WEEDS ON NON-AGRICULTURAL LAND AND IN WATER

Opening Remarks

by

S. A. EVANS

THIS session deals with two aspects of weed control which for the most part are of small interest to the agriculturalists. Even the control of water weeds, which concerns the farmers in so far as it affects the drainage of his land, may be the responsibility not of the farmer but of a River Board or a Drainage Board.

An important factor emerges when considering the practical development of chemical weed control in water or non-agricultural land. It is the large number of unrelated organisations which are in one way or another concerned and, generally speaking, the lack of any co-ordination between them. In 1956-7 the British Weed Control Council conducted an enquiry into the various organisations concerned and also into the knowledge available on the use of herbicides and the problems requiring urgent attention. I would like to draw attention to extracts from the 'Report on the activities of the Council since the 1956 Conference' circulated to Conference members. The Council concluded that there was, generally, a lack of research and development and of information on chemical weed control and a lack of co-ordinated approach to making good these deficiencies even though the organisations approached by the Council expressed a desire to secure any information they could.

To indicate the numbers and type of organisations which may have an interest in weed control on non-agricultural land, in a research, advisory or directive capacity, in statutory duties concerned with noxious weeds or in the actual control of weeds, the following are some of the official organisations concerned: Agricultural Research Council, Department of Scientific & Industrial Research, Nature Conservancy, Ministry of Agriculture, Fisheries & Food, Ministry of Works, Ministry of Transport & Civil Aviation, Air Ministry, War Department, British Transport Commission, Association of Municipal Corporations, Association of Rural District Council Surveyors, etc.

A similar state exists in regard to water weeds where the following organisations are some of those concerned: Agricultural Research Council, Department of Scientific & Industrial Research, Ministry of Agriculture, Fisheries & Food, River Boards Association, Association of Drainage Authorities, Water Research Association and the Freshwater Biological Association.

As the Council pointed out in its report, 'the use of chemicals in water may be hazardous to human beings, livestock and fish and official supervision is necessary. Moreover, it may be necessary to alter existing legislation to permit the use of herbicides in water'.

The present session deals with a special branch of weed control technology. Knowledge gained in the study of agricultural weed control is of limited application to weed control in non-agricultural land and water and the adoption of agricultural herbicides and techniques is not likely to give really satisfactory results. Special chemicals with special tools and methods are required and some of these are described in what follows.

THE CONTROL OF ROADSIDE VEGETATION

by

F. L. SMITH

(manuscript not received)

Discussion

Mr. K. E. Clare (Road Research Laboratory).—In reply to Mr. Evans' introductory remarks to the effect that little official support has been given to research into the use of weedkillers on non-agricultural land, I should like to draw attention to the fact that the Road Research Laboratory has been quite closely associated with the pioneering work in Gloucestershire.

In recent years a section has been formed at the Laboratory to deal with problems arising on roads overseas. This year, we have been requested by the Round Table Conference on Overseas Highway Problems to look into the possibilities of the utilisation and control of vegetation on overseas roadsides. With the assistance of the Colonial Office, information about the vegetation is being sought from Public Works Departments and other organisations, and a good deal of data regarding the flora concerned has already been obtained. Lallang, couch and elephant grasses present problems of control. It also appears that in many areas it is very important to encourage low-growing grasses to counter erosion.

With regard to the work in Gloucestershire, Mr. Hearsey, a colleague of Mr. Smith's, had mentioned during the discussion at the Road and Building Materials Group, that grasses treated with selective weedkillers had some commercial value as fodder to local farmers. Had Mr. Smith been able to take this factor into account in the figures he gave comparing the costs of mechanical and chemical maintenance?

Mr. F. L. Smith.—In reply to Mr. Clare's question, our experiments have been based on the comparison of 'normal methods' of cutting and disposal before and after treatment, and the value of the grass as fodder has not been taken into account. While the improved quality of treated roadside grass may come to be more generally appreciated from year to year, leading to an increased demand, local farmers are somewhat reluctant to take grass during the year in which it has been treated, because of alleged 'taint'. In view of the relative difficulties in harvesting roadside grass, and of the variations in local supply and demand, I think this is a factor which must be considered on a local basis.

Mr. P. A. Oram (Borax Consolidated Ltd.).—As a part of a farm improvement programme I have recently obtained quotations from a number of contractors for mechanical clearance of scrub woodland, mainly ash and hazel. These varied from £112 to £120 per acre, which seems to me a very high figure. This should provide plenty of scope for chemical to replace mechanical removal of scrub, if this can be done as cheaply as Mr. Smith's figure of £48 an acre for chemical treatment. However, there are two obstacles: (1) it is first necessary to cut down and burn the top growth before treating the cut stumps. As the major cost of mechanical treatment lies in this operation of cutting out and burning, has Mr. Smith tried felling or slashing the trunks and treating these without removal of top growth?; (2) the removal of stumps; can chemical treatment cause these to rot so that they do not have to be removed, and if so, how long does this take?

Mr. F. L. Smith.—The problems of agricultural scrub clearance are hardly comparable with those of the highway engineer, as the latter is not generally concerned with the removal of the root system. Dealing firstly with the question of stump removal, I have found that most of the smaller stumps up to about 2 in. in diameter will rot and become broken off within a period of 2 years. The stumps of larger trees, although dead, will only rot away slowly and it seems evident that the time factor is dependent upon the size of growth.

Scrub has been killed quite effectively and economically without cutting, by treatment on the foliage using water as the carrier instead of diesel oil. As this treatment takes some months to become fully effective, it has been restricted on roadsides to young growth, for amenity reasons. I have successfully treated the stumps of very large trees by slashing and spraying the bark, and see no reason why such treatment should not be successful on standing trees, although the problem of felling and disposing of the dead wood afterwards might well prove formidable.

Mr. K. Wilson-Jones (Tropical Products Institute).—I should like to take up two points with Mr. Clare on Colonial problems:

(1) the economics are the inverse of those in the U.K.—labour is cheap but the herbicides are dear;

(2) similarly with the weeds, Mr. Smith has described the desirability of replacing tall broad-leaf weeds with low grass sward, but in Africa the problem is frequently that of replacing tall grass by low-growing species. I offer no suggestions as to means of accomplishing this.

Mr. F. L. Smith.—The remarks of Mr. Wilson-Jones do emphasise the fact that the problem varies with local conditions, and how desirable it is that experiments should be carried out locally by all those concerned, in order to achieve the best results.

ADVANCES IN TOTAL WEED CONTROL, WITH SPECIAL EMPHASIS ON NEW METHODS OF CHEMICAL EVALUATION

by

J. R. COX

(Fisons Pest Control Ltd., Chesterford Park)

Introduction

The initial treatment of established vegetation in total weed control places heavy demands on any single weedkiller. Mixtures of chemicals may be more effective but their evaluation requires special experimental techniques. This paper describes the principles of experimental evaluation of mixtures for total weed control.

Total eradication of weeds is now commonly practised on industrial sites in order to prevent damage to mechanical or electrical equipment, permit free drainage of water, eliminate fire and personnel hazards, and improve the general appearance of the area. The initial eradication of weeds is of supreme importance, since once this has been achieved, total weedkillers can be used at much lower dosage rates and be sprayed on to weed-free areas to prevent a weed problem from recurring. This is of major importance when compared with mechanical methods of weed control, which can only be used once the problem has appeared and usually cause soil disturbance which actively ferments the germination of weed seeds. The evaluation of chemicals necessary to give total weed eradication can be a slow and laborious task, but new experimental techniques have recently been developed which give quick and reliable results.

Selective weed control places much less demand on weedkillers than total weed control, and this is almost entirely due to the assistance it receives from a strong crop. A checked weed in selective weed control is usually prevented from recovering and becoming vigorous by crop competition, but in total weed control it would recover unhindered. The weed could then, because of absence of competition, spread into areas of relatively bare ground and soon establish itself over a wide area. Thus although in total weed control a treatment might control 19 species out of 20 the remaining species can become so vigorous that it leaves an impression of complete failure of the treatment. It is therefore extremely important that the initial eradication of weeds be as complete as possible, and this places very heavy demands on any single weedkiller.

Use of mixed herbicides

Recent developments in selective weed control have led to the use of mixtures of chemicals to control a wider range of weeds. Mixtures such as dinoseb/MCPA, MCPB/MCPA, 2,3,6-TBA/MCPA and pentachlorophenol/aminotriazole give in many cases vastly superior results than do the separate chemicals alone, especially when used against mixed weed populations. A similar development in total weed control would also widen the range of weeds controlled and place less demand on any single chemical.

The use of mixtures would also have other beneficial effects in total weed control besides widening the range of weeds controlled. In many cases the speed of action would be increased considerably and the cost of treatment reduced. The initial treatment is generally required not only to kill all living weeds but also to prevent re-infestation by seedlings during the season following spraying. It is therefore a relatively persistent treatment and chemicals giving persistence are usually only slightly soluble in water. Such chemicals are largely taken into the plant through the roots and this makes them slow acting, especially against the deep-rooted species, and in areas with low rainfall it can be many weeks before lethal symptoms are apparent. This is always discouraging to the customer who often loses patience and assumes that the chemical has not worked. A mixture of chemicals could speed up the rate of action especially if one chemical were effective through the foliage, and then symptoms would be apparent in a few weeks. This also helps in more certain control of many species since they are attacked in two different ways, through both the leaf and the root.

The most powerful chemical for total weed control which is commercially available is simazin, 2-chloro-4,6-bis(ethylamino)-*s*-triazine. Simazin is exceptionally toxic to weed seedlings and has great persistency due to its very low solubility (5 p.p.m.). This enables it to remain in the upper layers of the soil for much longer periods than other weedkillers. It is taken up into the plant by the roots and thus seedling weeds are killed almost as soon as they have germinated. It is therefore the ideal weedkiller to maintain areas weed-free for long periods. When used on established perennial vegetation, however, simazin is slow in action, due to the slow movement of the chemical into the plant root zone, and occasionally very deep-rooted species will not be completely controlled purely because the chemical does not reach their root zones in lethal quantities. It can thus be seen that a mixture of chemicals with simazin would be beneficial when it is applied on established vegetation.

Evaluation of mixed weedkillers

Evaluation of mixtures in total weed control is an extremely difficult task, and it requires special experimental techniques. The optimum dosage rates of the component chemicals must be discovered in relation to types of vegetation, stages of growth, climatic conditions and soil types. The innumerable combinations of chemicals which would have to be tested would make evaluation from a knapsack sprayer a long and tedious task. The Chesterford logarithmic spraying machine has, however, proved invaluable in the evaluation of optimum dosage rates. The machine continuously dilutes a known concentration as the spraying proceeds, thus enabling a whole spectrum of concentrations to be covered in one operation. Any number of chemicals can be sprayed at decreasing rates, or, in the same operation, some chemicals can be sprayed at constant rates whilst others are sprayed at decreasing rates. A multiplicity of combinations of chemicals can therefore be quickly sprayed at decreasing rates to cover a wide dosage range. It also permits easy evaluation of different mixtures at equal costs over a wide price range.

Experiments with simazin

Experiments have been carried out in 1958 with many chemicals as additives to simazin, and examples of some of these compounds include MCPA, 2,3,6-TBA, 2,4-D, 2,4,5-T, trichloroacetic acid, sodium chlorate and many triazine compounds closely related to simazin. The chemicals used as additives were tested either singly or in groups, at logarithmically decreasing dosage rates with simazin at a constant rate. Markers were placed along the logarithmic plots at different price levels so that the variable effects of the treatments at these different costs could be easily studied throughout the season.

A total of 17 experiments was laid down comparing simazin and mixtures with the logarithmic sprayer, 12 of these being large trials with an average of nine logarithmic plots each. The sites necessarily had to be flat with a relatively uniform population of perennial weeds. By arrangement with the Air Ministry experiments were carried out on many disused aerodromes in East Anglia which provided large areas of waste vegetation ideally suited for logarithmic trials.

The experiments were mainly laid down in March and April with the vegetation varying in height from 4 to 15 in., and in every case completely covering the ground. A large number of different weed species were sprayed and most of the common troublesome weeds such as *Agropyron repens* (couchgrass), *Equisetum* spp. (horsetail species), *Herachleum sphondylium* (hogweed), *Tussilago farfara* (coltsfoot), *Urtica dioica* (perennial nettle), *Senecio jacobaea* (ragwort), *Cirsium arvense* (creeping thistle), *Rumex obtusifolius* (broadleaved dock) and *Taraxacum officinale* (dandelion) were included. Soils were analysed for pH, organic content and mechanical composition, and rainfall figures were obtained from the nearest recording station.

Experiments were assessed every 5 weeks after treatment, when the volume of surviving live vegetation was estimated as a percentage of the volume of live vegetation in untreated plots. Species were recorded during all assessments and chemical symptoms noted. At the time of writing only four assessments had been completed but it was hoped that two further assessments could be made before the onset of seasonal die-back. Unfortunately the results recorded here will not, therefore, be able to give much information on re-infestation which might occur during the autumn months. Total weed control experiments can never be fully assessed until the year following treatment since valuable information on re-infestation might not be available until then.

The results of some of the mixtures compared with simazin in the logarithmic trials are shown in Figs. 1 and 2. Fig. 1 shows the results obtained from simazin alone. The peak dosage rate

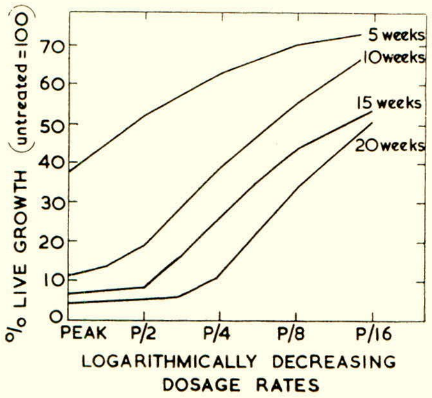

FIG. 1.—*Simazin applied on established perennial vegetation*
peak dosage = 40 lb. (active ingredient)/acre

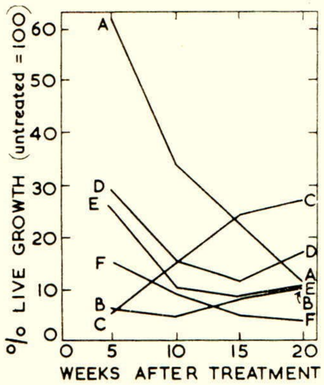

FIG. 2.—*Simazin + additives applied on established perennial vegetation*
All treatments at equal cost
Treatment A = simazin alone
Other treatments = simazin + various additives
Note different scale from Fig. 1

on the logarithmic plot was 40 lb. of active ingredient per acre, and it decreased to $2\frac{1}{2}$ lb. at P/16. It can be seen that there was regular improvement of all dosage rates with an increase in time, but 10 lb. of simazin (P/4) had taken 20 weeks before good results were achieved, and 5 lb. (P/8) was still not satisfactory. Fig. 2 shows the performances of some of the mixtures containing simazin compared with simazin alone at an equal price level. In all cases the use of mixtures greatly increased the initial effects, but in most of the mixtures there was a slight deterioration after 15 weeks. The main questions outstanding are the future trends of the treatments at the remaining two assessments, 25 and 30 weeks after treatment, since if treatment A continues to improve whereas the others worsen the initial advantage of a rapid effect might become offset by a loss of persistence. Similar graphs can be compiled at many other price levels, and thus comparisons between many different treatments are easily made. The ease with which such experiments are laid down with the logarithmic sprayer greatly facilitates this type of work.

Conclusion

The initial control of established vegetation is required to be as complete as possible since if the amount of vegetation present at the time of treatment has not been substantially reduced one year later, it can definitely be said that full benefit from the treatment has not been achieved. If, on the other hand, there was a substantial reduction, the subsequent treatment will have a less difficult task, and the dosage rate required will be automatically reduced. This, of course, will mean an accompanying reduction in cost. It is, therefore, well worth while that the initial treatment be made at the optimum time. The main disadvantage of the use of mixtures of chemicals with simazin is that the optimum time for application of each constituent in the mixture may be different, and the optimum time for the mixture itself therefore a compromise. Thus if application were made outside the optimum time, one or more of the constituent chemicals might not prove effective.

The importance of the initial treatment in total weed control cannot be over-estimated, and a few of the problems which must be met have been mentioned here. The success or failure of the methods described in overcoming these problems cannot, unfortunately, be fully evaluated until the forthcoming spring, and since it is always fatal to try to draw conclusions prematurely many questions must necessarily remain unanswered.

Acknowledgment

The author would like to express his thanks to Dr. R. K. Pfeiffer, head of the Botanical Dept., Chesterford Park Research Station, for designing the layout of the trials with the Chesterford logarithmic spraying machine.

OBSERVATION STUDIES ON TOTAL HERBICIDES

by

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Results are given for trials with simazin, monuron, monuron/borate and chlorate/borate as total herbicides and the affect of addition of 2,4-D and other selective herbicides.

Introduction

Until recent years advisory work in connexion with the use of non-selective herbicides was mainly confined to recommendations relating to the use of sodium chlorate and sodium arsenite. The fire hazard of the former and the poisonous nature of the latter were serious drawbacks to their widespread use on industrial, military or agricultural sites. During the last five years an increasing range of herbicides, suitable for non-selective weed control, has become available in this country. This influx of new chemicals has necessitated much field work to evaluate their efficiency, safety, persistence and other characteristics under a wide range of soil and climatic conditions and when applied to all types of vegetation found on various sites.

As a contribution to this work a number of preliminary observation study plots were laid down in the South East Region of the National Agricultural Advisory Service during 1956. These studies were designed to evaluate numerous herbicides recommended by commercial firms and to divide the chemicals into two main groups based on persistency and speed of action. It soon became evident that for many sites, where a very mixed flora was encountered, a mixture or combination of herbicides would give the most satisfactory results and that annual or biennial retreatment with relatively low-cost applications of herbicides would be required to maintain a weed-free area as desired on many sites. The observation study reported on here was commenced in 1957 to compare the effectiveness of various mixtures or combinations of herbicides alongside 'straight' applications of total herbicides and during 1958 the testing of maintenance treatments has been in progress.

Experimental

Site

The study was sited on land scheduled for development as a major roadway in the Thames Valley. Before the outbreak of war in 1939 there had been some disturbance of the natural soil. Since then, following settlement, the soil type could be described as London Clay in admixture with Valley Gravel giving a well drained gravelly loam with pH in the range 5·8–6·2. At the time of laying down of the study the flora consisted of several grass species dominated by cocksfoot with a wide variety of weed species (see Appendix 1).

Lay-out

All the plots laid down during 1957 were 2 yards × 10 yards and were separated by 2-ft. wide buffers with a centre corridor of 1 yard wide dividing two replicate series of plots. During 1958 one-half of each plot (10 sq. yd.) received a maintenance treatment, there being different retreatments for each of the two replicate plots of any one basic treatment. (See histograms, Appendices 2–5.)

Chemicals used were as shown in Table I.

Application

All dry materials—monuron/borate combinations and borate ore—were spread by hand, each plot receiving its dosage rate in two split applications on the same day.

The applications of sodium chlorate/disodium octaborate were made using a water can fitted with a fine rose, the rate of applications being 150 gal. of total spray/acre. Monuron and simazin were sprayed on to vegetation using the Oxford Precision Sprayer applying at the rate of 100 gal. total spray/acre. The remaining treatments—Dalapon/2,4-D and 2,4-D ester alone—were applied at low volume, 25 gal./acre, except where the latter was applied in combination with monuron or simazin wettable powders.

Table I

Compounds and application rates used in tests

Compounds	Nature of product used	Content of active ingredient	Rate of application per acre
A. Basic treatments			
(1) Monuron	Wettable powder	80% CMU	20–40 lb. (as CMU)
(2) Monuron/borate	Pelleted combination	4% CMU, 41·4% B_2O_3	2–6 cwt.
(3) Simazin	Wettable powder	50% active triazine	10–20 lb. (active)
(4) Sodium chlorate/ disodium octaborate	Soluble powder	25% $NaClO_3$+49% B_2O_3	3–6 cwt.
(5) Concentrated borate ore	Semi-granular	61·5% B_2O_3	8+12 cwt.
(6) 2,4-D butoxyethyl ester	Emulsifiable oil	70% acid equivalent	2 lb. a.e.
B. Maintenance treatments			
(1) Dalapon	Soluble powder	74% acid equivalent	10 lb. a.e.
(2) Sodium chlorate/ disodium octaborate	Soluble powder	25% $NaClO_3$+49% B_2O_3	2 cwt.
(3) Monuron/borate/2,4-D	Pelleted combination	3·5% CMU+5% 2,4-D acid+38·5% B_2O_3	1 cwt.
(4) Fenuron/borate/2,4-D	Pelleted combination	3·5% PDU+5% 2,4-D acid+38·5% B_2O_3	1 cwt.
(5) 2,4-D butoxyethyl ester	Emulsifiable oil	70% acid equivalent	2 lb. a.e.

a.e. = acid equivalent

Conditions at time of application

(1) *Basic treatments* (16th May, 1957)

(a) *Weather.*—Dry, temperature 59°F. Relative humidity 65%.

(b) *Vegetation.*—There was strong growth of grass, in particular cocksfoot, which in places tended to afford a cover over some dicotyledon weeds. All foliage was dry at the time of application. As will be observed from the histogram (Column 0) in Appendix 2, grass species occupied 72% of ground cover, there being no bare ground. The meadow grasses (*Poa* spp.) were in early flower stage with a few cocksfoot ears visible. Weeds such as ribwort, dandelion, creeping buttercup, thistle and daisy were in various stages of flowering from early bud development to full flower.

(2) *Maintenance treatments* (17th April, 1958)

(a) *Weather.*—Dry, temperature 53°F. Relative humidity 75%.

(b) *Vegetation.*—The ground cover shown in Column 2 for the control histogram (Appendix 2) indicates that 88% of the vegetation at time of retreatment consisted of grass species. The slow growth of dicotyledon weeds was largely due to the very dry cold conditions prevailing after mid-March.

Weather conditions during period of the study (see Table II)

A period of drought conditions lasting 3 weeks followed the application of basic treatments in May 1957. This was followed by very active growth conditions in mid-June. During the summer months there was prolific weed growth in the control plots and this was maintained well into the late autumn. In early spring 1958, very cold winds were experienced and growth was slow. These conditions continued until late May. Although the site is normally well drained the heavy rainfall during June and July 1958 caused some waterlogging. On 26th June 1·33 in. of rainfall was recorded in the area during a period of 24 hours. Under such conditions the leaching of chemicals was undoubtedly high, whilst grass and weeds showed vigorous growth in particular during August when soil temperature was high.

Methods of assessment

All the assessments carried out in this study have been based on visual estimations of the percentage ground cover of grass, weed and bare ground. They give an indication of vigour of growth of any one species but take no account of height of growth. These assessments were made at approximately three months' intervals omitting the first three months post basic-treatment application, although observations on rapidity of effect were noted then.

The percentage ground cover shown in the histograms (Appendices 2–5) is the average

Table II

Rainfall for period of study, recorded 1 mile from site

Period	Stage on histograms	Rainfall for period, in.	Monthly rainfall, in.
1957:			
16th May–31st October	Stage 0–1	12·41	1957: March, 1·16. April, 0·23. May, 1·30. June, 1·14. July, 3·41. Aug., 2·51. Sept., 2·51, Oct., 1·92.
1957–58:			
1st November–17th April	Stage 1–2	12·27	Nov., 2·13. Dec., 2·11. 1958: Jan., 2·78. Feb., 2·96. March, 1·68. April, 1·16.
1958:			
18th April–3rd July	Stage 2–3+5	5·56	May, 1·84. June, 3·59.
3rd July–31st August	Stage 3–4+6	5·89	July, 2·37. Aug., 3·65.
Total	Stage 0–4	36·13	

(20-year average rainfall 24·19 in.)

data covering two replicate plots for each basic treatment. In the case of maintenance treatments the percentage ground cover for individual half plots is shown. In addition a record of the dominant species of grass and weed remaining in any one plot at each assessment was also kept (see Appendix 1).

Discussion of results

(1) *The simazin group* (histograms Appendix 2)

Simazin, 2-chloro-4,6-bis(ethylamino)-*s*-triazine, was applied as a basic treatment at two rates—10 and 20 lb./acre of active ingredient (20 and 40 lb./acre of the present-day commercial product). At both rates of applications simazin was extremely slow-acting. There was only a slight dieback of vegetation 6 weeks post application whilst other herbicides had caused a considerable kill within the same period. Assessments carried out 24 weeks post application, however, showed over 95% bare ground for both rates of application. Amongst grass species tall fescue showed considerable resistance. At 15 months post application a 40% ground cover of dicotyledon weeds, mainly ribwort, tormentil and yarrow, was observed in the 10 lb./acre rate plots with the tall fescue remaining. By September 1958, in absence of any retreatment, a similar growth of dicotyledon weed covered 15% of the ground area in the 20 lb./acre plots. The application of 2 lb. a.e. of 2,4-D ester in admixture with simazin at the 10 lb. (active)/acre rate did not increase the bare ground area at any period of assessment, but had the effect of reducing the growth of dicotyledon weeds, in particular ribwort, in favour of grass growth. Further maintenance treatments with 2,4-D ester in April 1958 produced a 100% bare ground area in the high-rate simazin part plot, and reduced the dicotyledon growth to less than 5% ground cover in the low-rate simazin part plot as assessed in September 1958. The results following the application of dalapon/2,4-D as a maintenance treatment were variable, poor control of grass being obtained in one plot where meadow grasses and fine fescues showed considerable recolonisation within the six months post-application. A low rate (1 cwt./acre) maintenance treatment with the monuron/borate/2,4-D formulation maintained a part plot of a high-rate simazin treatment free of all growth for a further 6 months.

(2) *The monuron/borate group* (histograms Appendices 2 and 4)

In this group commercial rates—4 and 6 cwt./acre—of a monuron/borate combination were compared with 'double' basic treatments involving monuron/borate at rates of 2–4 cwt./acre and either 2,4-D ester or a sodium chlorate/disodium octaborate treatment. The application of 2,4-D ester at 2 lb. a.e./acre in addition to a basic treatment of 4 cwt./acre of monuron/borate in May 1957 did not give any additional control of dicotyledon weeds over a period of 18 months. A basic treatment of 3 cwt./acre of monuron/borate followed by spraying with 2,4-D ester on the same day did, however, compare favourably with the single treatment of 4 cwt./acre of monuron/borate over a similar period. The 'double' basic treatment of monuron/borate and sodium chlorate/disodium octaborate, each applied at rates of 2 cwt./acre, proved inferior to all other treatments in this group.

Following the application of monuron/borate treatments, the most resistant weed found in plots at this site was ribwort, but other weeds with similar rooting habits, e.g. wild carrot, were well established, in absence of retreatment, towards the end of the 18 months under observation. A monuron/borate combination gave good control of all grass species in all treatments over a long period.

Retreatment with 2,4-D ester in spring 1958 reduced the growth of dicotyledon weeds considerably, leaving only 2,4-D-resistant weeds such as yarrow. A dalapon/2,4-D treatment checked the regrowth of grass species but the efficiency of the 2,4-D appeared to be impaired. This lowering of the efficiency of control of dicotyledons, following admixture of 2,4-D with dalapon, is due in part to the removal of grass species allowing for speedy recolonisation by weeds on open ground. A low-rate application of monuron/borate/2,4-D combination as retreatment maintained the control of grass species given by basic rates of monuron/borate but was unable to check completely the growth of ribwort, ragwort and tormentil over the 6 months' observation period. The substitution of fenuron for monuron in the borate/2,4-D combination did not give as good a control of dicotyledon weeds over a similar period.

(3) *Monuron group* (histograms Appendix 3)

Preliminary studies during 1956 had indicated that certain weeds, in particular ribwort, showed strong resistance to treatment with monuron. The addition of 2,4-D ester to the monuron spray had not shown much improvement in the efficiency of dicotyledon control. In the study reported here the application of a mixed spray of 2,4-D/monuron was compared with separate applications of the two constituents on the same day. Whilst grass control was satisfactory, neither of the spray treatments gave good control of dicotyledons, such as ribwort, regrowth being in the region of 75% ground cover 12 months post-application where 20 lb. of monuron and 2 lb. a.e. 2,4-D ester had been applied per acre. A 40-lb. application of monuron (100% CMU) per acre also showed a similar breakdown in efficiency of dicotyledon control 15 months post-application.

Various retreatments applied to half plots in April 1958 were however fairly successful in reducing the growth of dicotyledons over a 3-month period post-application, whilst a low-rate application of monuron/borate/2,4-D combination gave a 90% bare ground area 6 months later. Again the replacement of monuron by fenuron in this combination gave an inferior control, particularly of dicotyledon weeds.

(4) *Chlorate/borate group* (histograms Appendix 5)

The chemicals in this group when applied as basic treatments are essentially quick-acting but low-persistency herbicides. In earlier studies, the borate/chlorate combination had shown its superiority over sodium chlorate, at equal rates of application of the commercial products, in the persistency of grass species control. This ability of a borate/chlorate combination to maintain a low grass content is also confirmed by the results in the present study.

The main interest in this group lies in the result of retreatments. A chlorate/borate combination or borate ore was applied to open up the sward prior to the application 12 months later of low rates of the monuron/borate/2,4-D combination or of a dalapon/2,4-D treatment. With the latter a good control of weed and grass was obtained over a 3-month period, but over a longer period dicotyledon re-infested the area. The monuron/borate/2,4-D combination gave good control of grass and weed over a 6-month period post-application.

Conclusions

Amongst basic treatments applied in this study, simazin and monuron/borate combinations, particularly at the higher rates of application, have given the most satisfactory results in non-selective weed control. The application of these and other total herbicides at lower rates coupled with retreatment 12 months later has also given satisfactory results over an 18-month period. On some sites, depending on type of vegetation present and the extent of growth, the application of quick-acting, low-persistency herbicides or mixture of herbicides followed at a later stage by low-rate applications of more persistent total herbicides would give better results. Where translocated selective herbicides are used as an aid to treatment with total herbicides, the activity of growth at the time of application will have considerable bearing on the efficiency of weed control.

The paramount fact emerging from a study of the efficiency of total herbicides is that mother Nature abhors blank spaces. It is comparatively easy by means of a combination of basic treatments followed by maintenance treatments to produce a 90% weed-free area, but there is always some resistant plant which will recolonise bare ground. The flora of a site can be changed completely by the use of chemicals and on some sites a regrowth of grass in absence of dicotyledon weeds may be an advantage. In advisory work connected with the application of total herbicides, each site demands an individual approach. The ultimate aim in terms of weed or grass control must be considered in relation to the flora present and in particular to the cost of attaining the desirable result following the use of various herbicides.

Acknowledgments

The author wishes to acknowledge the considerable assistance given in laying down the study plots by Messrs. L. J. Churchill and R. A. Lewis (N.A.A.S. Experiments Team, South East) and by Mr. W. G. Gwynne (Grassland Advisory Officer) in carrying out periodical assessments.

Appendix I

Details of flora at site and an indication of dominant species remaining post-treatments

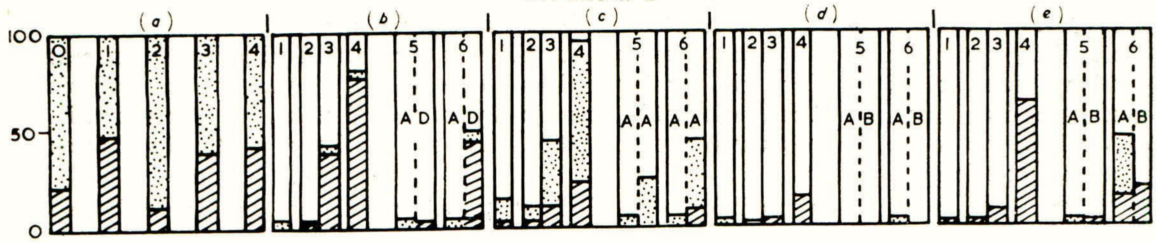
A. *Agrostis* spp. (bents)
B. *Agropyron repens* (couch grass)
C. *Bromus mollis* (soft brome)
D. *Cynosurus cristatus* (crested dogstail)
E. *Dactylis glomerata* (cocksfoot)
G. *Festuca* spp. (fescues)
H. *Holcus mollis* (Yorkshire fog)
J. *Poa* spp. (meadow grasses)
K. *Achillea millefolium* (yarrow)
L. *Bellis perennis* (daisy)
M. *Cerastium vulgatum* (mouse-ear chickweed)
N. *Crepis* spp. (hawksbear)
P. *Daucus carota* (wild carrot)
R. *Lotus corniculatus* (birdsfoot trefoil)
S. *Plantago lanceolata* (ribwort)
T. *Potentilla erecta* (common tormentil)
V. *Ranunculus repens* (creeping buttercup)
W. *Senecio jacobea* (ragwort)
X. *Sonchus oleraceas* (sow thistle)
Y. *Taraxacum officinale* (dandelion)
Z. *Veronica* spp. (speedwell)

Dominant species—post-application

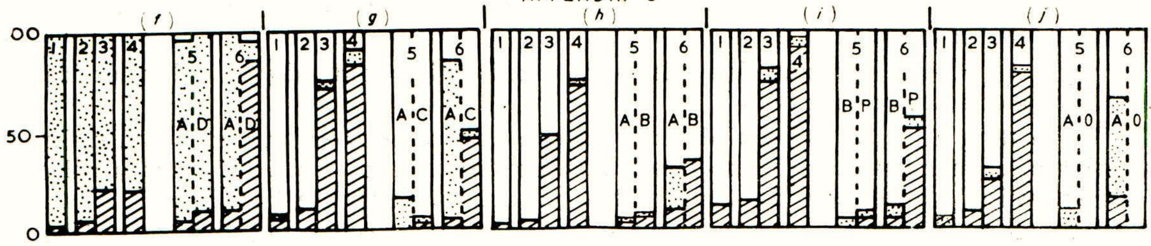
Basic treatment rate per acre	After 28 weeks		After 50 weeks		After 68 weeks	
Monuron/borate 4 cwt.		S		S M W	A E J	S W P
Monuron/borate 6 cwt.		S T		S M W T	J	S W T
Monuron/borate 4 cwt. + 2,4-D ester 2 lb.		S	E	S M W	E J	S W P
Monuron/borate 3 cwt. + 2,4-D ester 2 lb. a.e.		S P	E J	S M W Y	E J	S W P Y
Monuron/borate 3 cwt. + chlorate/borate 1 cwt.		S P M	E	S M W	E J	S W P Y
Monuron/borate 2 cwt. + chlorate/borate 2 cwt.		S T Y	E	S M T Y	E	S W P Y T
2,4-D ester 2 lb. a.e.	E A G	K	E A G J	W K	E A G J	S P W K
Monuron 20 lb.		S W M Z		S W M Y	E	S W P Y
Monuron 20 lb. + 2,4-D ester 2 lb. a.e. (separate)		S M Z	E	S W M	E J	S W P
Monuron 20 lb. + 2,4-D ester 2 lb. (mixture)		S W Y		S W M T	E	S W P T
Monuron 40 lb.		S W Y		S M T		S W P T
Simazin 10 lb. active	E G (Tall)	S	G J	S K Y	G (Tall)	J S W Y
Simazin 10 lb. active + 2,4-D ester 2 lb. a.e.	E G (Tall)	K	G J	S T K Y	G (Tall)	J S P W K
Simazin 20 lb. active	G (Tall)	T R V	G (Tall)	T V	G (Tall)	J T
Sodium chlorate/disodium octaborate 6 cwt.		N X L	E J	L M W Y	E	L W Y R
Sodium chlorate/borate 4 cwt. + 2,4-D ester 2 lb.	A E	N X L	E	L M W Y	E	S W Y
Sodium chlorate/borate 3 cwt. + monuron/borate 1 cwt.	A E	S	E G J	S M L	E G J	S P R
Conc. borate ore 12 cwt.	A E	L M Y	A E G J	M L Y	A E	P Y
Conc. borate ore 8 cwt. + 2,4-D ester 2 lb. a.e.	A B E C	M	A E G J	M	A E G J	S Y

Maintenance treatments—application 17th April, 1958	After 11 weeks		After 20 weeks	
2,4-D ester 2 lb. a.e.	A E G D	K	A E G J	S K T Y
2,4-D ester 2 lb. + 10 lb. a.e. dalapon		S	G J	S K T P W Y
Sodium chlorate/disodium octaborate 2 cwt.	J	N Y	E J	Y
Monuron/borate/2,4-D 1 cwt	E	S T	E	S P T W Y
Fenuron/borate/2,4-D 1 cwt.	E D	S T	E D	S T W Y

APPENDIX 2



APPENDIX 3



Histograms showing percentage ground cover

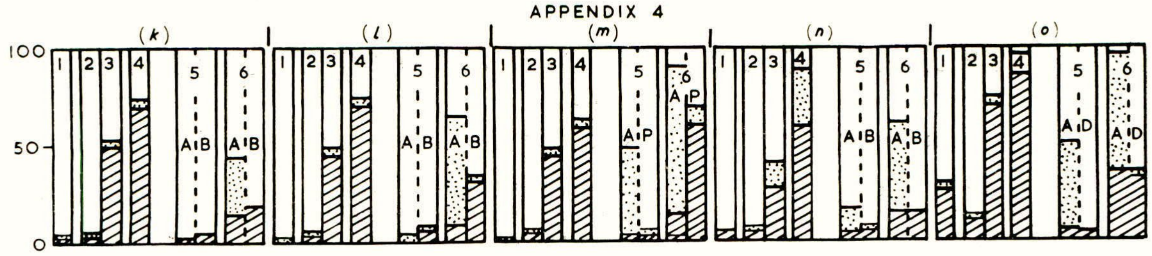
Key to Diagram—

Unshaded area represents bare ground. Dotted area represents grass species. Diagonally shaded area represents other weeds.

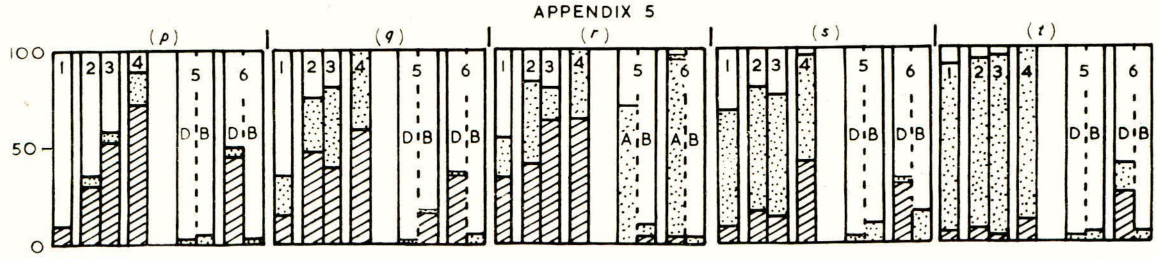
(*a*) control (no treatment) (*b*) simazin 10 (*c*) simazin 10 + 2,4-D ester 2 (*d*) simazin 20
(*e*) monuron/borate 6 cwt./acre (*f*) 2,4-D ester 2 (*g*) monuron 20 + 2,4-D ester 2 (applied separately)
(*h*) monuron 20 (*i*) as (*g*) applied as mixture (*j*) monuron 40
Basic treatment applied 16.5.57
Assessment on 0 pre-application, 16.5.57; 1, 31.10.57; 2, 17.4.57; 3, 3.7.57; 4, 3.9.57; 5, 3.7.58; 6, 3.9.58
Maintenance treatments applied 17.4.58:
A 2,4-D ester 2
D 2,4-D ester 2 + dalapon 10
B monuron-borate-2,4-D combination 1 cwt./acre
C chlorate/disodium octaborate 2 cwt./acre
P fenuron/borate/2,4-D combination 1 cwt./acre

(Quantities are lb./acre of active material or acid equiv. for 2,4-D ester and dalapon)

APPENDIX 4



APPENDIX 5



Histograms showing percentage ground cover

Key to Diagram—

Unshaded area represents bare ground. Dotted area represents grass species. Diagonally shaded area represents other weeds.

(*k*) monuron/borate 4 cwt./acre (*l*) as (*k*) + 2,4-D ester 2 lb./acre
(*m*) monuron/borate 3 cwt./acre + 2,4-D ester 2 lb./acre
(*n*) ,, ,, ,, ,, ,, + chlorate/disodium octaborate 1 cwt./acre
(*o*) ,, ,, 2 cwt./acre + ,, ,, ,, 2 cwt./acre
(*p*) chlorate/disodium octaborate 6 cwt./acre
(*q*) ,, ,, ,, 4 cwt. + 2,4-D ester 2 lb./acre
(*r*) ,, ,, ,, 3 cwt. + monuron/borate 1 cwt./acre
(*s*) conc. borate ore 12 cwt./acre (*t*) as (*s*) 8 cwt. + 2,4-D ester 2 lb./acre
(Weights of 2,4-D ester are acid equiv.)
Basic and maintenance treatments as above
Assessment dates as above

Discussion on the two preceding papers

Mr. R. H. Hirst (Plant Protection Ltd.).—I feel that there may perhaps be a little difficulty in applying the results given in these papers to industrial conditions, as the trials reported appear to have been carried out under agricultural conditions. I think that it is a pity Mr. Cox made no comparison with monuron, a chemical that has been known for several years longer than simazin. I would like to ask Mr. Hughes whether he thinks the addition of 2,4-D to a pelleted formulation has any practical advantage.

Mr. R. G. Hughes.—The addition of 2,4-D to a pelleted formulation can very definitely add to the efficiency of kill if:

(i) weeds susceptible to 2,4-D such as ribgrass, dandelion and wild carrot are present in the original weed cover; and

(ii) the pelleted formulation is applied when there is active growth of weed and not during a dormant growth period.

The study reported was carried out under conditions which are often encountered in the maintenance and construction of major roadways where hand-labour is prohibited or unavailable. Other studies have been carried out on industrial and military sites in the South East.

Mr. E. C. S. Little (New Zealand).—It has been shown in New Zealand that 2,4-D mixed with pellets of superphosphate will kill weeds of a rosette type. The pellet is retained in the axils of leaves and when dissolved by dew will result in a good kill. At least 2 cwt. of superphosphate per acre seemed necessary. Weeds killed are Scotch and winged thistle at the rosette stage.

CONTROL OF AQUATIC WEEDS BY COPPER SULPHATE

by

R. J. CHANCELLOR,* A. V. COOMBS† and H. S. FOSTER‡

Water courses at two sites were treated continuously for periods up to 6 months (summer, 1957) with copper sulphate to maintain approx. 1 p.p.m. of copper in the water at the treatment point. At another site this treatment was given at 0·25 p.p.m. copper (autumn and winter, 1957/58).

Effects on weed growth extended downstream for over a mile from the treatment point. The most notable was the suppression of algae which allowed a faster flow of water. The susceptibility of different species of aquatic weeds to copper varied greatly and susceptible and resistant species are listed.

Considerable reduction in total weed growth took place during treatment but, as the effects gradually became reduced below the treatment point, it hardly amounted to commercial control. Regrowth in the following spring (6 to 8 months after treatment ceased) was not much reduced but the composition of the flora remained affected.

Snails were greatly reduced or eliminated but fish appeared unaffected.

Introduction

The effects on water weeds of continuous small additions of copper sulphate to a stream were communicated to the 1956 Weed Control Conference,[1] and in view of the promising results obtained further experiments were laid down at new sites as well as being continued at the original one. The considerations which led up to the initiation of the trials were set out in that paper.

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‡ McKechnie Brothers Ltd., Widnes.

Spalding experiment

(a) *Location and site.*—A channel (Lock's Dyke) forming part of the Deeping Fen, Spalding and Pinchbeck Internal Drainage Boards' network was chosen for the trial. It was fed with water of pH 7·8 from a river through an adjustable sluice so that an approximately constant rate of flow could be maintained. (200–250 gal./min.) The channel consisted of three sections, each perfectly straight and uniform, of a total length of $1\frac{1}{4}$ miles, and the width of the water was about 4 ft., varying a little according to its level. The first 250 yards was left untreated as control.

(b) *Treatment.*—Copper sulphate was added by allowing it to dissolve from bags suspended in the water from a plank across the dyke. The number of bags necessary was ascertained by estimating the copper content of the water from time to time. A concentration of 1 p.p.m. of copper ($CuSO_4$, $5H_2O$, 4 p.p.m.) was aimed at. This was eventually obtained by the use of about five bags into one or two of which 13 lb. of copper sulphate (granulated) was put daily. With copper 1 p.p.m. 200 yards below the treatment point, the copper concentrations at 1000 and 2000 yards were on the average 0·6 and 0·4 p.p.m. respectively. The treatment started on 1st April, 1957, and continued for 6 months, altogether 1 ton of copper sulphate being used.

(c) *General results.*—The effect of the treatment on algae, which was complete control, soon became evident and persisted throughout the treatment and was seen not only in the dyke but also to some extent in the main channel into which it was discharged. The comparison of the growth of other weeds in the treated area with those on the control section was difficult because in the control section the plants were densely coated and matted together with algae. The effect of the treatment on flowering plants appeared to be negligible beyond the first 100 yards for the first 4 months, although *Lemna minor* (duckweed) disappeared. By the end of September general weed growth was much less vigorous for at least half a mile and certain species (see Table I) had disappeared. The Engineer to the Drainage Board described the total growth as very moderate, but probably sufficient to require manual clearance in ordinary circumstances and in December this was done. After treatment ceased, on 1st October, the site was kept under observation. The regrowth which took place in the spring seemed to be about normal in quantity, but species which had disappeared the previous year were still absent.

Louth experiment (Lincs.)

(a) *Location and site.*—In a channel under the care of the Louth Drainage Board at South Somercotes a trial was made similar to the previous one. The control was the channel from which the experimental dyke was fed and contained the same plants as the treated area. Although controlled by a sluice gate, the rate of flow of the water (pH 7·2) was somewhat uncertain and irregular.

(b) *Treatment.*—The copper sulphate treatment (21 lb. every 2 days, dissolving from suspended bags) was started on 23rd May, 1957, and continued to 14th November. This was calculated to give a copper concentration of 1 p.p.m. and a series of observations showed this at 1100 yards from the treatment point. At a mile below, more than traces of copper were never found. Much higher concentrations were sometimes found near the treatment point but these were irregular and were probably influenced by the lapse of time since refilling the bags. This dyke had more side drains leading into it and more connections with other channels than the one treated at Spalding and this probably accounts for the more rapid decrease in copper content downstream.

(c) *General results.*—The dyke was originally well stocked with common weeds, and like the other water courses in this system suffers periodically from growth on the water surface of a thick algal scum, locally called 'skin'. In August *Myriophyllum spicatum, Elodea canadensis* and *Potamogeton densus*, which had formed dense masses $\frac{1}{4}$ mile below the treatment point, had disappeared and dying stems on the bottom confirmed their control. Other species appeared unaffected (see Table I), but in general the total growth was considerably reduced. In September when the Drainage Board had the dyke cleaned in the usual way, the Engineer reported that the growth removed was much less than usual. In the spring the volume of new growth could not be said with certainty to be below normal. *Myriophyllum*, *Elodea* and *Potamogeton* had not reappeared up to mid-June. Algal growths were again normal, having presumably floated down from the control section, and *Callitriche stagnalis* was flourishing.

Tickenham experiment (Somerset)

(a) *Location and site.*—This is the site described at the 1956 Weed Control Conference.[1] The stream had been treated with copper sulphate in the summer of 1956 and the resulting suppression of growth of *Callitriche* spp. continued until May 1957, the stream remaining practically clear of weeds over a distance of about half a mile. By mid-June, however, growth mainly of *Callitriche* spp. was so vigorous that the Drainage Board ordered its clearance. After this, regrowth was approximately normal.

(b) *Treatment.*—In view of the promising result of this first experiment, weed control having been obtained for about 8 months, but at a rather heavy cost, it was decided to try the effect of a smaller dosage beginning in August 1957 using the same stream. The treatment point was moved downstream 150 yards, thus giving an additional control portion of the stream. The average rate of addition aimed at was a quarter of that used in 1956, viz., 0·25 p.p.m. copper in the water, and was obtained by suspending a bag containing 28 lb. of copper sulphate in the stream and renewing it weekly. This was continued for 16 weeks.

(c) *General results.*—After 8 weeks of this treatment, *Elodea canadensis*, *Potamogeton* spp. and *Lemna minor* had disappeared, but *Callitriche* spp. were vigorous. At the end of the 16 weeks of this treatment, the situation was essentially unchanged. The stream was then left untreated to see whether the delayed effect on *Callitriche* noticed after the first treatment in 1956 would occur again, but as this was not apparent up to the end of March, treatment at the same rate was recommenced and carried on for another 8 weeks, but no change resulted, *Callitriche* spp. remaining alive and *Elodea* and *Potamogeton* being absent. As with the heavier dosage, the treated portion of the stream was always much brighter and cleaner in appearance than the control, in which dark slimy algal growths were generally present.

Results in detail

The vegetation in the experimental channels at Spalding and Louth was assessed on four separate occasions and the results obtained are given in Table I. The Tickenham experiment is also included to show the similar results obtained there.

Table I

Relative susceptibility of water weeds to copper sulphate

	Spalding	Louth	Tickenham (1957/8)
Flowering plants:			
Potamogeton perfoliatus	S†	—	—
Potamogeton berchtoldii	S	—	—
Potamogeton densus	S	S*	—
Potamogeton pectinatus	—	S	—
Potamogeton crispus	—	S	S
Myriophyllum spicatum	S†	S*	—
Lemna minor	S*	S	S
Elodea canadensis	—	S*	S
Alisma plantago-aquatica	R	—	—
Juncus articulatus	R	—	—
Sparganium sp.	—	R	—
Sparganium simplex	—	—	R

	Spalding	Louth	Tickenham (1957/8)
Callitriche obtusangula	R	—	—
Callitriche stagnalis	—	R	—
Callitriche intermedia	—	—	R
Phragmites communis	R	—	—
Glyceria fluitans	R	—	—
Hippuris vulgaris	R	—	—
Veronica anagallis-aquatica	—	—	R
Non-flowering plants:			
Equisetum fluviatile	—	R	—
Algae:			
Oedogonium sp.	S	—	—
Spyrogyra sp.	S	—	S
Enteromorpha intestinalis	—	S	—
Vaucheria sp.	—	S	—
Mougeotia sp.	—	—	S

R = resistant to the treatment applied to the site.
S = susceptible to the treatment applied to the site.
* and †, see text.

At the first assessment of the Spalding and Louth experiments (June 1957) the only noticeable effect was the disappearance of the algae and *Lemna*. At the second (August 1957) the absence of the species marked * was very striking as earlier they had been prominent. They had not reappeared up to the time of the last assessment, which was several months after the end of treatment. At the third inspection (October 1957) the species marked † had disappeared. At the last assessment (June 1958) the only plants previously controlled which had reappeared were the algae and *Lemna minor* at Louth, having presumably floated down from the control. At Spalding the clinging submerged algae were absent both in the control and treated sections. At Spalding *Potamogeton berchtoldii* was not seen in 1957, but in June 1958 it was very common in the control portion and stopped so abruptly at the treatment point that it has to be presumed to be susceptible to residual copper.

Animal life

Water snails (mainly *Limnea stagnalis* and species of *Planorbis*) disappeared soon after the start of treatment and no living specimens were seen in October of the year of treatment as far as the outfall at Spalding and up to the 2-mile point at Louth. In the control portion of the dykes every handful of weed contained a noticeably large number.

No dead or sickly fish were ever seen, but fish were not much in evidence in either the control or treated parts of the dykes at Spalding and Louth and no attempt was made to assess the fish population. Fish of some size were seen in the treated dyke at Spalding in January 1958 and small fish were common in the stream at Twickenham under treatment at the lower rate (0·25 p.p.m. Cu).

Copper in the weeds

Estimations of the copper in the weeds and in mud from the bottom of the dykes were made to see how much copper was taken up by plants and how much accumulated in the mud (see Table II).

Table II

Copper content of plant and mud samples from the three sites

(Samples taken at Tickenham 50 yards above the 1957/8 treatment point were from a part of the stream that had copper treatment in 1956)

Sample	Date taken	Site	Distance from treatment point, yd.	Cu. content, p.p.m. (dry matter)	Sample	Date taken	Site	Distance from treatment point, yd.	Cu. content, p.p.m. (dry matter)
Callitriche	14.6.57	Spalding	100	1750	*Callitriche*	8.10.58	Tickenham	200*	65
,,	,,	,,	800	600	,,	,,	,,	50*	75
Mud	9.8.57	,,	70*	20	,,	,,	,,	200	125
,,	,,	,,	40	180	*Veronica*	,,	,,	50*	60
,,	,,	,,	1090	95	,,	,,	,,	100	95
,,	,,	,,	2070	95	Mud	,,	,,	50*	50
Alisma	16.8.57	,,	50*	50	,,	,,	,,	100	275
Hippuris	24.9.57	,,	2000	450	*Callitriche*	20.12.57	,,	300	700
Potamogeton	,,	,,	2000	330	Mud	,,	,,	300	120
Alisma (leaves)	,,	,,	20	950	*Callitriche*	31.1.58	,,	300	500
,, (stems)	,,	,,	20	1100	,,	9.5.58	,,	300	280
Callitriche	13.5.58	,,	800	65	,,	,,	,,	200*	50
,,	16.8.57	Louth	400	900					
,,	24.9.57	,,	900	1100					
,,	,,	,,	400	1500					
,,	17.1.58	,,	1300	240					
,,	13.5.58	,,	400	90					

* above treatment point, otherwise below

Conclusions

The table of susceptible and resistant species suggests that, in general, plants which are submerged or floating are susceptible, while those which are emergent are resistant presumably because they are deep rooted. The only exceptions are the three species of *Callitriche*. This resistance of *Callitriche* is outstanding and of importance.

The susceptible weeds were generally destroyed quite early in the treatment and were still absent many months after treatment ceased. As they were affected at distances of at least 1 mile from the treatment points it appears that considerably less copper than 1 p.p.m. is necessary to control them. This is borne out by the results of the later Tickenham experiment in which 0·25 p.p.m. of copper killed *Elodea canadensis* and other species.

The effect on algae was in all cases very striking and of great interest to the Drainage Boards' engineers, but it is, of course, not a new observation.

Acknowledgments

The authors gratefully acknowledge the co-operation of the Engineers to the Drainage Boards, viz., Mr. W. D. Miles of Spalding, and Mr. D. C. Morris of Louth, without whose constant help this work would not have been possible. Dr. W. Plant's continued supervision of the Tickenham work is also acknowledged with thanks, as is also Mr. K. Wilson-Jones' helpful advice in all these trials.

Further, the authors wish to thank the British Sulphate of Copper Association for the provision of material and Messrs. McKechnie Brothers for laboratory facilities.

Reference

[1] Foster, H. S., & Plant, W., *Proc. 3rd Brit. Weed Control Conf., 1956,* p. 787.

TOXICITY OF WEEDKILLERS, ALGICIDES AND FUNGICIDES TO TROUT

by

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(*Ministry of Agriculture, Fisheries and Food, London*)

Since the last note on the toxicity of weedkillers to trout[1] a number of proprietary weedkillers, algicides and fungicides and also several chemicals forming the active ingredient of such substances have been tested for their toxicity to trout.

Rainbow trout (*Salmo gairdnerii*) and in some cases also brown trout (*Salmo trutta*) were tested in several concentrations of each substance over a period of several days. The fish were between 3 and 12 months old, although only fish of the same age were used for testing any one substance. They were sorted at random into batches of 10 and acclimatised for at least 24 hours in 40-l. test aquaria in which the temperature was $18° \pm 0{\cdot}5°$ and the dissolved concentration close to the air saturation value. The fish were starved during this time and during the test period which immediately followed. Where possible the individual periods of survival of the fish were recorded and the median survival time estimated by the graphical method of Bliss.[2] The logarithms of the medians were plotted against the logarithms of the concentrations tested and a line fitted by eye to the points. The concentrations corresponding on the line to a median period of survival of 24 and 48 hours (the median tolerance limits) have been taken as a measure of toxicity and are listed in Table I for all the substances tested.

The results for the different substances are not strictly comparable because with some (Nos. 1–4, 8–12) the test solutions were renewed daily, whereas with the rest they were not. With batch replacements of the solution, estimates of the 48-hour median tolerance limits could be lower than they would be in static conditions. The toxicity of a weedkiller which is to be applied only once to water containing fish may thus be overestimated in a test in which the solution is renewed, and conversely, the toxicity of substances such as fungicides in paper-mill effluents which are discharged continuously to rivers may be underestimated by tests carried out with little or no replacement of the test solution. With some of the substances listed in the table additional tests were carried out under different conditions of replacement. With No. 6 a continuous rate of replacement of 0·25 l./min. was used and with Nos. 10, 13 and 15 a flow of 1·0 l./min. was tried. In the case of No. 10 the results were similar to

Table I

Toxicity of weedkillers, algicides and fungicides to trout
(all results for Rainbow trout, except those marked *)

No.	Ingredients	% approx.	Median tolerance limit, p.p.m. 24 hour	Median tolerance limit, p.p.m. 48 hour
1	Laurylpentachlorophenol	25·0	330	180
	Pentachlorophenol	0·01		
	Borax	0·6		
	Water	74·0		
2	As No. 1 except pentachlorophenol	0·5	80	68
3	Laurylpentachlorophenol	25·0	68	36
	Pentachlorophenol	0·01		
	Polyoxyethylene	3·0		
	White spirit	15·0		
	Water	57·0		
4	As No. 3 except pentachlorophenol	0·5	47	24
5	Sodium chlorate	40·0	1150	1100
	Sodium metaborate (+8H_2O)	57·0		
	CMU	1·0		
6	Sodium chlorate	40·0	2000	1800
	Sodium metaborate (+8H_2O)	58·0		
7	2,2-Dichloropropionic acid (Na salt)	85·0	340*	210*
8	2-chloro-4,6-bis(ethylamino)-*s*-triazine	50·0	95	85
	Calcium carbonate	40·0		
	Lignin sulphonate	5·0		
	Sodium ethylene glycol polyether sulphonate (active ingredient)	1·7		
9	No. 8	4·0	2200	—
	Plasticiser	1·3		
	Quartz sand	95·0		
10	Sodium salt of dichlorophen	40·0	0·8 0·6* 0·8‡	0·54 0·38* 0·63‡
	Water	60·0		
11	2,3-Dichloro-1,4-naphthaquinone	30·0	0·34	0·31
12	Tributyltin oxide	95·0	0·028	0·02[illegible]
13	Copper 8-quinolinolate	100·0	0·3 0·2*	0·14 0·10*
14	Phenyl mercuric acetate	100·0	0·005 0·007*	0·004 0·006*
15	Sodium pentachlorophenate	90·0	0·29 0·29*	0·17 0·17*
16	2,4-D triethanolamine salt	50·0†	250	210
	Water	50·0		
17	2,4,5-T butyl ester	50·0†	12	9·5
	Emulsifiable oil	50·0		
18	2,4-D hexyl ester	50·0†	17	27
	2,4,5-T hexyl ester	25·0†		
	Emulsifiable oil	25·0		

† acid equivalent ‡ one year between replicate tests

those obtained with daily batch replacement and with the others the results were similar to those found under static conditions. With No. 8 additional tests were made in solutions containing initial concentrations of 40 and 80 p.p.m. which were changed daily and in solutions with the same initial concentrations which were not changed. At the end of 4 days the percentage mortality in the solutions which were changed was 10 and 50, respectively, and in the static solutions, 0 and 10, respectively.

There are no published figures available for comparison for the formulated substances and only a few for the pure chemicals. Heron & Sproules[3] quote figures for sodium pentachlorophenate which are similar to those presented here. They say, however, that 0·01 p.p.m. of phenylmercuric acetate is regarded as a safe upper limit for fish whereas in the tests reported here trout died within 24 hours in this concentration.

References

[1] Alabaster, J. S., *Proc. 3rd Brit. Weed Control Conf., 1956*, p. 807

[2] Bliss, C. I., *Ann. appl. Biol.*, 1937, **24**, 815

[3] Heron, P. N., & Sproules, J. St. G., 'The Chemical Nature of Fungicidal Agents employed in the Paper and Pulp Industry', Section of the British Paper & Board Makers' Ass. Inc., 1957, **38**, (June), Part 2