic to fish than those soluble in water. In auxin herbicides, therefore, application of ester formulations has to be avoided at places inhabited by fish. Considering the recent interest in 2,4,5-TP, mentioned previously, from the point of view of fish toxicity the investigation of salt formulations is very interesting. With the commonly used PGBE-ester formulation apparently some fish toxicity has been observed.

It might be useful to mention briefly what determinations have been carried out in the Netherlands before the conclusion was drawn that of the several herbicides considered only dalapon, amino triazole and salts of MCPA and 2,4-D do not have detrimental influences on the water environment. The investigations, which are based on spraying in 10 cm deep water, are not finished yet, the results will probably be published some time in the future. In these investigations the following aspects have so far been considered:

1. the influence of the chemicals on some fish-species and fish-food organisms;
2. the influence on bacteria, of importance in the purification of surface waters;
3. the influence on the biological oxygen demand, the B.O.D.-5, indicating the biological oxygen consumption of organic material in water, determined after 5 days of incubation at 20°C;
4. the influence on some soil protozoa, occurring in silt from water purification installations.

As to these effects dalapon, amino triazole and salts of MCPA and 2,4-D were considered sufficiently safe to allow temporary approval in aquatic weed control. From these chemicals amino triazole has not been officially cleared because of insufficient data concerning the public-health aspects connected to application of the product.

In the meantime with the chemicals mentioned and also others, further research is planned and is to be carried out on differences in susceptibility between adult fish, young fish and fish-brood, on the influence of water composition, on the toxicity and on the persistence of the chemicals in the water environment. About this last aspect hardly any data are available and more research is certainly required.

I hope to have covered in my discussion the main aspects of the use of herbicides in aquatic weed control. In most European countries this practice will take its place next to mechanical ditch cleaning, the two methods supplementing each other.

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FIG. 1. PROPANE KNAPSACK SPRAYER

In front: 4 lb steel propane bottle ("Primus") with stopcock and pressure regulating valve.
At back: 16 l liquid pressure tank in carrying harness. High pressure spraying tube of PVC leading to nozzles.

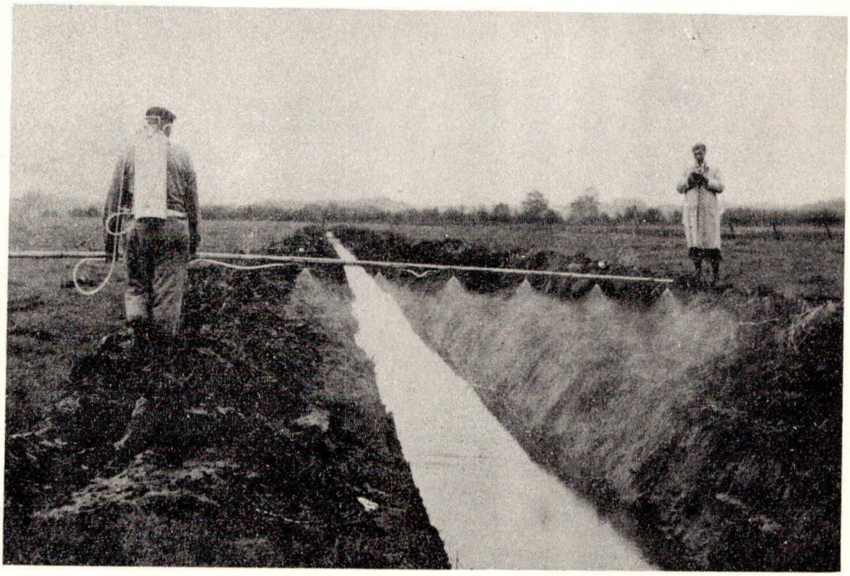

FIG. 2. PROPANE KNAPSACK SPRAYER

Combined carry-and sprayboom composed of three sections like an anglers rod, with 6 nozzles and a working width of 3 m. For use in and along watercourses with water level only slightly below the land surface.

FIG. 3. FROPANE KNAPSACK SPRAYER

Hinged spray boom with 3 nozzles and working width of 1.5 m for use in ditches with a low water level.

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RESULTS OF SOME PRELIMINARY EXPERIMENTS ON THE USE OF PELLETED HERBICIDES FOR CONTROLLING SUBMERGED WATER PLANTS.

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Summary: In the experiments detailed in this report no useful effect on submerged vegetation was obtained using a variety of relatively insoluble pelleted herbicides in small plots (20 sq yd) in flowing to nearly static water.

INTRODUCTION

The development in recent years of a new technique in North America (Grigsby et al. 1956 and Grigsby, 1957) for the control of submerged water plants had aroused considerable interest in this country. In general terms the technique is to apply herbicides in relatively insoluble form as granules. These are applied where feasible, on to ice in winter by means of a fertilizer spreader, (the pellets sinking when the ice melts), or by hand, by pellet distributors or by aircraft. Applications in winter or early spring are reputed to ensure control of submerged plants throughout the growing season of the year of application and in some instances for up to eighteen months. Some of the pellets are thought to act through the roots of submerged plants (Grigsby and Smith, 1958). An experiment in 1959 carried out by the National Agricultural Advisory Service (Proctor, 1960) showed great promise in that 2,4-D ethyl hexyl ester on clay pellets* gave excellent control of a number of submerged plants. Control continued into the following year. It was therefore decided to test as many pelleted formulations as were available of chemicals suitable for this purpose to see if the technique was suitable for use in this country. If satisfactory the technique would allow localised treatment of submerged weeds in flowing water without pollution of the water, because it was believed that release would be so slow that the concentration of chemicals would not be appreciable in the water.

The experiments reported here were carried out mostly in 1960, but details of several earlier ones have also been included. The sites treated in 1960 were selected to give as wide a range as possible not only of conditions, but also of the species of plants present.

METHODS AND MATERIALS

Experiments on ditches were laid out with treated and untreated lengths alternating. Plots were usually 20 sq yd in area (of water surface). Treatments were never replicated because of limitations of the sites. All treatments were broadcast as evenly as possible by hand. Each experiment is treated separately because of the great variability between sites.

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* Supplied by Reasor Hill Corp.

Supplier	Ingredients of pellets	Common Name or Number	Conc. of Act. Ingredient (as percentage)
American Chemical Paint Co.	2,4-D butoxy ethanol ester in granulated (8/15 mesh) attaclay.	ACP-M-518C	10 a e w/w.
" " "	2,4,5-TP butoxy ethanol ester in granulated (8/15 mesh) attaclay	ACF-M-518G	10 a e w/w.
" " "	2,3,6-trichlorophenylacetic acid in granulated (8/15 mesh) attaclay	ACF-M-816	10 a e w/w.
Borax Consolidated Ltd.	2,3,6-TBA in granulated sodium borates	Benzabor Sample No. 952	4 a e w/w.
" " "	Methoxypropazine in granulated sodium borates.	EH 592 Sample No. 953	2.5 w/w.
" " "	2,4-D in granulated sodium borates.	DB granular Sample No. 995	7.5 a e w/w.
Chipman Chemical Co.	Telvar 'W' (80% monuron), Borax (decahydrate) and Neobor (pentahydrated borax)	Monax granules	5 w/w. 81.5 w/w. 11.5 w/w.
" " "	Telvar 'W' (80% monuron), Borax (decahydrate), Sodium chlorate and 2,4-D-sodium.	Chlorea granules	3 w/w. 37.5 w/w. 38 w/w. 1.25 a e w/w
Fisons Pest Control Ltd.	Monuron pellets	CP/36/56	25 w/w.
J.R. Geigy, S.A.	Simazine on sand	-	2 w/w.
Plant Protection Ltd.	Fenuron pellets	YF 3356	50 w/w.
Reasor-Hill Corp.	2,4-D iso-octyl (2-ethyl hexyl) ester and inert ingredients (clay).	Weed Rhap 20	20 a e w/w.
" " "	2,4-D and 2,4,5-T mixed iso-octyl (2-ethyl hexyl) esters inert ingredients (clay)	-	10 a e w/w. 2,4-D and 10 a e w/w. 2,4,5-T.

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Supplier	Ingredients of pellets	Common Name or Number	Conc. of Act. Ingredient (as percentage)
Shell Research Ltd.	2,4-D acid bound in resin pellets	-	70 a e w/w.
Shell Research Ltd.	2,4-D acid bound in resin pellets	-	80 a e w/w.
" " "	2,6-dichlorobenzonitrile granulated.	Batch No. B4/60.	2.5 w/w.

RESULTS

(Note: All doses are as lb a e or a i /ac)

1. Experiment No. H/39/55. Location: Hingham, Norfolk.
Plants present: Sparganium sp. (bur-reed) floating leaves only.
Date of treatment: 10.9.55.
Treatments: Fenuron pellets 50 per cent were applied at 12, 24 and 48 lb/ac on to 1/50 acre plots.
Site: Margin of a shallow lake of clear water about 1½ feet deep. Trial area shaded, no water flow apart from wind movement.
Assessment: 10 months after treatment.
Results: No effects apparent.

2. Experiment No. H/39/55. Location: Hingham, Norfolk.
Plants present: Carex spp. and a little Sparganium sp.
Date of treatment: 18.5.56.
Treatment: Monuron pellets containing 50 per cent monuron, applied at 25 lb/ac
Site: As above.
Assessment: 24.5.57.
Results: Very effective treatment, complete suppression of Carex and Sparganium.

3. Experiment No. W/20/57. Location: Oxford.
Plants Present: Elodea canadensis (Canadian pond-weed), Callitriche stagnalis (Starwort), Myriophyllium spicatum (spiked water-milfoil) Hottonia palustris (water violet) and Utricularia vulgaris (greater bladderwort).
Date of treatment: 12.7.57.
Treatments: 4 lb/ac simazine pellets (2 per cent w/w).
Site: Narrow drainage channel, water clear and about 2 ft deep; treated area shaded; little flow of water.
Assessments: Many visits were made during 1957 and 1958.
Results: No apparent effects.

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4. Experiment No. W/26/57. Location: Spalding, Lincs.

Plants Present: Alisma plantago-aquatica (water plantain,) Sparganium ramosum (bur-reed), Myosotis sp. (forget-me-not), Glyceria fluitans (flote-grass), Callitriche obtusangula (Starwort), Juncus spp. (rushes), Polygonum hydropiper (water pepper), and several algae including Chara spp. and Entermorpha intestinalis.

Date of treatment: 16.8.57.

Treatments: Simazine on sand (2 per cent a i) at 2, 10 and 20 lb/ac of water surface.

Site: Small drainage ditch 6 ft wide and water 1½ - 2 ft deep. Water clear and flowing, unshaded.

Assessments: 25.10.57 and 12.6.58.

Results: Although counts indicated some reduction in the number of shoots of Alisma and Sparganium on the treated plots, the plots were not distinguishable from untreated lengths of the ditch.

5. Experiment No. W/9/59. Location: Oxford.

Plants present: Mainly Elodea canadensis (Canadian pond-weed), with a few plants of Callitriche sp. (Starwort), Sparganium ramosum (bur-reed), Nasturtium officinale (watercress), Hottonia palustris (water violet), Equisetum fluviatile (water horsetail), Glyceria maxima (reed-grass) and Myriophyllum spicatum (spiked water-milfoil).

Date of treatment: 23.6.59.

Treatments: 2,4-D (ethyl hexylester) on clay granules at 5, 10 and 20 lb/ac, simazine on sand (2 per cent) at 2 and 4 lb/ac, 'Monax' granules (4 per cent monuron on sodium borates) and 'Chlorea' granules (2,4-D 1 per cent sod. chlorate 38 per cent and monuron 2.4 per cent) both to give 25 lb/ac of monuron.

Site: A three foot wide drainage ditch, partly shaded. Water clear, flowing, 1 ft over deep mud.

Assessments: Several visits were made in 1959 and 1960.

Results: No effects apparent.

6. Experiment No. W/3/60. Location: Chatteris, Cambs.

Plants present: Hottonia palustris (water violet), Myriophyllum sp. (water-milfoil) Carex sp. (sedge), Sparganium sp. (bur-reed), Callitriche sp. (Starwort), Phragmites communis (reed) Alisma plantago-aquatica (water plantain) Juncus bulbosus (bulbous rush) Hippuris vulgaris (mare's tail) Ranunculus trichlophyllu (crowfoot) and the algae Chara and Spirogyra.

Dates of treatment: 17.3.60 and 19.4.60.

Treatments: (1) 17.3.60, 20 lb/ac 2,4-D (ethyl hexyl ester) on clay and 20 lb/ac equal mixture of ethyl hexyl esters of 2,4-D and 2,4,5-T. (2) 19.4.60, 20 lb/ac (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) (methoxy propazine) 2½ per cent on sodium borates, 2,3,6-TBA 4 per cent on sodium borates at 4 lb/ac, butoxy ethanol ester of 2,4,5-TP (10 per cent on granulated 8/15 mesh attaclay) at 20 lb/ac.

Site: Drainage ditch 6 ft wide, water muddy, 1-2 ft deep over mud, unshaded, flowing slightly, pH 7.8.
Assessments: 19.4.60, 20.5.60 and 20.9.60.
Results: No effects apparent on plots treated at either date.

7. Experiment No. W/5/60. Location: Oxford.
Plants present: Hottonia palustria (water violet), Sparganium ramosum (bur-reed), Carex riparia (Great pond sedge), Myriophyllum spicatum (spiked water milfoil) and Elodea canadensis (Canadian pondweed).
Date of treatment: 28.3.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, 2,4-D acid resin-bonded pellets (70 per cent w/w) at 20 lb/ac, butoxy ethanol ester on granulated 8/15 mesh attaclay of 2,4,5-TP and 2,4-D each at 20 lb/ac and 2,3,6-trichlorophenylacetic acid 10 per cent on attaclay at 20 lb/ac.
Site: Drainage channel, partially shaded, water clear, about 2-3 ft over mud, slight flow, pH 7.8.
Assessments: Several visits during 1960.
Results: No useful effect from any treatment, although some treatments, notably 2,4-D butoxyethanol ester on attaclay, produced a number of deformities of leaves of Hottonia and slight twisting of the flower stems, but there was no effect on the subsequent flowering of this species.

8. Experiment No. W/7/60. Location: Dymchurch, Kent.
Plants present: Ranunculus sp. (crowfoot), Callitriche sp. (starwort) Elodea canadensis (Canadian pondweed) Potamageton crispus (curled pond-weed) Phragmites communis (reed), Sparganium ramosum (bur-reed), Potamogeton pectinatus (fennel-leaved pond-weed).
Date of treatment: 26.4.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, butoxyethanol esters of 2,4-D and 2,4,5-TP each 10 per cent on 8/15 mesh attaclay each applied at 20 lb/ac, 2,4-D acid resin-bonded as pellets (80 per cent) at 20 lb/ac, 2,3,6-trichlorophenylacetic acid 10 per cent on 8/15 mesh attaclay at 20 lb/ac, (2-methoxy-4,6-dis-isopropylamino-s-triazine) (methoxypropazine) 2½ per cent on sodium borates at 10 lb/ac 2,3,6-TBA 4 per cent on sodium borates at 4 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac (a i).
Site: Drainage channel 12 ft wide, 2-3 ft deep, water clear and flowing over deep mud, slightly shaded, pH 6.4.
Assessments: 23.5.60, 23.8.60.
Results: No effects apparent.

9. Experiment No. W/8/60. Location: ,Pikefish stream, Nr. Marden.

Plants present: Sparganium ramosum (bur-reed), Callitriche sp.Kent. (starwort), Phalaris arundinacea (Reed-grass), Potamogeton natans (broad-leaved pond-weed), Lemna minor (duckweed), Hydrocharis morsus-ranae (frogbit) and Equisetum fluviatile (water horsetail).

Date of treatment: 27.4.60.

Treatments: 2,3,6-TBA (4 per cent w/w) on sodium borates at 4 lb/ac (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) (methoxypropazine) 2½ per cent w/w) on sodium borates at 10 lb/ac (a i) butoxy ethanol esters of 2,4-D and 2,4,5-TP 10 per cent on 8/15 mesh attaclay granules and 2,3,6-trichlorophenylacetic acid 10 per cent on 8/15 mesh attaclay granules all applied at 20 lb/ac, 2,4-D acid in resin-bonded granules (80 per cent) at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac and 2,6-dichlorobenzontrile 2½ per cent granules at 10 lb/ac (a i).

Site: Drainage channel, 10 ft wide, banks of clay, water 2-3 ft deep, clear and flowing over deep mud, no shade, pH of water 6.4.

Assessments: 23.5.60 and 23.8.60.

Results: No effects apparent.

10. Experiment No. W/9/60. Location: Oxford.

Plants present: Ranunculus sp. (crowfoot), Sparganium ramosum, (bur-reed), Elodea canadensis (Canadian pondweed) Callitriche sp. (starwort) and Polygonum amphibium (Amphibious bistort).

Date of treatment: 30.4.60.

Treatments: 2,4-D acid 80 per cent resin-bonded in pellets at 20 lb/ac 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 10 per cent on clay pellets at 20 lb/ac, (2-methoxy-4-6-bis (isopropylamino)-s-triazine (methoxypropazine) 2½ per cent on sodium borates at 10 lb/ac.

Site: Newly dredged, narrow drainage channel, 6 ft wide, water 1-2 ft deep, unshaded, slight water movement, water clear, pH of water 7.8.

Assessments: Several visits during summer, 1960.

Results: No effects apparent.

11. Experiment No. W/12/60. Location: Southery, Norfolk.

Plants present: Phragmites communis (reed) Callitriche spp. (starwort), Apium nodiflorum (fool's watercress) Veronica sp. (Speedwell) Sparganium ramosum (bur-reed) Solanum dulcamara (bitter-sweet), Agrostis stolonifera (Fiorin) Berula erecta (narrow-leaved water parsnip), Epilobium hirsutum (Great hairy willow-herb), Lycopus europaeus (Gipsy-wort), Rumex sp. (dock) and Phalaris arundinacea (reed-grass).

Date of treatment: 25.5.60.

Treatments: 2,4-D (2-ethyl hexylester) 20 per cent on clay pellets on 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay pellets at 20 lb/ac, 2,4-D (70 per cent) resin-bonded in pellets, 2,4-D (7½ per cent) on sodium borates at 20 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.

(78178)

Site: Overgrown drainage channel with steep tall sides, 8 ft wide at the bottom, mostly 2-3 in. of static water over deep mud, in places wet mud only, partly shaded.
Assessments: 17.8.60 and 9.9.60.
Results: No effects apparent.

12. Experiment No. W/10/60. Location: Cowbit, Lincs.
Plants present: Alisma plantago-aquatica (water plantain), Myriophyllum alterniflorum (alternate-flowered water milfoil) Veronica sp. (speedwell), Elodea canadensis (Canadian pondweed) Callitriche sp. (starwort) Ceratophyllum demersum (hornwort) Hippuris vulgaris (mare's tail), Sparganium ramosum (bur-reed), Ranunculus aquatilis (water crowfoot) Glyceria maxima (reed-grass) and Glyceria fluitans (flote-grass), Hottonia palustris (water violet) Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (fennel-leaved pondweed).
Date of treatment: 4.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent on clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent on clay granules at 20 lb/ac, 2,4-D acid (70 per cent) resin-bonded as pellets, methoxypropazine (2-methoxy-4,6-bis-(isopropylamino)-s-triazine) 2½ per cent on sodium borates at 10 lb/ac, and 2-6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Drainage ditch, 8 ft wide, water 1-2 ft over deep mud, no water flow, clear, unshaded.
Assessment: 18.8.60.
Results: When treated little could be seen of submerged plants because the ditch had recently been cleared out, but when assessed several plots were filled with dense Potamogeton crispus (curled pondweed) and Potamogeton pectinatus (Fennel-leaved pondweed) and no effects were noticeable on the others.

13. Experiment No. W/13/60. Location: Stretham, Cambs.
Plants present: Glyceria maxima (reed grass), Phalaris arundinacea (reed grass), Callitriche sp. (starwort), Elodea canadensis (Canadian pondweed), Lemna minor (duckweed), Lemna trisulca (Ivy duckweed), Ranunculus sp. (crowfoot), Potamogeton crispus (curled pondweed), Nasturtium officinale (watercress) Veronica catenata (speedwell) Alisma plantago-aquatica (water plantain) and Potamogeton densus (opposite-leaved pond-weed).
Date of treatment: 25.5.60.
Treatments: 2,4-D (2-ethyl hexyl ester) 20 per cent in clay pellets at 20 lb/ac, mixed ethyl hexyl esters of 2,4-D and 2,4,5-T 20 per cent in clay pellets at 20 lb/ac, 2,4-D acid (80 per cent) resin-bonded as pellets at 20 lb/ac. 2,4-D (7½ per cent) on sodium borates at 20 lb/ac and 2,6-dichlorobenzonitrile 2½ per cent granules at 10 lb/ac.
Site: Narrow steep-sided drainage channel, water 6 ft across and one foot deep and densely filled with submerged plants. No water flow.
Assessments: 18.8.60.
Results: No effects apparent.

DISCUSSION

Before discussing the reasons for the almost complete lack of effects in these experiments, the mode of action of these pellets should be considered. Grigsby and Smith (1958) summarising four seasons' work concluded (a) that the mode of action appears to be by destroying the root system of rooted submerged and emergent plants, (b) that date of application is important: early spring is best because summer applications are slow in acting although they too will ultimately destroy rooted weeds, (c) that the depth of water appears to have no effect upon the amount of herbicide required to give control, (d) 40 - 70 lb/ac 2,4-D will control Myriophyllum, Ceratophyllum and Potamogeton species for 2-4 years, (e) only compounds of the general group of phenoxyacetic acid compounds were effective. The fact that the depth of water is immaterial, in conjunction with the mention in an earlier report (Grigsby et al. 1956) that 'the boundaries of the plots were as well marked by absence of vegetation as though a mechanical shield had been placed on the bottom', appears to indicate most definitely that the effects are not due to the formation of a chemical solution in the water as a whole, especially so because the test plots of 50 x 50 ft were in a 20 acre lagoon which varied from 3 to 8 ft in depth. In addition, the destruction of the root system appears to indicate that the chemical is taken up by the roots from the surface of the mud where concentrations may be locally appreciable, although in view of the time taken for the effects to occur it may be that very small quantities of chemical are continuously taken up over a long period from low concentrations.

The experiments carried out in 1960 included species of the same genera mentioned in the North American work and some of the pellets were of similar formulations. It appears therefore that other factors such as environmental conditions or the doses applied might be the significant ones. The dose of 2,4-D formulations was standardised at 20 lb/ac because of the excellent result obtained in 1959 (Proctor, 1960) with 30 lb/ac 2,4-D pellets (supplied by Reasor Hill Corp.) and also because of useful results at 20 lb/ac elsewhere (Younger, 1959). The excellent result in 1959 mentioned above was obtained in a dammed off length of ditch which might indicate, despite evidence quoted above, that the action was by the formation of a solution throughout the water becuase the same formulation when applied to an undammed ditch on the same farm in 1960 (Expt. No. W/3/60) showed no effects. However, in Experiment No. W/12/60 at Southery in Norfolk where the water was only 2-3 in. deep and in places only wet mud, thus ruling out water movement, the results with the same formulation were again equally ineffective.

Apart then from the possible influence of unrecorded factors such as temperature, rate of plant growth etc. there appears to be no immediately obvious reason for the absence of effects. The useful result of unformulated monuron pellets in Experiment No. H/39/55 is equally unrelatable to the factors discussed above. It is therefore necessary to carry out experiments under controlled conditions to elucidate the factors influencing the action of pelleted herbicides.

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EXPERIMENTS ON THE CHEMICAL CONTROL OF EMERGENT WATER PLANTS

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Summary: This paper describes experiments carried out on the use of chemicals, mainly dalapon (as the sodium salt), for controlling emergent water plants. Details of the effects in each experiment are given as assessed in the year after spraying. All important water plants are considered and some of less importance are also noted and included in the table of susceptibilities given at the end which is a summary of all work known to the author that has been carried out in the British Isles. The results show in general that dalapon at doses in the range of 10 - 40 lb gives satisfactory control of important emergent water weeds, although occasional failures are apparently liable to occur.

INTRODUCTION

Investigations into the use of 2,4-D have shown that useful effects on emergent water weeds in general cannot be obtained with this chemical (Dadd 1953). However, the advent of dalapon, specific to certain monocotyledons and particularly grasses, provided a possibly suitable chemical treatment because most large emergent water plants are grasses or are closely allied to them. Since the discovery of dalapon a great number of experiments have been reported, mainly from North America, on the uses of this chemical for controlling emergent water weeds. To test these uses under the conditions existing in this country and on the water plants occurring here, a number of experiments have been laid down: they are summarised in this report. More recently a recommendation (Eipper and Brumstead 1959) on the use of amino triazole for the same purpose led to the inclusion of this chemical in three experiments. A few other chemicals have also been investigated and are included.

A great number of foreign reports list only a limited number of water plants in each experiment so that information is available for only a few species. The practice adopted in the experiments detailed in this report has been to make notes on the susceptibilities of every plant present and although most of these are not included in the assessment data under each experiment they are included in the tentative table of susceptibilities at the end. In addition attention has been paid where possible to the changes occurring in the composition of the vegetation. This is of particular importance because the use of a selective chemical on a stand of mixed species could possibly result in a different problem of equal importance to the original; but perhaps less easy to solve.

METHODS, MATERIALS AND RESULTS

Because of the variability of stands of water plants it has not been possible to lay out proper replicated experiments as is usual in herbicide work. Most of these experiments are therefore observation plots which were replicated where possible. This limits the presentation of data: each experiment has here been treated separately.

All references to dalapon refer to "Dowpon"[x] and references to amino triazole with ammonium thiocyanate to "Weedazol TL"[*]. Technical amino triazole refers to unformulated chemical (98 per cent). The use of additional wetting agents are mentioned when appropriate in the text.

Note: All doses are given in lb a e /ac or a i /ac.

H/38/55: Hingham, Norfolk.

Plants present: Sparganium ramosum (bur-reed) Typha latifolia (great reedmace, cat's-tail), Typha angustifolia (lesser reedmace), Carex pseudocyperus (cyperus sedge), Iris pseudacorus (yellow Flag) and Phragmites communis (reed).

Object: A preliminary experiment to discover the most suitable chemicals for further investigation.

Dates of spraying and treatments: (i) 9/9/55. dalapon (sodium salt) at 20 and 40 lb/ac, ammonium sulphamate at 20, 40 and 60 lb/ac, 2,4-D (butyl ester) at 1, 2 and 4 lb/ac as an oil emulsion, monuron (as a wettable powder and as a dust) at 25, 50 and 100 lb/ac, sodium arsenite to give 7½ and 15 parts per million of arsenic trioxide.

(ii) 18/5/56, dalapon (sodium salt) at 2½, 10 and 20 lb/ac and sodium arsenite at 5 and 10 ppm of As_2O_3,

Spraying data: Spraying was carried out by a multiple jet assembly ("boomjet") or a handlance attached to a Land-Rover mounted sprayer or by a knapsack sprayer. Dusts were applied by hand. Volume rate varied from 16 gal/ac by the "boomjet" to 150 gal/ac by the handlance. Rain fell towards the end of the applications, but water-soluble treatments had been completed several hours before it started. Plots were 1/200 acre in area (1 replicate).

Site: The area varied greatly from standing water 1 - 2 ft deep to bare mud.

Assessments were made in the year following each spraying.

Results: Dalapon at 20 and 40 lb in 150 gal/ac gave a more or less complete clearance of Sparganium, Carex and Typha. Iris, however, was resistant although reduced in numbers and deformed. A little Sparganium regrew later in the following year. To confirm the effects on Iris, one further plot was sprayed in 1956 with 20 lb/ac. In the following year a considerable reduction had occurred and survivors were stunted and deformed. Other plots principally of Carex spp were treated with dalapon at 2½, 10 and 20 lb/ac in 1956, but these showed inconsistent results in 1957. Ammonium sulphamate at 20, 40 and 60 lb/ac also gave good initial clearance of the plots, but regrowth occurred and after ten months little overall effect was visible. 2,4-D (butyl ester)

[*] supplied by Messrs. A. H. Marks & Co.

[x] supplied by Dow Agrochemicals Limited.

at 1, 2 and 4 lb/ac in 16 gal/ac gave good control of Sparganium but Iris was resistant. Carex showed variable results and Typha augustifolia and Phragmites were unaffected. Monuron both as a dust and as a wettable powder at 25, 50 and 100 lb/ac gave complete control of Sparganium, Carex and Typha latifolia, but not of Iris. The effects were, however, very slow to appear and were complete only after ten months. Sodium arsenite at 7½ and 15 ppm gave variable results on Sparganium but no effects were apparent on Phragmites, Potamogeton sp. or Iris. Carex spp. were, however, killed by 5 and 10 ppm applied on other plots in 1956.

These results showed the possible usefulness of dalapon and monuron, but because monuron is a danger to trees (Baumgartner 1955), is slow to act and is an expensive treatment, it was decided in later experiments to concentrate on dalapon.

H/39/55: Gorehanbury

The results of experiment H/38/55 were confirmed in part by this one sprayed in September 1955. Dalapon at 20 and 40 lb/ac in 150 gal/ac gave effective control of Carex sp. and Schoenoplectus lacustris (bulrush), while 2,4-D (butyl ester) as an oil emulsion at 2 and 4 lb/ac did not. Other plants controlled by dalapon were Sparganium sp. and Glyceria fluitans (flote-grass). Equisetum fluviatile (water horsetail) was resistant to dalapon.

The results of these two experiments gave rise in 1958 and 1959 to a series of experiments using mainly dalapon to determine the susceptibilities of as wide a range of water plants as possible.

W/5/58: Oxford

Plants present: Glyceria maxima (reed-grass) the only plant.

Date of spraying: 1/9/58.

Treatments: Dalapon (sodium salt) at 5, 10 and 20 lb/ac (2 replicates).

Spraying data: Applied with an Oxford Precision Sprayer at 20 gal/ac.

Site: Deep alluvial mud on river bank, no surface water.

Assessments: Shoot counts in 8 sq yd/2 plots.

Results:

TABLE I. GLYCERIA MAXIMA (SHOOT COUNTS)

Date of assessment	6/4/59		28/4/59		17/6/59	
Treatment	Shoot counts	percent reduct cf. control	Shoot counts	percent reduct cf. control	Shoot counts	percent reduct cf. control
Dalapon 5 lb/ac	111	90.8	350	66.9	718	29.7
" 10 "	16	98.7	68	93.6	838	17.9
" 20 "	3	99.8	12	98.9	173	83.1
Controls	1208		1058		1021	

(prespray controls 1360)

The considerable regrowth of Glyceria occurring on 5 and 10 lb/ac plots between the second and third assessment is characteristic of the effect of dalapon on certain grasses: a dormancy is induced which may disappear later on. In June 1960 (two years after spraying) counts were made of the commonest invading plants. Urtica dioica (stinging nettle) averaged 98 shoots per treated plot and controls averaged 4; Epilobium hirsutum (Great hairy willow-herb) averaged 54 on treated plots with one on controls and Equisetum palustro (Marsh horse-tail) averaged 13 and 1 shoot on controls. These figures show the great increase of other species once the dominance of Glyceria is broken. Invading species that occurred less frequently were Cirsium arvense (creeping thistle), Poa trivialis Rumex conglomeratus (sharp dock), Galium aparine (cleavers) and Cardamine pratensis (lady's smock).

W/7/58: Oxford

Plants present: Phragmites communis (reed)

Date of spraying: 12/9/58, resprayed 11/9/59

Treatments: Dalapon (sodium salt) at 2½, 5, 10, 20 and 40 lb/ac.

Spraying data: Sprayed with an Oxford Precision Sprayer, 20 gal/ac.

Sites: Waterlogged field.

Results: Counts in June and September of the following year showed little useful effect by any dose (40 lb/ac gave 65 per cent reductions of average control plots in September). 10, 20 and 40 lb/ac plots were resprayed with the same doses on 11/9/59 and counts in the following August showed no increased effects. The poor results after repeated large doses are at variance with results obtained elsewhere.

W/14/58: North Hinksey, Oxford

Plants present: Sparganium ramosum (bur-reed), Phragmites communis (reed), Carex spp. (sedges) and Iris pseudacorus (yellow flag)

Date of spraying: 16/9/58

Treatments: Dalapon (sodium salt) at 10, 20 and 40 lb/ac in 100 gal/ac with 1 per cent "Teepol" added (1 replicate)

Spraying data: Sprayed with an adjustable hollow cone nozzle on a hand-lance attached to a Land-Rover mounted sprayer.

Site: A ditch with shallow (c. 1 ft deep) water, more or less static, covering deep mud.

Assessments: 12/5/59 and 21/7/59.

Results: All doses of dalapon gave excellent clearance of the vegetation. On the control area the water surface was hardly visible at all but on treated plots with the exception of a few small shoots the ditch was clear. It is of interest that no invasion by other plants occurred and even Callitriche sp. which had been present originally had not increased.

W/15/58: Oxford.

Plants present: Schoenoplectus lacustris (bulfush), Sparganium ramosum (reed-grass), Carex spp. (sedges) Iris pseudacorus (yellow flag) and many others.

Date of spraying: 16/6/58, resprayed 27/8/59.

Treatments: Dalapon (sodium salt) at 5, 10, 20 and 40 lb/ac in 100 gal/ac with 1 per cent "Teepol" added. (2 replicates with controls at both ends of each treated plot).

Spraying data: Sprayed with an adjustable hollow-cone nozzle on a handlance attached to a Land-Rover mounted sprayer.

Site: Water-logged bank of drainage channel.

Assessments: A number of assessments were made both in 1959 a year after the first spraying and in 1960, the year following the respraying.

Results:

TABLE II. THE RESPONSE OF EMERGENT SPECIES TO A SINGLE TREATMENT WITH DALAPON AS MEASURED BY SHOOT COUNTS IN THE YEAR FOLLOWING TREATMENT

(2 replicates. 10 sq yd/plot)

Sprayed 16/9/58, assessed 17/6/59

Treatment:	Schoenoplectus lacustris (bulrush)		Sparganium ramosum (bur-reed)		Phragmites communis (reed)	
Treatment:	Shoot totals	percent reduct cf. controls	Shoot totals	percent reduct cf. controls	Shoot totals	percent reduct cf. controls
Dalapon 5 lb/ac	326	-61.4	54	60.0	9	88.3
Adjacent controls	202		135		77	
Dalapon 10 lb/ac	264	21.2	104	37.3	36	18.2
Adjacent controls	335		166		44	
Dalapon 20 lb/ac	203	59.2	83	46.8	2	89.5
Adjacent controls	497		156		19	
Dalapon 40 lb/ac	65	85.8	37	78.1	6	80.6
Adjacent controls	459		169		31	

TABLE II. (Continued)

Treatment:	Glyceria maxima (reed-grass) shoot totals	Glyceria maxima (reed-grass) percent reduct cf. controls	Carex spp. (sedges) shoot totals	Carex spp. (sedges) percent reduct cf. controls	Iris pseudacorus (yellow flag) shoot totals	Iris pseudacorus (yellow flag) percent reduct cf. controls
Dalapon 5 lb/ac	70	65.5	23	63.5	310	24.0
adjacent controls	203		63		408	
Dalapon 10 lb/ac	33	83.7	18	77.8	240	32.8
adjacent controls	203		81		357	
Dalapon 20 lb/ac	11	95.1	15	79.5	165	54.8
adjacent controls	225		73		365	
Dalapon 40 lb/ac	21	90.7	13	81.7	69	86.3
adjacent controls	227		71		503	

Selected plots were resprayed on 28/8/59. The plots that originally received 20 and 40 lb/ac were resprayed with either 20 or 40 lb/ac to give four treatments. The average effect of these double doses (20 + 20, 20 + 40. 40 + 20 and 40 + 40) as counted in the following year are shown in Table III. Of the two plots that originally received 5 lb/ac one was treated with amino triazole (technical) at 20 lb/ac and the other with amino triazole with ammonium thiocyanate also at 20 lb/ac. To all these resprays 1 per cent "Teepol" was added.

TABLE III. THE EFFECT OF DOUBLE APPLICATIONS OF DALAPON ON DENSITY OF EMERGENT WEEDS

(Average counts from doses of 20 + 20, 20 + 40, 40 + 20 and 40 + 40)

Shoot counts in 40 sq yd/plot

Plant	Treated Plots	Untreated plots	percent reduction cf. controls
Schoenoplectus lacustris (bulrush)	105	1023	98.7
Sparganium ramosum (bur-reed)	374	747	49.9
Phragmites communis (reed)	21	167	87.4
Glyceria maxima (reed-grass)	25	246	89.8
Carex spp. (Sedges)	113	67	80.6
Iris pseudacorus (Yellow flag)	206	1102	81.3

TABLE III. (Contd.)

Plant	Treated Plots	Untreated Plots	Percent reduction cf. Controls
	Shoot counts in 40 sq yd/plot	Shoot counts in 40 sq yd/plot	
	Plant counts in 40 sq yd/plot		
Caltha palustris (Marsh marigold)	224	156	-43.6
	Shoot counts in 10 random sq yd quadrat/plots		
Mentha aquatica (Water mint)	2321	718	-223.3
Equisetum fluviatile (Water horsetail)	2432	696	-249.4
Oenanthe fistulosa (Water dropwort)	988	448	-120.5
Ranunculus repens (Creeping buttercup)	291	144	-102.1

This table shows that the large water weeds have all been usefully reduced in numbers with the possible exception of Sparganium. Conversely the plants that are resistant to dalapon treatments, which in this experiment are all small herbs, have increased in number. Amino triazole treatments gave promising clearance of large plants and controlled a greater number of species than dalapon, notably Mentha aquatica. Additional plots in this experiment with a cover mainly of Glyceria maxima, Sparganium ramosum and Iris pseudacorus were sprayed on August 27th 1959 with 2-chloro-4-ethyl amino-6-isopropylamino-s-triazine (atrazine) and isodiazine at 4 lb/ac in 100 gal/ac. Assessment in 1960 showed no apparent effect with either.

W/26/59: Oxford

In 1959 three sets of observation plots were laid down, (W26, 28 and 29/59) (W/26/59) was a test to confirm the susceptibility of Schoenoplectus lacustris to dalapon. Small stands of the plant were sprayed with 20 and 40 lb/ac of dalapon in 100 gal/ac with ½ per cent "Teepol" added. Assessment in 1960 showed about 90 per cent kill with both doses.

W/28/59

This was on Glyceria maxima and was to obtain confirmatory evidence on the susceptibility of this grass to dalapon and also to test out amino triazole with ammonium thiocyanate added. Plots were sprayed with dalapon at 40 lb/ac and amino triazole at 20 lb/ac in 20 gal/ac on 11/10/59. An assessment in May 1960 showed virtually no regrowth, but by July all plots were almost indistinguishable from the controls except for a slight reduction in height. It is evident that the induced dormancy mentioned under W/5/58 above has, in this instance, not persisted at all although the dalapon dose was higher.

W/29/59: Oxford

This was on several water plants comparing the effects of dalapon and amino triazole with ammonium thiocyanate added. Dalapon was applied at 20 and 40 lb/ac and amino triazole at 20 lb/ac in 100 and 200 gal/ac with 0.25 per cent "Teepol" added on 11/9/59. Assessed on 3/6/60 dalapon at 20 lb/ac had given very good control of Glyceria maxima. Amino triazole had given good control of Sparganium ramosum and Schoenoplectus lacustris, but on one of the three plots of the latter there was only about 50 per cent kill.

In 1960 observation plots were laid down on Iris pseudacorus. Iris appears to be one of the more resistant water plants and when it was reported (Watson and Leasure 1959) that O-(2,4-dichlorophenyl) O-methyl isopropylphosphoroamidothioate was toxic to cultivated Iris in North America, it appeared that this compound merited investigation.. It was sprayed onto Iris pseudacorus at 9½, 60 and 90 lb/ac in 106, 40 and 60 gal/ac respectively on 17/5/60. Assessment of the plots on 2/9/60 showed no apparent effect at any dose.

DISCUSSION

The results obtained from W/15/58 indicate the useful selectivity of dalapon and the change in the composition of the vegetation that has taken place. This shift in populations of different species was beneficial as far as the maintenance of water-courses is concerned. The resistant species that increased in abundance cannot be regarded as undesirable. They are small and unlikely to impede water flow and may in fact be useful in holding mud and preventing it eroding. A rather different change in flora, however, occurred on the river bank in experiment no. W/5/58. The reduction of Glyceria maxima allowed a number of plants to colonise the area, of these the new dominant species i.e. Urtica dioica and Epilobium hirsutum cannot be considered desirable. A third type of result was seen in a shallow ditch in experiment no. W/14/58 where a mixed stand of water weeds was cleared and remained clear for at least 10 months after spraying. All the experiments fall into one of these three categories. In some it would be difficult to forecast what the change would be: these are the areas where all species present are susceptible. Where there are mixed susceptible and resistant plants, the resistant species are likely to spread over the area.

On the whole there is comparatively good agreement of results between the effects of dalapon on a species in one experiment and the effects on the same species in another, but there are occasional results that do not conform to the general picture. These exceptions may be due to a number of factors and it will take a long time to investigate them on water plants. The primary purpose behind the experiments detailed above was to collect as much information on as many species as possible so that a table could be drawn up of their approximate susceptibilities to dalapon. This has been done and is given in Table IV.

TABLE IV. TENTATIVE LIST OF THE SUSCEPTIBILITY OF WATER PLANTS TO DALAPON

(Treatments have varied between 10 and 40 lb/ac and as a number of gradings of small plants are based upon only one or two observations no definite dose of dalapon is given).

S = susceptible
MS = useful results can be obtained in the dose range 10-40 lb/ac
MR = no useful results obtained
R = unaffected.

When more than one grading is given, they show the variations obtained from several experiments.

Alisma plantago-aquatica (Water plantain)	R
Apium nodiflorum (Fool's watercress)	R
Butomus umbellatus (Flowering rush)	R
Callitriche sp. (Starwort)	R
Caltha palustris (Marsh marigold)	R
Carex pseudocyperus (Cyprus sedge)	S
Carex spp. (sedges)	S-MS-MR
Dipsacus fullonum ssp. sylvestris (Wild teasel)	R
Epilobium hirsutum (Great hairy willow herb)	R
Equisetum fluviatile (Water horsetail)	R
Filipendula ulmaria (Meadow sweet)	R
Galium palustre (Marsh bedstraw)	R
Glyceria fluitans (Flote-grass)	S-MS
Glyceria maxima (Reed-grass)	S-MS-MR
Hydrocharis morsus-ranae (Frog-bit)	R
Impatiens capensis (Orange balsam)	R
Iris pseudacorus (Yellow flag)	MS-MR
Juncus effusus (Soft rush)	S
Lemna gibba (Gibbous duckweed)	R
Lemna minor (Duckweed)	R
Lysimachia vulgaris (Yellow loosestrife)	R
Lythrum salicaria (Purple loosestrife)	R
Mentha aquatica (Water mint)	R
Menyanthes trifoliata (Buckbean)	R
Myosotis palustris ssp palustris (Water forget-me-not)	R
Nasturtium officinale (Watercress)	R
Nuphar lutea (Yellow water-lily)	R
Oenanthe fistulosa (Water dropwort)	R
Oenanthe fluviatilis	R
Phalaris arundinacea (Reed-grass)	MS
Phragmites communis (Reed)	S-MS-MR
Polygonum amphibium (Amphibious bistort)	R
Polygonum hydropiper (Water pepper)	R
Potamogeton natans (Broad-leaves pond-weed)	R
Ranunculus lingua (Great spearwort)	R
Ranunculus repens (Creeping buttercup)	R
Rumex conglomeratus (Sharp dock)	R
Rumex hydrolapathum (Great water dock)	R
Sagittaria sagittifolia (Arrow-head)	R
Schoenoplectus lacustris (Bullrush)	S-MS
Scrophularia nodosa (Figwort)	R
Scutellaria galericulata (Skull-cap)	R
Sium latifolium (Water parsnip)	R

Solanum dulcamara (Bittersweet)	R
Sparganium ramosum (burreed)	S-MS-MR
Stachys palustris (Marsh woundwort)	R
Stellaria paulustris (March stitchwort)	R
Typha augustifolia (Lesser reedmace)	S
Typha latifolia (Great reedmace)	S
Veronica catenata (Speedwell)	R

Most of these gradings are derived from experiments carried out by the Weed Research Organisation, but a few are from experiments by Borax Consolidated Ltd., Dow Agrochemicals Ltd., and the Kent River Board.

Although three-quarters of the species in Table IV are resistant, most of the resistant plants are small dicotyledons, while the majority of the large water plants are to varying degrees susceptible. All plants with surface floating leaves that have been tested are apparently resistant. All submerged plants are apparently resistant to sprayed applications of up to at least 40 lb/ac.

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CHEMICAL CONTROL OF WEEDS IN FARM DYKES 1959 and 1960

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Summary: Acrolein gave a rapid kill of broad leaved species in stagnant water but application was difficult and control of some species was short-lived. Acrolein might have value where the rapid killing and collapse of vegetation was required in emergency conditions. Atrazine, and to a lesser extent, simazine, appeared to have some value for the control of vegetation in marshy-bottomed dykes. Good results were produced by 2,4-D pellets. Some excellent control was obtained of a wide range of broad leaved species and Sparganium in near-stagnant water. Pellets appeared to be a very suitable formulation for dyke work.

INTRODUCTION

The N.A.A.S. Eastern Region Crop Husbandry Department became interested in the work following the success reported by the Shell group in U.S.A. with acrolein (Van Overbeek 1958). The Department's co-operation was sought by the A.R.C. Unit of Experimental Agronomy for field scale trials with this material and the opportunity was taken of testing other new materials. The work was carried out in 1959 and 1960.

METHODS AND MATERIALS

Chemicals were tested in single lengths in any one farm dyke, dams being used to separate plots in some cases. The wide variation in the distribution of species encountered in most dykes made replication and critical control impossible This was not wholly unsatisfactory since large effects only were being sought.

The materials tested were acrolein (liquid), simazine, atrazine, trietazine (each as a 50 per cent wettable powder) "Chlorea", "Monax" (pelletted herbicide mixtures containing monuron) and 2,4-D pellets (several formulations). Fuller details are given in the Table I. Most of the work was carried out near Manea, Cambs. Consultations were held with the Ouse River Board to ensure that fishing interests would not be affected by any of the chemicals used.

Note: All doses are in terms of a e or a i.

RESULTS

Acrolein

The 1959 work was predominantly with acrolein. This very volatile liquid was injected into the dykes by a special hand operated apparatus (Stovell 1960) and immediately stirred in by hand. The latter operation was laborious but essential to prevent complete loss of the chemical into the air. Water flow was in no circumstances sufficient to allow it to be used as in the U.S.A. where it is mixed at weirs and allowed to flow down stream in a weed killing blanket. By comparison with the United States experience, fairly high rates were used since temperatures were considerably lower. Acrolein is highly toxic to fish but is rapidly inactivated.