TABLE I. DETAILS OF

(NOTE - Lack of mention may imply that the species was not present
In the interests of brevity, weed species are referred to
more than one species of any genus is involved)

Chemical	Composition	Supplier	Dose	Date Applied
Acrolein	Acrolein	Shell Chem. Co.	15, 30 & 60 ppm	26. 5. 59.
Simazine	50 per cent wettable powder	Fisons Pest Control Limited	20 lb ac	"
Atrazine	"	"	"	"
	"	"	"	"
Trietazine	"	"	"	"

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where the chemical was tested.
by their generic name after their first mention, except where

Dyke Condition	Species markedly affected	Notes
c. 9 in. of water-plots contained within dams. Water temperature 53°F.	Alisma plantago-aquatica, Hippuris vulgaris, Sparganium ramosum, Callitriche sp., Myriophyllum spicata, Elodea canadensis, Potamogeton crispus, Ranunculus aquatilis, Nasturtium officinale, Chara and other algae (all seriously affected within 4 days.)	Glyceria maxima, Phragmites communis, Carex sp. and Typha latifolia were resistant. Regrowth of Alisma was evident within 4 weeks and the dyke was completely choked with a variety of species within a year. Differences between rates not very marked.
Marshy bottomed	Alisma, Callitriche sp., Berula erecta, Epilobium hirsutum, Hippuris, Hottonia palustris, Ranunculus scleratus, Juncus spp., brambles, Glyceria, Agrostis stolonifera, Galium palustre and Lysimachia vulgaris	Practical control for 16 months
Marshy bottomed	As simazine but also Typha latifolia	" " " "
c. 9 in. water - dam at lower end of plot	None	-
Marshy bottomed.	None	-

TABLE I.

Chemical	Composition	Supplier	Dose	Date Applied
"Chlorea"	Pelleted mixture of sodium chlorate, borate, 2,4-D and monuron ⁂	Chipman Chem. Co.	2 cwt/ac, equiv. to about 10 lb ac monuron	26. 5. 59
"Monax"	Pelleted mixture of borates and monuron ≁	-	" "	" "
2,4-D ("Weed Rhap 20")	20 per cent 2,4-D clay based pellets ⁂⁂	Reasor-Hill Corp.	30 lb/ac	"
2,4-D	75 and 80 per cent 2,4-D resin bonded pellets.	Shell Chem. Co.		31. 5. 60 8. 8. 60 18. 8. 60 26. 5. 59 From 8. 6. 59 to 20. 5. 60

⁂ Telver 'W' (80 per cent monuron 3 per cent; powdered Borax (decahydrate) cent; 2,4-D Sodium salt .125 percent.

≁ Telver 'W' (80 per cent monuron) 5 per cent; Borax (decahydrate) 81.5 per

⁂⁂ 2,4-D iso-octyl (2-ethyl hexyl) ester 30.12 per cent and 69.88 per cent inert

(Contd.)

Dyke Condition	Species markedly affected	Notes
Marshy bottomed.	Typha, Alisma and Agrostis stolonifera.	Control for 16 months. Lower rate of 2/3 cwt was unsatisfactory
Marshy bottomed.	None	Some check to Typha.
c. 9 in. of water	None	-
c. 9in. of water - dam at upper end of plot. 6 in. of water within dams 6-18 in. of water within dams, long dyke.	Alisma and Sparganium (apparently affected most readily) Callitriche, Nasturtium, Ranunculus aquatilis, Potamogeton crispus, Hippuris, Myriophyllum and Oenanthe sp., Elodea least affected	Where applied in May '59 Alisma and Sparganium were still well controlled (86 per cent and 100 per cent respectively) 12 months later. Submerged species did not completely recolonize until about 12 months after application. No evidence of differences between formulations which were not compared directly until 1960, most of which tests failed through absence of dams.
6-18 in. of water, long stagnant dyke.		
Marshy bottomed	None	
Various standing water dykes with no dams.	None	

37.5 per cent; Sodium carbonate dense, 20.25 per cent; Sodium chlorate 38 per cent; powdered glue 2 per cent; Neobor (pentahydrated) Borax 11.5 per cent

ingredients (clay) = 20 per cent a e w/w 2,4-D

Where dams were employed, acrolein applied on 26th May at 15, 30 and 60 ppm gave, within four days, an excellent kill of most of the leaves of a wide range of broad leaved species and Sparganium ramosum. Regrowth of Alisma plantago-aquatica and Sparganium ramosum was fairly rapid so that the plots required to be roded in the normal manner in the autumn. Where short plots without dams were treated control was poor. This was thought to be due to dilution of the chemical.

Simazine, Atrazine and Trietazine

These were applied on 26th May, 1959 at 20 lb/ac. In marshy-bottomed dykes atrazine was more rapid in its action than simazine. Both gave a complete top kill of a wide range of species and a good control was still evident 16 months later. Typha latifolia was well controlled by atrazine but not by the other two triazines. Trietazine was not effective in marshy conditions. Only atrazine was tested in standing water where it was found to be ineffective.

"Monax" and "Chlorea"

These pelleted "Complete" weedkiller mixtures were applied at up to 2 cwt/ac (giving 10 lb monuron/ac besides other chemicals). Applied on 26th May "Chlorea" gave a very good control (for at least 16 months) of Typha latifolia in a marshy bottomed dyke while "Monax" was less satisfactory. "Monax" was quite ineffective in standing water.

Pelleted 2,4-D

All were tested at 30 lb/ac. No real comparison was made between them, the main reason for using the different formulations being their availability. All were described as being slow release formulations and it was thought that the chemical might be taken up directly by the roots with negligible release into the water and consequently no risk in water use.

The first applications were made on 26th May, 1959 in a marshy dyke and in standing water with a dam at one end of the plot. Although effects were slow in comparison with acrolein the water application gave a very good control of Alisma and Sparganium and markedly reduced the growth of submerged species. In marshy conditions the treatment was ineffective. Several further applications were made in standing water, without dams to control water flow, with no apparent effect on the weeds. At the time this was thought to be due to the lateness of application.

Due to the first excellent results in standing water more extensive testing was planned for 1960. The plan was to compare monthly applications beginning in mid March (2 dykes) and study the effects of the material in contrasting dyke conditions (3 widespread sites). By 20th May only very minor effects of treatment could be discerned and the only possible explanation seemed to lie in the loss of the chemical in the water. Work elsewhere (Chancellor 1960) with 2,4-D pellets, without dams, was reported to be equally unpromising. A comparison was then made in dammed plots of two types of 2,4-D pellets and a spray application, on 31st May. All treatments were very effective, the spray being slightly quicker and affecting Carex sp. in addition to the species controlled by the pellet formulations. It was subsequently observed in a non-dammed dyke that a late May application caused distortion of Alisma to a gradually reducing extent for 150 yd "downstream" and only 20 yd upstream from the treated area, the rate of water flow being imperceptible.

On 8th August 2,4-D pellets were applied, at Manea, in a ½ mile of *Alisma*-infested dyke which was sealed off at the pipes under bridges. Nevertheless an appreciable water flow was observed ten days later, following heavy rains. Effects on *Alisma* were very apparent at that date and by 20th September it was clear that a very good control had been obtained of both *Alisma* and *Sparganium*, although it was thought that earlier application would have been better. Samples of water were taken from this dyke on 18th and 23rd August and tested for presence of 2,4-D by the Went pea test. These showed a slight but positive reaction. No reaction was observed on a sample taken on 29th August.

On 18th August about a ½ mile of dyke was treated with 2,4-D pellets at Wormegay in Norfolk. The dyke was blind at one end and constricted at the other so that water flow could be expected to be very limited. A Went pea test on a water sample taken on 29th August was more clearly positive than any obtained at Manea. On that date it was clear that the *Callitriche* sp. was markedly affected, the leaves being curled though still fairly green. By 20th September practically all the *Callitriche* was dead and *Alisma* and *Sparganium* were dead or dying. Only *Potamogeton natans* appeared to be unaffected.

Both long stretches of dyke were treated at the request of the farmers.

Details of species controlled by the different treatments are given in Table I.

DISCUSSION

The maintenance of free water-flow in dykes is directly related to weed growth. Weed clearance is laborious and costly and during the time of maximum growth, dykes may be so clogged that there may be a danger of flooding should heavy storms occur. The general problems of chemical control have, however, been fully discussed previously (Dadd 1953). The particular value of acrolein would seem to be its ability to give a rapid kill of aquatic vegetation but the difficulty of applying it and the danger to fish suggest that it is unlikely to be used on a wide scale. In any case it would require to be handled by a trained operator. Acrolein compares unfavourably with 2,4-D pellets so far as persistency of control is concerned. While those chemicals giving total weed control may have an occasional place on the farm, the rates necessary are heavy and a danger to crops could arise when dykes were dragged out. Of those tested, atrazine would seem most effective. 2,4-D pellets were, by comparison, with acrolein, rather slow acting. Circumstantial evidence suggests that 2,4-D acted directly through water solution and not through the roots as had been supposed. This raises the question whether it would not be better to apply 2,4-D as a spray which would be more effective on emerged species than the pellet formulation. Sprays so far have not been accepted for this work due largely to a lack of suitable equipment, the difficulties of access, danger of drift onto adjoining crops and the general dangers to other water users of 2,4-D in solution. Pellets applied by hand are very convenient by comparison. It is possible that the slowness of the 2,4-D release from the pellets might greatly reduce the danger from this chemical to other users of the water as its concentration in the water would be very low by comparison although present over a long period. On the other hand quick release would give better control where there was appreciable water movement.

It is obvious that careful investigation of the risks of water contamination must be made before the material can be recommended for farm use, particularly in areas where dyke water is used for irrigation. On a cost basis (approx 2s 0d per chain 4 ft wide) 2,4-D pellets compete very favourably with other methods of control, especially since some species may be controlled for 16 months or more.

Acknowledgements

Grateful thanks are due to the farmers in whose dykes the work was done; also for advice received from the Great Ouse River Board. Thanks are also due to the suppliers of the chemical formulations.

The extensive help received from Mr. R. J. Chancellor and colleagues in the N.A.A.S., particularly Mr. C. V. Dadd, is gratefully acknowledged.

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A PROGRESS REPORT ON THE DEVELOPMENT OF AQUATIC WEED CONTROL

F. R. Stovell

Shell Chemical Co. Ltd.

Summary: The report describes five trials with an acrolein formulation (EF 1015) and three trials with 2,4-D pellets for the control of submerged aquatic weeds, carried out during 1959 and 1960. A method of using EF 1015 in static water is described and the danger to fish is discussed. This is thought to be inversely proportional to the opportunities for the fish to move to untreated waters. Resin-based 2,4-D pellets of very low toxicity to fish are described. Their use is effective in static and slow moving water but may provide hazards, which are at present being investigated, if this is used for crop irrigation.

INTRODUCTION

The River Boards and other authorities are already well equipped with weed cutting boats for dealing with the problem of aquatic weeds in navigable channels but the small water courses, which are of vital importance in land drainage, present a more difficult task, the major part of which must be carried out by hand. The figure of £850,000 has been mentioned (Spalding 1958) as spent by water boards alone annually, on hand clearing ditches, so bearing in mind the advance in chemical weed control over the last decade, it was only natural that those concerned with the control of aquatic weeds should turn to chemicals for assistance in this work. Emergent species may be tackled relatively easily by means of a spray application to the aerial shoots, but the principal restriction to water flow is caused by submerged weeds. The majority of these submerged species are relatively simple organisms and susceptible to chemicals used for terrestrial weed control. The problem lies in the method of treatment and the selection of most suitable material. Two possible candidate materials have been considered, the acrolein based herbicide (F.98) (Van Overbeek 1958) and a granular formulation based on 2,4-D. The acrolein based herbicide seemed promising because of its rapid action and particular effectiveness against algae while the granules seemed to offer a simple method of application.

PART I. ACROLEIN HERBICIDE FORMULATION EF.1015

Results from the U.S.A. indicated that, in stagnant water, five ppm was sufficient at 70°F to control weeds and that the dose must be doubled for each 10° fall in temperature. Trials to confirm this for the lower temperatures usually obtaining in the United Kingdom were carried out in 1959 and are reported elsewhere (Proctor 1960). In these trials acrolein (F.98) was injected beneath the surface in small doses of 5 - 10 ml at intervals calculated to produce the required concentration. The doses were accurately measured and introduced by a special metering device, the operator carrying a small can of acrolein on his back. The water was agitated to ensure adequate mixing of the herbicide.

The results from the initial trials were variable. The control was less satisfactory where the shallowness of the stream, or the quantity of emerged weeds made agitation difficult. Further work was carried out on the formulation to improve the rapidity with which was dispersed in the water, this was given the number EF.1015. On the applicator the flexible outlet was changed for a semi-rigid one terminating in a fan jet to assist further in dispersing the toxicant. The connections to the drum were also improved.

These modifications were tested but owing to the advancing season application was difficult due to the presence of flowering heads of *Alisma*. The results of this trial were disappointing, but it was decided to repeat the work.

METHODS, MATERIALS AND RESULTS

A series of plots were treated at Stalham, Norfolk, on August 26th 1959.

Water Temperature: 67 - 68°F.

Site: Dyke 12 ft wide 15 in. deep. Dammed to prevent movement.

Treatments: Acrolein at 10, 7½ and 5 ppm.

Plot lengths: 30 to 50 yd half plots only agitated

Weeds Present: *Myriophyllum* sp. *Callitriche* sp. *Chara* sp. algae, *Lemna minor*, *Lemna trisulca*, *Elodea canadensis*, *Potamogeton natans* and *Alisma plantago-aquatica*.

Weeds mainly submerged, some flowering heads of *Alisma* present.

Observations:

Treatment 26.8.60	5 ppm	7½ ppm	10 ppm
4.9.60	All effect much slower. *Lemna* and algea still present, but both brown. Agitated and unagitated plots the same	Good control but not so much collapse as 10 ppm. Some *Alisma* still emerged.	No weeds above surface but plenty of dead weeds collapsing beneath the water which was clearing. Agitated and unagitated plots equal.
16.9.60	Water now clear. No weeds above surface. Decomposing weeds below surface.	Some patches of algae 2-3" diameter present. Pinkish-white in appearance. Patches possibly larger in unagitated plot. Dead weeds visible under water.	Water still clear. Few decomposed weeds visible.
19.10.60	Some leaves of *Alisma* being produced.	Algae patches disappeared. Plot weed free.	Still clear of all growth.

No significant difference could be seen between the plots agitated and those not agitated except for 7½ ppm plot on September 16th. Some difficulty was experienced in treating this plot owing to emerged heads of *Alisma*.

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A further trial with improved apparatus was laid down at Stalham on July 11th 1960.

Water Temperature: 60°F

Site: Dyke 12 ft wide 9 in. deep. No damming and possibly slight flow occurred.

Weeds present: Myriophyllum sp., Alisma plantago-aquatica, Callitriche sp., Elodea canadensis, Lemna minor, Sparganium sp. and Potamogeton natans.

Treatments: Acrolein 10 ppm

Observations:

	I	II	III
Treatment 11.7.60	From one side with agitation	From one side without agitation	5 ppm from each side without agitation.
Observations 3.8.60	Some Callitriche still present but over 90 per cent weed control. Bottom clearly visible.	Some Potamogeton still present but control over 90 per cent	Myriophyllum, Potamogeton, and Callitriche disintegrating. Bottom clearly visible.

By August 3rd any differences between the effects of these treatments would have evened out and the slight variations recorded are likely to be due to the distribution of the original weed population.

At the same time another plot 6 in. deep was treated without agitation in a smaller dyke. This showed 90 per cent control of species present, Potamageton natans, Callitriche sp. and Lemna minor.

Two further bankside applications were made in 1960 with the co-operation of the Essex River Board.

Site: Tillingham 22 ft wide average depth 18 in.

Water Temperature: 60°F

Weeds: Potamogeton pectinatus, Enteromorpha intestinalis

Treatments: 10 ppm acrolein, water agitated and static.

Observations:

Treatment 22.7.60	(i) agitated	(ii) not agitated
3.8.60	Weeds dying, but not disintegrated. Algae well controlled	Not quite as good as (i) but since it was upstream (i) may have had the benefit of some of (ii)'s treatment. Algae well controlled.
15.8.60	Weeds now disintegrating. Some algae present having drifted down from upstream.	No difference now between plots.

Site: Marsh House. A much narrow stream 6 ft wide varying from 6 in. to 12. depth.
Water: Temperature 67°F

Weed: pure stand of Potamogeton pectinatus Very thick

Treatment: 15.9.60 10 ppm acrolein, agitated and not agitated.

Application was made about noon with very little water flow but 12 hours of rain fell from 6 p.m. onwards and the rate of flow increased rapidly.

Observations 5.10.60: About 50 per cent kill of foliage obtained. The surfaces of the plants were scorched but thick clumps were not penetrated. This poor result is probably due to the short exposure of acrolein due to rain.

To examine the effect in large masses of water, part of the lake at Hamptworth, Hants was treated from a punt. The acrolein (EF 1015) was released in a steady flow controlled by a constant head device. The boat traversed a series of parallel courses 15 ft apart marked by canes in the lake bed. The application was made on 21.6.60 in water of an average depth of 3 ft and a temperature of 65°F. One half of an acre was treated.

Weeds Present: Potamogeton pectinatus, Elodea canadensis. The weeds were growing up to the surface of the water.

Observations, July 6th; Weed growth had collapsed and sunk in the treated water, the bottom being visible in bright sunlight. No dead fish were found though a local bailiff had kept a constant watch.

DISCUSSION

As a result of these trials it was confirmed that a 10 ppm concentrate of acrolein in water at a temperature of 60°F controlled Callitriche sp., Chara sp., Elodea canadensis, Myriophyllum sp., Potamageton pectinatus, Potamageton natans. (submerged species) Alisma plantago-aquatica, large plants of Hippuris vulgaris and Sparganium sp. (emerged species).

In general the reaction of weeds to acrolein was fairly rapid. Stems of emerged plants rotted below water and subsequently collapsed. The leaves of Alisma bronzed, all the floating leaves of Potamogeton natans became brown, while Chara turned almost completely straw coloured in one or two days. Callitriche sp. browned much more quickly. Other submerged species showed no obvious signs of dying although they disintegrated completely by the end of 14 days. The effect of acrolein is to kill back the stems and foliage and its action, which has been described as a "chemical cutting", is extremely effective, because it is so complete. If necessary treatment can easily be repeated.

The most widely published property of acrolein is its irritant vapour which, while this makes the chemical difficult to use, has the advantage that its presence can be detected in very small quantities, far smaller than would constitute any toxic hazard. Similarly, though very toxic to fish (LD 50 for Harlequins being 0.14 ppm for 24 hours) (Alabaster 1960) if they can escape they will. In experiments in a dammed dyke thought to be free of fish an occasional eel was found killed, yet where about 1/8th of the area of a lake was treated at one time, no dead fish were seen though it was known to be well stocked with

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fish. The weed control indicated that very little movement of the acrolein occurred outside the treated water.

A simple test for the presence of acrolein is the rapid discolouring of potassium permanganate. Two drops of an 0.5 per cent solution of potassium permanganate in 10 ml of water are decolourised in less than one minute where more than 1 of acrolein is present. However, this test needs to be interpreted with care as decaying organic matter also causes the discolouration of the water. Cases have occurred where the reaction was negative to acrolein a few days after application yet later became increasingly positive due to the presence of organic matter in the water.

Thus it appears that given special circumstances, which must include the absence of fish or adequate opportunity for their escape, acrolein provides a rapid and effective means of clearing water channels of submerged weeds and algae in a manner least likely to cause blockages to pump inlets and sluices. While normally all traces of chemical are broken down within 48 hours, it can easily be detected both in the air and in the water by means of a simple test. This product should only be applied by trained operators.

PART II. GRANULAR 2, 4-D FORMULATIONS

The investigation of granulated weedkillers followed reports of their successful use in the U.S.A. (Grigsby and Smith 1958). Two formulations were tested, one clay, the other in a resin compound to produce a slow release of toxicants.

METHODS, MATERIALS AND RESULTS

Site: Stalham

Materials: 6 per cent 2, 4-D clay pellets. 80 per cent resin-based 2, 4-D pellets

Treatments: Clay pellets applied 26th August, 1959 to give 30 lb.ae/ac. Resin pellets applied 4th September to give 30 lb ae/ac.

Weeds present: Myriophyllum sp., Alisma plantago-aquatica, Callitriche sp., Chara sp., Elodea canadensis, Lemna minor and Algae.

Observations:

Treatments	Clay Pellets	Resin Pellets
16.9.59	Most weeds turning brown. Potamogeton and Alisma showing greatest effect.	Slight browning of weeds on plots treated with resin pellets.
19.10.59	Some regrowth of Callitriche	No regrowth. All weeds dead

The question of formulation was re-considered before work started in 1960. From field observations, it was decided that a granular formulation should have the following characteristics.

1. Good carrying properties to enable application to be made to wide water channels and in moderate wind speeds.

2. Freedom from dust to avoid possible damage to susceptible crops.

3. Slow release of toxicant into the water or mud, so that the concentration which might escape is as low as possible and so that some degree of persistence can be obtained.

While clay pellets could be produced to meet requirement 1, they failed requirement 2 as they rapidly became dusty when the bags were handled. A suitable resin-based formulation EF 1223 was produced which appeared to fulfil all three requirements. This formulation also possessed the additional advantage that when tested by the Freshwater Fish Laboratory it was 6½ times safer than clay pellets to fish, which themselves did not present a hazard. The product contains 80 per cent 2, 4-D and the pellets are uniform, free from dust and about 3 mm in diameter, when applied at 20 lb ae/ac the pellets are less than 3 in. apart. This high concentration would enable the operator to treat 13/8th of a mile of dyke 6 ft wide with a single 28 lb pack of product, using a fiddle drill to distribute the granules.

Further applications were made at Stalham on 11th July, 1960, Three areas were treated with 2,4-D resin pellets.

Dose	Weeds	Observations
20 lb a e/ac.	Myriophyllum sp., Potamageton sp., Callitriche sp., Sparganium sp.	3rd August. Partial control Some Myriophyllum persisting.
30 lb a e/ac.	Myriophyllum sp., Sparganium sp., Potamogeton sp., Callitriche sp.,	Good control of all species.
30 lb a e/ac	Potamageton sp., Callitriche sp., Elodea canadensis.	Some Callitriche and Potamogeton persisting.

A further site at Ashby Folville, Leics. was treated on 2nd August.

Weeds Present: Callitriche sp., Alisma plantago-aquatica, Potamogeton natans, Lemna minor.

Observations: 11th September. Considerable flow had occurred yet 80 per cent of weeds had been controlled. There was no effect on Lemna minor though this may have come down from upstream.

DISCUSSION

Rainfall during the season of 1960 was much higher than in 1959, and it appeared that the water flow through the dyke was affecting action of the chemicals. American workers had hinted that no 2,4-D was released into the water and Chancellor could find no trace of 2,4-D in water that had stood over pellets for 8 days yet the same formulations of pellets failed to work under conditions of flowing water in 1960 (Chancellor). It is possible that the action of the water on the pellets may be affected by its pH but it appears that the main route for the toxicant is through the leaves and not via the mud and roots as was originally supposed. Thus the action of the pellets was to produce a local solution of 2,4-D. Assuming immediate release of all the chemical, with no loss by absorption or by breakdown, the strength of a solution in a dyke only 6 in. deep would be approximately 14.5 ppm. In practice the release only occurs slowly and there will be losses by absorption and breakdown so that the concentration will be considerably lower. However, more work must be done on the rates of release and absorption to determine the risk from using this water for irrigation, though on a farm it would be possible to damp up ditches temporarily for treatment to prevent any escape of contaminated water. It appears that while 2,4-D pellets show considerable promise for the treatment of some species of aquatic weeds in stagnant water, the likelihood of the method working in flowing waters is much less, decreasing with increasing rate of flow. In all cases use of the water must be borne in mind.

Acknowledgements

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Discussion of papers on water weeds.

Mr. G. B. Lush It would seem to me that one of the problems of this type of weed control is the fate of the weedkiller further down the watercourse. I would be interested to hear what experiences any of the speakers have had on what happens further downstream where a farmer wishes to irrigate his land or to use the water for cattle. What precautions should be taken?

Mr. J. Proctor This is a very important aspect. We have no information ourselves. It must be investigated before we can use certain of these herbicides on a large seale.

Mr. Spalding (Chairman) In quite a number of sites where weeds are present, there is no 'downstream', in fact the water is stagnat. For instance, the Romney Marsh is dammed up during the summer and it is only in the event of a sudden flood that there is downstream movement of water.

Mr. G. B. Lush In was the Fenland areas, where Mr. Proctor has been operating, that I was thinking about in particular.

Dr. van der Weij In Holland we have very strict regulations for the use of herbicides in waterways. For example, we prohibit the use of herbicides in waterways flowing through horticultural districts where the water might be used for making up sprays or for overhead irrigation. These aspects are discussed more fully in my paper but there is not time to discuss them here in detail.

Mr. R. E. Longmate When spraying waterways with weedkillers, would it not be an advantage if some colouring agent could be added to such chemicals as dalapon? It would then be possible to see just where the chemical has gone? Is a colouring agent added in Holland and if so which is the agent used?

Dr. van der Weij In Holland we have never had any need for such a thing. It is important to use good equipment and we have no difficulty when using such equipment.

Dr. K. Holly We have seen in Mr. Chancellor's paper that many very important emergent weeds can be controlled by the use of dalapon, leaving a population of small resistant herbs. Are these populations of small herbs successful in preventing re-invasion by the weeds that have been controlled? Do we know what the ideal bank-side vegetation should be for keeping out emergent weeds on the borders of waterways? Should one aim to improve the grass population or something else?

Mr. R. J. Chancellor There is no precise answer. The ultimate vegetation is not known, as our experiments have been under way for only two or three years. The grasses are reduced by the use of dalapon and small herbs and dicotyledoneus weeds take their place, but whether they persist as a stable community or not is unknown.

Dr. van der Weij In canals used for navigation it may be important to have a border of weeds to maintain the ditch/banks and in that case it might be better simply to check their growth. We would leave about 1 m of weeds along the banks under these circumstances.

Mr. Spalding (Chairman) From an engineering point of view the vegetation should be all roots and no top growth.

Dr. J. K. Leasure We are doing a considerable amount of work on the control of aquatic weeds. We use dalapon for the emergent weed. For the control of submerged weeds, in ponds of up to 100 acres, silvex (2,4,5-TP) is now widely used. We have had good results up to 2 years later. We have found that slightly acid or neutral waters give the best results.

Mr. J. R. Sterry Dr. Leasure says that he is using dalapon, but other people are using other things! Regarding the use of dyes with spray materials, we have known applicators demand dye materials, both oil-soluble and water-soluble, but after the first day of spraying the applicators have gone home covered in red and the demand has subsided. Have any of the speakers found any difference in rates of application of chemicals needed for emergent water weeds that are growing on dry land, or for example the ditch bank, and for those with their roots actually in the water?

Dr. van der Weij We have no conclusive results but we got the impression that on marshy soils and under water Glyceria is more susceptible to dalapon treatment.

Mr. Chancellor When I started this work, from reading the literature it appeared that weeds growing in water were less susceptible: but our results show no conclusive evidence either way.

Dr van der Zweep There is one general observation I would make. When Glyceria is growing in willow plantations, our general experience has been that it is easier to control in this situation than when it is growing in water. The willow is used for dam protection.

Mr. J. Proctor Where we have used dalapon at 15 lb/ac on reeds (Phragmites) we apparently have obtained better control than some people are getting in water. We have obtained an excellent control for at least 2 years.

Dr. van der Weij I might add something that I believe I omitted from my lecture and that is the effect of volume of spray on the efficiency of dalapon. In past years rather high doses of dalapon were used - 40 to 50 lb/ac. We have now found that 15 lb/ac is satisfactory.

Formerly in Holland it was considered advisable to spray at 1,000 l/ha or about 100 gal/ac but now we never use more than 30 gal/ac. This is because we are using a wetting agent and the higher volumes result in run-off. The film on the leaves should not be too thick. Where vegetation is dense it is necessary to use more water and also a high pressure in order that the spray will penetrate into the vegetation. There is another important matter, namely the time of application; you may be applying dalapon too early in the year. You will kill parts above the soil but will get regrowth from the treated rhizomes and it might be that this is one of the causes of your inconsistent results. I have got the impression that you do not know the best way to spray.

Mr M. V. Grant I wonder whether any of the speakers have any advice to give on the control of Equisetum in clay-lined lakes. We are finding in Oxfordshire the weed is causing the lining to break up and resulting in excessive loss of the water.

Dr. van der Weij Equisetum can be controlled by low doses of MCPA but you will have to repeat the treatment several times to get rid of the weed entirely.

SESSION X

CHAIRMAN - Dr. E. K. WOODFORD

NEW HERBICIDES AND TECHNIQUES

AN ASSESSMENT OF THE NEW HERBICIDE 2,6-DICHLOROBENZONITRILE

G. E. Barnsley

"Shell" Research Ltd., Woodstock Agricultural Research Centre

Summary: Initial screening work was carried out in the laboratory, glasshouse and field in 1959 and 1960 to define the spectrum of activity of 2,6-dichlorobenzonitrile, the herbicidal properties of which were independently discovered at the Woodstock Agricultural Research Centre in the U.K. and by Phillips Duphar in the Netherlands.

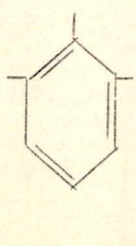
The compound's outstanding biological feature is its very high toxicity to seeds and to buds generally, and it shows, by virtue of this activity, considerable promise for the control of a wide range of annual and perennial weeds, including grasses and broad leaved species. Several important woody crops showed considerable tolerance of the compound, but otherwise 2,6-DBN has no wide selectivity. Its use in herbaceous crops will depend on the exploitation of its relatively short persistence and low water solubility. Persistence was substantially influenced by method of application and by the formulation used. Incorporation into the soil by cultivation, drenching by irrigation, or rain fall after spraying increased the persistence, and 2,6-DBN was more persistent when applied as a granule than as a spray.

INTRODUCTION

The herbicidal activity of 2,6-dichlorobenzonitrile has been recorded by Koopman (1960), Hagood (1959), and Alley (1960). Prior to these publications the present author and colleagues, investigating the phytotoxic properties of aromatic nitriles, independently discovered this highly active compound, and a detailed paper is in the press (Barnsley and Rosher) recording two years study of some of its more important properties. However, no account has yet been published of the compound's general spectrum of herbicidal activity and this is attempted in the present paper. Exploratory screening experiments are described to illustrate the potential scope of this new herbicide and factors which seem likely to influence its performance significantly.

METHODS AND MATERIALS

2,6-Dichlorobenzonitrile (2,6-DNB) has the structure.



The pure material is a white crystalline solid with a M.P. of 142°C, a vapour pressure of 5×10^{-4} mm Hg at 25°C (determined by Effusometer) and a water solubility of approximately 20 ppm at 25°C. The compound is appreciably volatile, and the 'half life' of a fine deposit on glass with an air flow of 0.5 l/min in an oven of volume 100 l was two days 40°C and fourteen days at 25°C. Its acute oral toxicity to rats is >1000 mg/Kg.

The material used in the present experiments contained not less than 95 per cent of 2,6-DBN. Doses quoted are of 100 per cent 2,6-DBN.

Laboratory experiments

In the seed germination experiment no. 1/59, 2,6-DBN was applied in acetone to 11 cm diameter germination pads in petri dishes. After allowing the solvent to evaporate 15 ml of distilled water were added, 50 seeds placed on each pad, and the dishes incubated at 25°C. The length of shoots was measured after five days.

The exposure of crop seeds to the vapour of 2,6-DBN in experiment no. 4/49, was carried out in two 10 l bell jars each containing uniform volumes of the various seeds separately contained in open petri dishes. Air was drawn through each jar at 0.5 l/min via a 9 in. length of 2 in. diameter glass tubing containing cotton wool, half of which was impregnated either with 10 gm of 6 per cent dust of 2,6-DBN or filler alone. The remainder of the cotton wool served as a filter to prevent solid particles passing out of the tube. The jars were held at 20°C for twenty days, a sample of each crop seed removed, washed in running tap water for one hour and then germinated in pots in the glasshouse.

Glasshouse experiments

In the *Salvinia* experiment no. 6/60, five plants each bearing four fronds were placed in nutrient medium with varying concentrations of 2,6-DBN. After four days, two plants from each treatment were washed in distilled water and placed in fresh culture medium free from 2,6-DBN. They were kept for ten days for an estimate of recovery to be made.

In the remaining glasshouse experiments 2,6-DBN and simazine were used as aqueous suspensions derived from a 50 per cent wettable powder. Compounds were applied either by a micrologarithmic sprayer in a volume corresponding to 50 gal/ac or as a drench at the rate of 15 ml or 30 ml per 3½ in. or 5 in. diameter pot respectively.

In all glasshouse tests, seeds were germinated and plants raised in 3½ in. or 5 in. polyvinyl pots with sterile John Innes No. 1 potting medium, except in experiment no. 3/60 in which the pre-emergence tests were carried out in 3 in. x 9 in. x 14 in. polyvinyl seed trays. The pre and post-emergence toxicity of 2,6-DBN to the crop test plants was estimated by determining the fresh weight of shoots seven to ten days after treatment, and also by germination counts in experiment no. 2/59.

The rhizomes of *Agropyron repens* and *Aegopodium podagraria* used in the glasshouse experiments, nos. 7/59 and 8/59, were obtained from dormant pure stands in a weed garden. Five sections with 1 - 3 buds on each were cut and planted 2 - 3 in. deep in John Innes No. 1 potting medium in 5 in. pots which were then transferred to the glasshouse and the compounds applied. Subsequent growth was recorded as fresh weight of shoots of Agropyron, or dry weight of roots and rhizomes in the case of Aegopodium.

In the persistence experiment no. 12/60, air dry John Innes potting medium in 5 in. pots was sprayed with 2,6-DBN and kept in the glasshouse until the appropriate time when 50 mustard seeds were sown on the surface of the soil, covered with $\frac{1}{4}$ in. of fine silver sand, and then watered by subirrigation as required until the end of the experiment.

Field experiments

All experiments were conducted at Woodstock in Kent on a Brick Earth Loam soil in 1959 and 1960. 2,6-DBN and simazine were sprayed as aqueous suspensions derived from a 50 per cent wettable powder, and the nitrile was also applied in the form of a $2\frac{1}{2}$ per cent granule in experiment nos. 13/60 and 14/60. Spraying was carried out with an Oxford precision Knapsack Sprayer at the volume of 50 or 100 gal/ac. Treatments were applied to single plots only, and these were separated by discards of the same size.

Experiment no. 5/59 (potato sprout inhibition)

One cwt quantities of tubers (var. Bintje) were spread out and dusted with 100 gm of filler containing 0.25 to 5.0 gm of either 2,6-DBN or 2,3,5,6-tetrachloro-1-nitrobenzene (TCNB). The potatoes were then stored in hessian sacks in a farm building from November until January, when a 10 lb sample of tubers was obtained from each sack and the fresh weight of sprouts recorded.

Experiment no. 9/59 (herbaceous crops treated pre-emergence)

All the test crops were drilled except ryegrass which was broadcast. The plot size per dose level was 1/100 ac. Spraying was carried out as soon as possible after sowing on 4.7.59., and followed by an overhead application of about $\frac{1}{4}$ in. of water from a line irrigator. Emergence was assessed by counts of seedlings in 3 x 12 ft rows of French bean and sweet corn, 9 x 12 in. random row lengths in radish, oat, rice and sugar beet, and in 10 x 6 in. x 6 in. quadrat areas in ryegrass.

To assess the long term persistence of 2,6-DBN this experimental area was ploughed to a depth of 7 in. in March 1960 and drilled with Blenda oats. The yields subsequently obtained were based on total weight of sheaves from 1/300 ac plots i.e. from the centre one third of the original sprayed plot.

Experiment no. 10/60 (herbaceous crops treated post-emergence)

Tomatoes, leeks, celeriac, sweet corn, and cabbage were established by transplanting and the remaining crops by drilling seeds in situ. Plots 1/80 ac in size were sprayed on 13.7.59., when the crops were at the stages of growth indicated in Table XII, and then watered by overhead irrigation as in the previous experiment. All crops except the onions and leeks were weed-free when sprayed and were subsequently kept clean by hand weeding until harvested. The first weeding in the onions and leeks, one month after spraying was timed to obtain an estimate of post-emergence weed control. Yields of the various crops were estimated by recording the total number and fresh weight of plants, either in part or whole, on 1/135 ac plots.

Experiment no. 13/60 (gooseberries)

Plots 1/135 ac in size, with six eight year old bushes (varieties Careless or Leveller) were treated on 28.4.60. Sprays containing simazine or 2,6-DBN were applied over and between bushes, and the granule formulation of the nitrile uniformly over the plot. Weed cover at the time of spraying was about 75 per cent, and the dominate species were Stellaria media, Cirsium arvense, Poa annua, and Veronica sp. No subsequent hand weeding was carried out, but one series of plots was rotovated once to a depth of approximately 3 in. the day after application of the chemicals. Weed cover was estimated nine weeks after treatment by means of a 50 x 50 cm^2 grid quadrat. Yield of fruit per plot (i.e. six bushes) was recorded.

Experiment no. 14/60 (blackcurrants)

Plots 1/135 ac in size with six, three year old bushes (two of each of the varieties Baldwin Hilltop, Boskoop Giant, and Wellington XXX) were treated on 28.4.60. Sprays containing 2,6-DBN were applied either over and between bushes, or under and between bushes. The 2,6-DBN granules were spread uniformly over the plots. These were weed free when treated, and were subsequently kept clean by hand weeding as required. One such weeding 13 weeks after treatment was timed to obtain an estimate of weed control. Yield of fruit per plot (i.e. six bushes) was recorded.

Determination of 2,6-DBN and simazine residues in soil

In the gooseberry and blackcurrant experiments soil samples were taken on all plots by means of 1.5 in. diameter corer, sufficient cores being taken to obtain 2 - 3 lb of soil per treatment. The soil samples were transferred to sealed tins and placed in a cold store until analysed.

The method for 2,6-DBN was to dry the soil by admixture with anhydrous sodium sulphate, extraction for two hours with redistilled n-hexane, followed by determination of the 2,6-DBN in the extracts by gas-liquid chromatography.

The method for simazine involved a modification of the one used by Birchfield and Storres (1956) for the determination of chloranilino triazines.

RESULTS

The toxicity of 2,6-DBN to seeds

The results in Tables I and II indicate that the toxicity of the compound to germinating seeds was of a very high order both in vitro and in soil; the margin of selectivity, however, being relatively narrow. 2,6-DBN was presumably imbibed in the solid phase and in solution in both experiments. In marked contrast, when unimbibed seeds were exposed to the vapour of 2,6-DBN considerable selectivity was observed (Table IV) the dicotyledon species being notably more tolerant then the monocotyledons.

Field data on the toxicity of 2,6-DBN to weed seeds, not presented here, have been obtained on some 30 species, both temperate and tropical. These results resemble those given for the cultivated species (Table IX) in that no wide range in selective toxicity was found. More than half the weeds succumbed to 1.0 lb/ac or less and none survived a dose of 3.0 lb/ac.

The toxicity of 2,6-DBN to other bud producing organs

The results in Tables V, VI, VII, and VIII indicate the high activity of 2,6-DBN in killing or inhibiting buds. Appreciable effects were obtained at very low dose levels e.g. 1.0 gm/ton and 1.0 ppm severely inhibited bud development in potatoes and *Salvinia* respectively.

As was expected from this activity as a bud inhibitor 2,6-DBN proved highly toxic to herbaceous perennial weeds (Tables VII and VIII) which propogate from bud producing organs such as stolons, rhizomes and tubers, when the compound was applied around the organs in the early stages of bud growth.

In the experiment with *Aegopodium podagraria* (Table VIII) not only was 2,6-DBN more toxic than simazine, but it killed the rhizome even at the lowest dose of 2.0 lb/ac while simazine failed to do so at the highest level of 16.0 lb/ac judging by healthy buds that were present on the rhizomes when these were examined four months after treatment.

A wide range of similar herbaceous perennial weeds has been found to be susceptible, including such important species as *Agrostis stolonifera*, *Pteridium aquilinum*, *Epilobium angustifolium*, and *Cirsium arvense*.

The toxicity of 2,6-DBN to plants

The compound was found to be generally less toxic to plants than to seeds (Table III) and bud producing organs, the level of toxicity being predominantly influenced by the age and morphology of the plant and whether applied to leaves or roots. Woody species appeared to be more tolerant than herbaceous plants, sensitivity to 2,6-DBN decreased rapidly with increasing maturity, and the compound evidently penetrated roots more readily than leaves. However, in experiments not reported here it was found that 2,6-DBN vapour readily enters leaves.

Seedling herbaceous plants wilt within a few hours of treatment when in active growth. Days later laminae become abnormally dark green in the interveinal areas whereas, leaf veins, petioles and stem become brown, spongy and necrotic frequently producing exudates. Root and shoot growth is rapidly inhibited and meristems also become grossly discoloured and necrotic.

In more mature herbaceous and woody plants symptoms are slower to appear, less acute or absent altogether. Additional effects such as acceleration of anthocyanin pigmentation in or abcission of leaves have been observed.

Crop plants (post-emergence)

The results of a field screen carried out in July - September 1959 are presented in Table XII. Carrot, sugar beet, and cabbage proved highly sensitive to 2,6-DBN and were severely damaged by 2 lb/ac or less. Leeks, onions, celeriac, tomato and sweet corn appeared to tolerate 3 lb/ac, a dose which gave useful post-emergence control of the weeds present in this experiment (Table X).

In the field screening tests carried out in soft fruit in 1960 (Tables XVII and XVIII) gooseberries and blackcurrants appeared to tolerate about

4.0 lb/ac of 2,6-DBN but the results also showed that formulation, method of application and subsequent soil cultivation influenced the tolerance level. Although fruit yield appeared to be depressed in some instances no other growth abnormalities were observed.

Weeds (post-emergence)

Applied as a soil drench 2,6-DBN was highly toxic to a wide range of seedling broad leaved weeds treated soon after emergence (Table XIII) and none of the 20 species survived a dose of 1.5 lb/ac. In the field, sprays required much higher doses to achieve comparable weed control. In experiment no. 9/59 (Table 10) 3.0 lb/ac followed by ½ in. of rainfall was highly effective, but 8.0 lb/ac in experiment no. 13/60 applied in drought was ineffective. In the latter experiment the granule form of 2,6-DBN was strikingly more effective than the spray, and this result is clearly attributable to the greater persistence of 2,6-DBN (Table XIX).

The persistence of 2,6-DBN

As might be expected from its appreciable vapour pressure 2,6-DBN is highly volatile. More than 20 experiments have been conducted, to determine the influence of volatility on the persistence and hence the herbicidal activity of 2,6-DBN using biological and chemical methods of assessment. Both methods have shown that when 2,6-DBN is sprayed onto soil without further incorporation by cultivation or rainfall, it has a 'half-life' of about two days under temperate conditions, (Table XIV) and a few hours in the tropics. In the U.K. the 'half life' can fall to <1day in the summer (Tables XV, XIX) and in the winter can extend to 5 - 10 days. The main difference between experiment nos. 13/60 and 14/60 was the presence of a substantial weed cover in the former. Comparison of spray residues in the two experiments suggests that the presence of such a soil cover, in the absence of rainfall soon after spraying, effectively reduces the soil residue of 2,6-DBN. The penetration of this canopy by the granule was observed in experiment no. 13/60 and this factor was no doubt partly responsible for the greater persistence and herbicidal activity obtained with this formulation.

If spraying was followed by a light overhead irrigation (Table IX) or cultivation (Table XV) persistence was greater. When temperatures were low and cultivation followed immediately, the persistence of 2,6-DBN was dramatically extended, and a 'half life' 50 days or more obtained. However, the results obtained in experiment no. 9/59 with oats, a sensitive indicator crop, (Table XI) suggest that the persistence of appreciable residues of 2,6-DBN for a year is unlikely with normal doses.

DISCUSSION

The toxicity of 2,6-DBN to germinating seeds is its outstanding biological characteristic and is of a very high order. In the case of oats (var.Blenda), a sensitive species, the LD 50 in petri dish germination is about 0.1 mg/kg of imbibed seed fresh weight. Such high toxicity is rare in the entire pesticide field, and indicates 2,6-DBN to be an exceedingly potent biocide.

Our work has indicated that 2,6-DBN is probably taken up by seeds both in aqueous solution and as a vapour, and suggests the possibility that lethal amounts of the herbicide can be absorbed onto or into dormant seed, or vegetative organs such as tubers and rhizomes. The most obvious potential of 2,6-DBN lies in exploiting these properties, which considered in the light of the relatively short persistence of the compound might provide a means of cleaning land of both annual and perennial weeds before cropping. 2,6-DBN could be the first economic, safe, wide spectrum phytosterilant, and find use in the U.K. in a chemical winter fallow, possibly the most logical and the cheapest time to fallow land.

Although 2,6-DBN shows some selective toxicity to seeds in vitro and in soil, we do not yet have any indication that this may be of a biochemical or physiological kind. The higher apparent tolerance of larger seeds, at least in soil, is likely to be due in part to greater planting depth resulting in a lower effective dose reaching the seed. If the compound penetrates into or is absorbed onto seeds, the dose per seed would be related to the ratio of seed volume/seed surface area. Assuming equal ease of penetration it might be that the larger seeds take up a lower dose on a weight or volume basis.

The effectiveness of 2,6-DBN applied post-emergence was of a lower order, and more variable. Conditions favouring uptake by roots, the predominant mode of entry, may be expected to give best results. No wide margin of selectivity was found in herbaceous abnuals. Where differences in depth of rooting and/or age of crop and weeds exist, as in experiment no. 10/59, useful selectivity may be obtained. In general it would seem that the post-emergence use of 2,6-DBN in herbaceous field crops may be limited, technically by the narrow margin of selectivity and economically by the rather high doses required for effective weed control.

The tolerance of 'woody' crops is, however, of a much higher order, and the prospects for 2,6-DBN in these appear promising. Preliminary tests indicate that in addition to gooseberries and blackcurrants reported here, apple, plum, citrus, cacao, vine, and numerous ornamental species appear to tolerate upwards of 4.0 lb/ac 2,6-DBN. However, it is considered that tests over several seasons are required with such crops, before safe rates of application can be determined.

The appreciable volatility of 2,6-DBN at normal temperatures is a highly significant factor influencing its penetration into and persistence on leaves, distribution and persistence in soil, and the effectiveness of different formulations. Since in practice 2,6-DBN is most active when applied to the soil and taken up by roots, its persistence in the soil largely determines the effective as distinct from the applied dose, and hence the herbicidal effect obtained and the subsequent permissible freedom of cropping. The indications are that relative to such compounds as simazine 2,6-DBN possesses a short persistence, and land should be safe to crop within a few weeks or months depending on the method of use. Because of its low water solubility and high rate of loss from soil surfaces the persistence of 2,6-DBN is increased rather than decreased by overhead irrigation, rainfall, or cultivation after spraying. From a large number of experiments not reported here it appears that the rate of loss by volatilisation can be decreased by a factor of four by cultivation.

Acknowledgements

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TABLE I. THE TOXICITY OF 2,6-DBN TO CROP SEEDS GERMINATING IN VITRO

(Lab. Exp. no. 1/59)

Concentration ppm	Length of shoot after five days at 25°C							
	mm				Percent reduction in length			
	M	L	B	O	M	L	B	O
2,500	4	3	2	0	83	96	95	100
1.000	6	5	3	0	75	93	92	100
0.500	10	7	7	0	58	90	82	100
0.250	14	30	18	4	42	58	57	71
0.100	24	53	23	6	0	25	45	57
0.050	27	67	31	5	-13	6	26	64
0.025	26	67	37	7	- 8	6	12	50
0.000	24	71	42	14	-	-	-	-

M = Mustard L = Linseed B = Barley O = Oats

TABLE II. THE TOXICITY OF 2,6-DBN TO CROP SEEDS GERMINATING IN STERILISED JOHN INNES COMPOST AT 20°C

(Glasshouse Exp. no. 2/59)

Crop	Dose reducing emergence by 50 per cent lb/ac	Reduction in fresh wt/ shoot of surviving plants at LD 50 per cent
Sweet corn	1.2	86
Peas	0.6	75
Mustard	0.3	3
Linseed	0.5	20
Barley	0.7	10
Wheat	0.5	32
Ryegrass	0.3	-
Oats	0.3	-

TABLE III. THE SPECTRUM OF PHYTOTOXICITY OF 2,6-DBN

(Glass house Exp. no. 3/60)

50 per cent Growth Inhibition Dose lb/ac																							
Seeds								Plants															
Pre-emergence								Post-emergence															
Soil spray								Foliar spray								Soil drench							
O	RG	SC	P	SB	L	K	M	O	RG	SC	P	SB	L	K	M	O	RG	SC	P	SB	L	K	M
< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.4	1.2	5.6	8.3	3.8	> 10.0	> 10.0	> 10.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	3.5	2.1

O = Oats, RG = perennial ryegrass, SC = Sweet corn, P = peas, SB = Sugar beet, L = Linseed, K = Kale, M = Mustard

TABLE IV. THE TOXICITY OF 2,6-DBN IN THE VAPOUR PHASE TO DORMANT UNIMBIBED SEEDS EXPOSED FOR 20 days

(Lab. Exp. no. 4/59)

Seed	Germination per cent			Inhibition of germination per cent	Seedling shoot fresh wt (gm)		
	Control		Treated		Control		Treated
Oats	75	**	0	100	0.15		-
Mustard	96	N.S.	94	2	0.14	N.S.	0.13
Barley	90	**	69	23	0.26	*	0.15
Per. ryegrass	73	*	6	83	0.01		-
Peas	99	N.S.	97	2	0.65	N.S.	0.69
Sunflower	84	N.S.	92	9	1.38	N.S.	1.39

N.S. = not significant
* = significant at 5 per cent level
** = significant at 1 per cent level

TABLE V. THE RELATIVE INHIBITION OF SPROUTING IN STORED POTATOES DUSTED WITH 2,6-DBN AND 2,3,5,6-TETRACHLORO-1-NITROBENZENE (TNCB)

(Field Exp. no. 5/59)

Material applied	Dose gm/ton of tubers	Fresh wt of sprouts (2) per 20 lb tubers (gm)
2,6-dichlorobenzo-nitrile	5 50 100	7 0 0
TCNB (1)	5 50 100	46 27 9
Blank dust formu-lation	0	42
Control	0	41

(1) Dosage recommended commercially 140 gm/ton.
(2) After three months storage.

TABLE VI. THE TOXICITY OF 2,6-DBN TO SALVINIA AURICULATA WHEN INCLUDED IN THE AQUEOUS NUTRIENT MEDIUM

(Glasshouse Exp. no. 6/60)

Concentration of 2,6-DBN in nutrient ppm	0.0	0.1	0.5	1.0	5.0	10.0	20.0
Frond number minus 4 (= original inoculum) after 13 days in nutrient with 2,6-DBN	68	43	6	0	0	0	0
Frond number of 2 plants, 4 days in nutrient with 2,6-DBN, followed by 10 days in pure nutrient	22	28	5	0	0	0	0
Bud development	++	++	+	+	-	-	-

++ Normal Bud development
+ small deformed buds
- no buds

TABLE VII. THE TOXICITY OF 2,6-DBN AND APPLIED AS A SOIL DRENCH TO THE BUDDED RHIZOME SECTIONS OF AGROPYRON REPENS

(Glasshouse Exp. no. 7/59)

Compound	Dose lb/ac	Shoot fesh wt gm/3 x 5 in. pots			Reduction in shoot wt per cent		
		A 1st cut	B 2nd cut	C 3rd cut	A 1st cut	B 2nd cut	C 3rd cut
2,6-dichloro-benzonitrile	0.1	37.3	34.7	24.7	9	-14	- 2
	0.2	21.0	18.3	21.5	48	40	11
	0.4	5.2	0.2	0.0	87	99	100
	0.8	1.8	0.0	0.0	96	100	100
Control	0.0	40.7	30.3	24.3	-	-	-

A, B, C, 4, 8, 14 weeks after spraying

TABLE VIII. THE RELATIVE TOXICITY OF 2,6-DBN AND SIMAZINE APPLIED AS SOIL DRENCHES TO BUDDED RHIZOME SECTIONS OF AEGOPODIUM PODAGRARIA

(Glasshouse Exp. no. 8/59)

Compound	Dose lb/ac	Dry wt* of roots and rhizomes gm/3 x 5 in. pots	Reduction in dry wt* roots and rhizomes, per cent
Simazine	2	11.1	75
	4	14.6	67
	6	13.4	70
	8	5.9	88
	12	3.7	92
	16	4.6	90
2,6-dichloro-benzonitrile	2	3.3	93
	4	4.4	91
	6	0.8	98
	8	0.5	99
	12	1.0	98
	16	2.7	94
	0	45.0	-

* harvested four months after treatment.

TABLE IX. THE TOXICITY OF 2.6-DBN TO CROP SEEDS IN THE FIELD SOWN UP TO 45 DAYS AFTER SPRAYING

(Field Exp. no. 9/59)

Initial Dose lb/ac	Period between spraying and sowing (days)	Reduction in germination per cent							
		French Bean	Radish	Sweet corn	Rice	Rye Grass	Oats	Carrot	Sugar Beet
0.5	0	28	43	21	-	100	68	100	100
	36	-	0	0	0	6	5	18	0
	45	0	0	0	-	0	0	4	0
1.0	0	15	77	27	-	100	83	100	100
	36	-	0	0	0	37	15	85	15
	45	0	0	0	-	0	0	48	0
2.0	0	63	84	63	-	100	100	100	100
	36	-	0	0	0	20	57	88	42
	45	0	0	0	-	0	0	70	16
3.0	0	61	100	69	-	100	100	100	100
	36	-	0	11	0	51	67	96	75
	45	0	0	0	-	0	0	100	63
6.0	0	100	100	66	-	100	100	100	100
	36	-	0	14	0	48	95	100	100
	45	0	0	0	-	0	37	100	96
8.0	0	100	100	66	-	100	100	100	100
	36	-	5	31	6	42	100	100	100
	45	0	0	0	-	15	81	100	100
12.0	0	100	100	83	-	100	100	100	100
	36	-	0	31	17	100	100	100	100
	45	0	0	0	-	53	89	100	100
16.0	0	100	100	100	-	100	100	100	100
	36	-	31	72	38	100	100	100	100
	45	0		0		58	91	100	100

- indicates not sown

TABLE X. WEED CONTROL ACHIEVED IN ONIONS AND LEEKS WITH 2,6-DBN APPLIED POST-EMERGENCE TO CROPS AND WEEDS

(Field Exp. no. 9/59)

Principal weeds	Dose lb/ac	Reduction in hoeing time per cent
Chenopodium album)	0.5	11
Solanum dulcamara)	1.0	41
Urtica urens)	2.0	68
Stellaria media)	3.0	87
	6.0	100

TABLE XI. THE YIELD OF BLENDA OATS SOWN 8 MONTHS AFTER APPLICATION OF 2,6-DBN TO THE SOIL

(Field Exp. no. 9/59)

Dose of 2,6-DBN applied July 1959 lb/ac	Yield of straw and grain in 1960 tons/ac	
	Treated plot	Adjacent discards (mean)
0.5	3.8	4.2
1.0	4.5	4.5
2.0	4.2	4.9
3.0	5.4	5.6
6.0	4.3	5.2
8.0	5.2	5.3
12.0	3.9	5.6
16.0	4.7	5.7

TABLE XIII. SUSCEPTIBILITY OF SEEDLING WEEDS TO 2,6-DBN (POST-EMERGENCE DRENCH APPLICATION IN POT EXPERIMENT)

(Glasshouse Exp. no. 11/59

Weed species	Dose lb/ac				
	0.25	0.5	1.0	1.5	3.0
Matricaria maritima	B	A	A	A	A
Polygonum persicaria	B	A	A	A	A
Veronica spp.	A	A	A	A	A
Geranium molle	D	D	A	A	A
Capsella bursa-pastoris	D	C	A	A	A
Achillea millefolium	A	A	A	A	A
Plantago media	A	A	A	A	A
Sonchus oleraceus	A	A	A	A	A
Prunella vulgaris	C	B	A	A	A
Taraxacum officinale	A	A	A	A	A
Chrysanthemum leucanthemum	C	A	A	A	A
Urtica urens	D	A	A	A	A
Chenopodium album	A	A	A	A	A
Sinapsis arvensis	C	C	A	A	A
Papaver rhoeas	C	C	A	A	A
Stellaria media	C	B	A	A	A
Polygonum convolvulus	C	C	C	B	A
Plantago major	A	A	A	A	A
Galium aparine	A	A	A	A	A
Raphanus raphanistrum	D	C	C	A	A

Abbreviations: A = Virtually 100 per cent kill.
B = 100 per cent kill, but unlikely to recover.
C = 100 per cent kill, but likely to recover.
D = No significant growth inhibition.

TABLE XII. THE EFFECT OF 2,6-DBN

(Field Exp.

Crop and stage of growth when sprayed	Percentage reduction in no. plants harvested										
	Dose of 2,6-DBN lb/ac										
	0	½	1	2	3	6	8	12	16	0	½
Leeks - 6 - 8 in.	-	15	3	9	6	9	9	12	16	7.3	6.5
Onions - 4 - 6 in.	-	8	0	6	0	5	40	36	78	8.1	8.6
Celeriac - 4 - 6 in.	-	0	0	0	0	0	20	33	60	6.8	8.0
Tomatoes - first truss set	-	0	0	0	0	0	0	0	0	16.3	19.0
Sugar beet - 4 - 6 in.	-	7	21	30	6	33	75	85	100	30.0	26.6
Carrots - 2 - 3 in.	-	30	41	66	100	100	100	100	100	14.0	8.4
Sweet corn - 18 - 24 ins.	-	0	0	0	0	0	0	33	77	20.2	19.3
Cabbage 6 - 8 in.	-	0	0	0	6	29	35	41	65	27.0	26.5
French bean - in flower	-	0	0	0	0	0	0	0	0	3.4	3.2

* French bean, tomato - fruit only
Celeriac, sugar beet, carrots - whole plants
Onions, leeks, sweet corn, cabbage - stem and leaf only

APPLIED POST-EMERGENCE ON CROP YIELDS

no. 10/59)

Yield*															
Dose of 2,6-DBN lb/ac															
tons/ac							Percentage reduction								
1	2	3	6	8	12	16	0	½	1	2	3	6	8	12	16
8.7	7.8	6.7	6.0	6.5	6.2	5.7	-	7	-10	8	15	10	9	15	14
11.5	9.9	12.4	7.3	3.1	5.1	1.8	-	3	-16	7	-23	-20	37	20	73
7.8	6.8	7.3	5.7	4.4	4.5	2.5	-	-18	-16	-1	- 8	16	31	33	63
19.5	16.8	16.8	12.9	13.6	9.9	12.0	-	-17	-20	-3	- 3	21	16	39	26
30.4	28.0	30.9	15.1	9.9	5.6	0.0	-	11	0	7	0	13	67	81	100
11.1	4.6	0.5	0.0	0.0	0.0	0.0	-	23	26	71	96	100	100	100	100
19.1	20.2	21.6	18.2	15.7	7.7	4.5	-	4	5	0	- 7	10	22	38	78
24.3	18.4	17.3	13.2	11.1	7.8	2.7	-	2	11	32	36	50	59	71	89
3.2	2.4	2.3	2.2	2.2	1.6	0.9	-	7	7	31	33	36	36	52	73

TABLE XIV. THE PERSISTENCE OF 2,6-DBN IN JOHN INNES POTTING MEDIUM MEASURED BY GERMINATION OF MUSTARD SEED

(Glasshouse Exp. no. 12/60)

Dose lb/ac	Fresh weight of emerged seedlings in 2 x 5 in pots					Reduction in fresh wt emerged seedlings per cent				
	Delay in sowing after spraying (days)									
	0	2	4	8	16	0	2	4	8	16
0.0625	0.4	15.5	15.2	21.3	19.5	98	13	13	- 7	12
0.125	0.2	4.3	9.2	27.3	27.6	99	77	47	-63	-23
0.250	0.0	0.7	0.6	18.7	25.7	100	96	66	6	-14
0.500	0.0	0.0	0.0	4.5	14.3	100	100	100	77	43
1.000	0.0	0.0	0.0	0.2	5.6	100	100	100	99	75
0.0	22.6	17.8	17.5	19.9	22.5					

TABLE XV. THE INFLUENCE OF FORMULATION AND POST TREATMENT CULTIVATION ON THE PERSISTENCE OF 2,6-DBN IN SOIL

(Field Exp. no. 13/60)

Compound	Dose lb/ac	Formulation	Soil Cultivation	Residue ppm in dry soil (0-3 in.) after (days)			
				1	15	29	65
2,6-DBN	4.0	50 per cent w.p.	-	0.3	0.2	0.1	0.1
	4.0		+	0.3	0.2	0.3	0.3
	8.0		-	0.3	0.2	0.1	0.1
	8.0		+	1.1	0.9	0.9	0.9
2,6-DBN	4.0	granule	-	2.0	0.3	0.6	0.1
	4.0		+	2.7	2.1	0.5	0.4
	8.0		-	7.3	0.3	0.6	0.2
	8.0		+	8.5	5.1	2.3	2.3
Simazine	4.0	50 per cent w.p.	-	-	2.7	3.6	1.4
	4.0		+	-	3.2	4.1	2.6
	8.0		-	-	5.1	5.6	2.1
	8.0		+	-	6.2	6.6	6.2

TABLE XVI. THE EFFECT OF SIMAZINE AND 2,6-DBN ON WEED COVER TREATED POST-EMERGENCE IN GOOSEBERRIES 9 WEEKS AFTER SPRAYING (VARIETIES LEVELLER AND CARELESS)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Percentage reduction in weed cover	
			Uncultivated	Cultivated (1 day after spraying)
2,6-DBN	spray	4.0	0	60
2,6-DBN	granule	4.0	36	99
Simazine	spray	4.0	94	94
2,6-DBN	spray	8.0	0	90
2,6-DBN	granule	8.0	73	100
Simazine	spray	8.0	98	100

TABLE XVII. THE EFFECT OF 2,6-DBN AND SIMAZINE ON THE YIELD OF GOOSEBERRIES (VARIETY LEVELLER)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Mean fruit yield (oz per bush)			
			Uncultivated		Cultivated (1 day after spraying)	
			Treated	Untreated	Treated	Untreated
2,6-DBN	spray	4.0	28	30	21	25
Simazine	spray	4.0	19		16	
2,6-DBN	granule	4.0	29		30	

TABLE XVIII. THE EFFECT OF 2,6-DBN AND SIMAZINE ON THE YIELD OF GOOSEBERRIES (VARIETY CARELESS)

(Field Exp. no. 13/60)

Herbicide	Formulation	Dose lb/ac	Mean fruit yield (oz per bush)			
			Uncultivated		Cultivated (1 day after spraying)	
			Treated	Untreated	Treated	Untreated
2,6-DBN	spray	8.0	8.7	9.3	7.5	7.0
Simazine	spray	8.0	11.0		5.0	
2,6-DBN	granule	8.0	8.6		10.0	

TABLE XIX. THE INFLUENCE OF FORMULATION ON THE PERSISTENCE OF 2,6-DBN IN SOIL

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Residue (ppm in dry soil) 0 - 3 in. after			
		1 day	6 days	15 days	49 days
spray	2.0	0.6	0.3	0.3	0.2
granule	2.0	0.7	0.7	0.3	0.3
spray	4.0	1.4	0.8	0.8	0.2
granule	4.0	5.2	3.0	1.1	0.2
spray	8.0	2.2	0.8	1.0	0.6
granule	8.0	8.8	4.5	3.0	1.3

TABLE XX. THE EFFECT OF 2,6-DBN ON THE TIME REQUIRED TO HAND HOE WEEDS IN BLACKCURRANTS 13 WEEKS AFTER APPLICATION

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Per cent reduction in hoeing time	
		Overall spray	Soil only treated
Spray	2.0	42	61
Granule	2.0	-	73
Spray	4.0	83	81
Granule	4.0	-	85
Spray	8.0	89	92
Granule	8.0	-	94

TABLE XXI. THE EFFECT OF 2,6-DBN ON THE YIELD OF BLACKCURRANTS

(Field Exp. no. 14/60)

Formulation applied	Dose lb/ac	Per cent reduction in hoeing time	
		Overall spray	Soil only treated
Spray	2.0	25.0	25.7
Granule	2.0	-	26.3
Spray	4.0	25.2	18.3
Granule	4.0	-	18.7
Spray	8.0	21.3	25.0
Granule	8.0	-	18.5
	0	25.3	

(78178)

A PRELIMINARY EXPERIMENT ON CONIFER SEEDBEDS WITH 2,6-DICHLOROBENZONITRILE

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Summary: In an experiment on conifer seedbeds, 2,6-dichlorobenzonitrile (2,6-DBN) at 1 or 2 lb/ac (active ingredient) cultivated into the top 2-3 inches of conifer seedbeds completely controlled annual weeds from the time of application until mid-July. The material was applied as a wettable powder 8, 4 or 2 weeks before plots were sown (in early April or early May). The number and height of seedlings of *Pinus sylvestris*, *Larix leptolepis*, *Tsuga heterophylla* and *Picea sitchensis* was seriously reduced on plots treated with 2 lb/ac cultivated in, and by some, but not all, applications of 1 lb; on plots treated with 1 lb/ac of 2,6-DBN 4 or 8 weeks before sowing, the weed control was good and *Picea sitchensis* and *Larix leptolepis* seedlings were undamaged. Applications of ½ lb/ac of 2,6-DBN cultivated in had little effect on crop or weeds. Applications of 2,6-DBN to the soil surface had little effect on crop or weeds.

INTRODUCTION

2,6-DBN was supplied with the information that it had shown promise as a killer of both dormant and germinating seeds. The compound was said to be moderately persistent but that this property was influenced by whether the compound was incorporated in the top layers of the soil or left on the soil surface From this preliminary information, 2,6-DBN appeared to have a potential value in forest nurseries if applied to seedbeds well before sowing, the seedbeds being as nearly ready for sowing at the time of treatment as possible.

METHODS AND MATERIALS

2,6-DBN was applied as a 50 per cent wettable powder to prepared seedbeds at Kennington Nursery, Oxford, at rates of ¼, ½, 1 and 2 2 lb/ac active ingredient. It was sprayed on the soil surface as a suspension in water at 60 gal/ac, and immediately after spraying, half the plots in the experiment were lightly cultivated so that the 2,6-DBN was incorporated in the top 2-3 in. of soil. The compound was applied on six dates, 8, 4 and 2 weeks before sowing in the first week in April, and 8, 4 and 2 weeks before sowing in the first week in May. A 5 x 3 x 2 x 2 factorial design with a single replication was used in this experiment.

Plots 3 ft x 3 ft in area, were sown with seed of Scots pine (*Pinus sylvestris*), Sitka spruce (*Picea sitchensis*), Western hemlock (*Tsuga heterophylla*) and Japanese larch (*Larix leptolepis*). Seed was sown on the soil surface (which had been consolidated and lightly raked immediately before sowing); the seed was then covered with coarse sand.

The soil at Kennington is a light loam, pH 5.5. The weed flora is composed of annuals, the most important of which are *Poa annua*, *Senecio vulgaris*, *Spergula arvensis*, *Polygonum persicaria* and *Chenopodium album*.

Assessments were made of the number of seedlings at the end of May and at the end of June, and of the height and number of seedlings at the end of the growing season, i.e. early October. (These last assessments were not available at the time this paper was written). Weed growth was assessed by measuring the time taken to remove by hand all the weeds on a plot, weeding being done at intervals of 4 weeks.

Samples of soil from 0 to 3 in. in each plot were taken at the time of sowing for determination of residues of 2,6-DBN.

RESULTS

Table I gives the number of conifer seedlings at the end of June on plots sown in early April and in early May. The table shows that 2 lb/ac of 2,6-DBN cultivated into the top 2-3 in. of soil, and applied 8, 4 or 2 weeks before sowing in April or May, drastically reduced the number of seedlings of all species. 1 lb of 2,6-DBN cultivated in, reduced the numbers of April-sown Scots pine and Japanese larch whatever the interval between treatment and sowing but did not affect other species sown then. On plots sown in May, the same treatment reduced the numbers of three species, but only where plots had been treated 2 weeks before sowing (4 weeks also for larch). The fourth species, hemlock, failed on all plots.

Applications of ¼ or ½ lb/ac of 2,6-DBN had no effect on the number of plants on any plot or species except for Scots pine where ½ lb/ac cultivated in 2 weeks before sowing in May appreciably reduced the number of seedlings of this species.

The height of seedlings (judged by eye) at the end of the season was less on plots where the number of seedlings was reduced by treatment with 2,6-DBN, but not on other plots.

Table II shows that where 1 or 2 lb/ac of 2,6-DBN was cultivated-in, almost complete weed control was obtained which lasted until mid-July; the weed growth in August and September was very slight on these plots and could have resulted from re-infestation of the plots with weeds from outside the plot as much as from germination of dormant resistant seeds. Applications of ½ and ¼ lb of the compound cultivated-in gave moderate control of weeds on some plots, but not on others. Where 2,6-DBN was applied to the soil surface, there was little control of weeds, even at the highest dose.

There were no residues of 2,6-DBN greater than 0.1 ppm dry soil in soil samples taken from 0-3 in. on any plot. It was not possible to detect residues at lower concentrations than this. (0.1 ppm is equivalent to approx. 0.1 lb/ac).

DISCUSSION

The striking feature of the results of this experiment is the almost complete control of weeds on plots treated with 1 or 2 lb/ac of 2,6-DBN when this is cultivated in. While the higher of these doses seriously damaged all four species of conifer, where 1 lb/ac had been cultivated in 8 weeks before sowing, Sitka spruce and Western hemlock were not affected at all, and Scots pine and Japanese larch were reduced in numbers only on April sown plots. There is some suggestion that Scots pine was most susceptible to 2,6-DBN, Sitka spruce and Western hemlock least susceptible and Japanese larch intermediate. This might possibly be related to speed of germination. Scots pine is the quickest to germinate of the species used here, normally coming through in 12-18 days, where the larch and spruce would take 21-28 days and the hemlock slightly longer still. If 2,6-DBN is more toxic to germinating than to dormant seeds then one would expect quickly-germinating species to be more affected than species germinating slowly.

Comparison of the numbers of seedlings at the end of May and at the end of June shows quite clearly that on all those May-sown plots where the number of plants had been affected by 2,6-DBN, plants had emerged and were alive and apparently healthy at the end of May but had died by the end of June, the plants not having developed beyond the cotyledon stage. Of the species sown in early April and affected by 2,6-DBN, only Sitka spruce seedlings died in appreciable numbers between the counts at the end of May and at the end of June. Seedlings on the other April-sown plots affected by 2,6-DBN had died by the time the May count was made. These results suggest three possibilities: firstly, that there was 2,6-DBN in the soil around the seed and germinating seedlings but that it did not enter the plant until after emergence; secondly, that there was no 2,6-DBN in the surface soil but that it was present an inch or so below the surface and the seedling roots only came into contact with it later, or, thirdly, that the seed picked up the 2,6-DBN soon after it was sown but only succumbed to its effect after several weeks.

The effect of the interval between application of 2,6-DBN and sowing is not consistent. Table I shows that whatever the interval, i.e. 2, 4 or 8 weeks, between application and sowing in April, there was no clear effect on the number of seedlings; in contrast, on May-sown plots, applications two weeks before sowing depressed numbers of seedlings at doses which had no effect when applied four and eight weeks before sowing. There is no evidence that the interval between application of 2,6-DBN and sowing had any effect on weed growth after plots were sown. Any weed growth which developed before sowing was removed when the appropriate plots were consolidated and lightly raked in preparation for sowing. The only note made at this time was that the plots where higher doses of the compound were cultivated in were clean. The consolidation and raking at the time of sowing (which are standard operations in all forest nurseries) may also have disturbed the surface soil and brought up healthy weed seeds from ½-1 in below the surface, so reducing the effect of treatments applied to the surface of the soil.

The date on which plots were sown had some effect on plant numbers; there were more Scots pine seedlings but fewer Western hemlock, Sitka spruce and Japanese larch on the May-sown plots than on the April-sown plots. These differences agree with evidence from other experiments where the date of sowing is varied. The date on which plots were sown also affected the amount of weed growth at the time of the first weeding, this being due to the timing of assessments. The first weeding was carried out on 25th May on all plots. The plots sown in early April had seven weeks in which to develop a weed cover while the May-sown plots only had three weeks. There is no difference in development of the weed population later in the season.

Acknowledgement

The 2,6-dichlorobenzonitrile (2,6-DBN) used in this experiment was supplied by "Shell" Research Ltd., through Mr. G. E. Barnsley, whose help and suggestions have been most welcome. Mr. Barnsley also arranged for soil samples to be examined for residues.

TABLE I. THE NUMBER OF CONIFER SEEDLINGS AT THE END OF JUNE

Dose applied lb/ac	2,6-DBN cultivated in 8 wks before sowing	4 wks	2 wks.	2,6-DBN applied to soil surface 8 weeks before sowing	4 weeks	2 weeks
Scots pine (Pinus sylvestris) — Plots sown in early April						
0	119	92	121	105	81	104
¼	102	99	98	110	102	106
½	89	86	66	104	120	116
1	26	19	23	111	106	95
2	0	13	0	122	85	105
Plots sown in early May						
0	142	124	119	105	126	125
¼	105	122	136	115	121	110
½	120	116	39	128	120	120
1	119	96	25	120	117	93
2	5	4	0	118	112	134
Sitka spruce (Picea sitchensis) — Plots sown in early April						
0	170	149	172	142	123	140
¼	154	149	152	152	160	111
½	160	133	138	152	163	153
1	146	118	113	134	170	137
2	15	28	56	144	123	119
Plots sown in early May						
0	128	100	92	68	99	88
¼	110	120	63	100	89	57
½	88	104	95	90	57	75
1	103	63	28	88	71	69
2	25	33	0	70	76	66
Western hemlock (Tsuga heterophylla) — Plots sown in early April						
0	99	143	214	105	85	52
¼	145	215	189	208	178	130
½	105	191	132	166	103	88
1	159	161	126	185	106	163
2	20	0	22	192	100	171
Plots sown in early May						
0	31	3	26	10	20	3
¼	33	32	3	61	6	1
½	37	35	3	4	0	9
1	0	3	0	16	6	19
2	0	0	0	1	1	2

TABLE I (Contd.)

Dose applied lb/ac	2,6-DBN cultivated in 8 wks before sowing	4 wks	2 wks	2,6-DBN applied to soil surface 8 weeks before sowing	4 weeks	2 weeks
Japanese Larch (Latrix leptolepis) Plots sown in early April						
0	54	52	63	55	37	46
¼	79	53	66	63	73	42
½	87	81	54	88	80	67
1	27	41	37	63	70	66
2	3	4	4	63	64	59
Plots sown in early May						
0	43	40	40	34	42	51
¼	65	38	56	37	54	26
½	49	32	37	48	52	36
1	24	5	5	51	40	39
2	6	0	0	37	53	24

TABLE II. THE EFFECT OF 2,6-DBN ON WEED GROWTH
(ASSESSED BY THE TIME TAKEN TO REMOVE WEEDS BY HAND)

Method and time of treatment	Dose lb/ac	Time taken to remove weeds (Seconds/sq yd) Date of weeding 25.5	24.6	21.7	17.8	9.9	Total Time
Cultivated in 2 weeks before sowing in April	0	178	50	9	58	5	300
	¼	82	10	0	20	0	112
	½	26	2	0	40	19	87
	1	12	2	2	9	7	32
	2	0	0	0	16	0	16
Left on surface 2 weeks before sowing in April	0	164	64	47	56	23	354
	¼	198	20	7	26	15	266
	½	132	50	15	48	33	278
	1	52	12	13	40	5	122
	2	102	11	19	36	5	173
Cultivated in 2 weeks before sowing in May	0	12	140	16	16	5	189
	¼	0	106	17	15	0	138
	½	0	44	11	38	42	135
	1	0	2	0	40	0	42
	2	0	0	0	15	4	19

TABLE II (Contd.)

Method and time of treatment	Dose lb/ac	Time taken to remove weeds (Seconds/sq yd) Date of weeding 25.5	24.6	21.7	17.8	9.9	Total Time
Left on surface 2 weeks before sowing in May	0	54	32	39	34	62	221
	¼	38	46	21	5	22	132
	½	40	58	21	54	2	175
	1	4	64	39	49	42	198
	2	22	30	36	30	36	154
Cultivated in 4 weeks before sowing in April	0	138	20	7	30	16	211
	¼	94	20	5	18	5	142
	½	126	30	12	9	2	179
	1	0	2	0	3	11	16
	2	0	0	0	3	0	3
Left on surface 4 weeks before sowing in April	0	176	24	2	20	0	222
	¼	82	0	5	30	30	147
	½	78	6	0	40	20	144
	1	68	46	8	48	40	210
	2	42	17	10	10	3	82
Cultivated in 4 weeks before sowing in May	0	50	52	16	52	42	212
	¼	11	26	25	52	18	134
	½	26	40	51	59	50	226
	1	0	2	3	54	30	89
	2	0	0	2	13	16	31
Left on surface 4 weeks before sowing in May	0	46	24	16	18	22	126
	¼	82	0	5	30	30	147
	½	34	60	10	28	16	148
	1	60	30	18	22	18	148
	2	44	50	7	36	9	146
Cultivated in 8 weeks before sowing in April	0	80	20	4	16	6	126
	¼	66	3	5	3	7	84
	½	58	24	2	18	15	117
	1	0	0	0	8	0	8
	2	0	0	0	20	2	22
Left on surface 8 weeks before sowing in April	0	122	34	19	34	7	216
	¼	142	40	7	56	5	250
	½	72	12	3	11	5	103
	1	58	15	6	28	5	112
	2	68	2	7	28	0	105
Cultivated in 8 weeks before sowing in May	0	28	70	22	36	5	161
	¼	14	52	7	12	3	88
	½	2	23	8	20	16	69
	1	0	7	16	31	0	54
	2	0	0	4	14	5	23
Left on surface 8 weeks before sowing in May	0	17	46	14	26	8	111
	¼	48	28	2	32	18	128
	½	42	42	30	30	11	155
	1	13	80	2	24	5	124
	2	34	16	2	47	2	101