
Chemical Control of Weeds in the Forest

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PLATE 1. Mistblower knapsack sprayer applying 2,4,5-T spray to foliage of Sweet chestnut coppice regrowth, in area in process of conversion to conifer plantation. (Alice Holt Forest, Hampshire).

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CHEMICAL CONTROL OF WEEDS IN THE FOREST

INTRODUCTION

1. This leaflet contains recommendations for the use of herbicides* which are of most value to the forester in Great Britain. Those herbicides which show promise in the forest but which have not been tested fully are recommended tentatively, but no mention is made of the many materials developed for agriculture which are ineffective or damaging in the forest.

2. Information on the chemical control of weeds in forest nurseries may be found in Forestry Commission Bulletin 14 *Forestry Practice*, (H.M.S.O. 1964), or in the two volumes of the *Weed Control Handbook* (Fryer, 5th edition 1968). This latter volume also contains up-to-date information on the control of weeds in most agricultural and horticultural crops and on waste-land, roadside verges, etc. Earlier work and papers giving details of the research leading to the present recommendations are summarised in Forestry Commission Research and Development Paper No. 40 (Aldhous, 1967a). The present scale of use has been summarised by Wood, 1967.

WHEN TO INTRODUCE WEED KILLERS

3. Before detailed recommendations are set out, several general points must be made:—

The use of herbicides can be justified as a means of saving money on weeding, or of reducing seasonal peak labour requirements. The materials mentioned below can be recommended for one or both these reasons. It is always hoped that they will also lead to the quicker establishment and more rapid growth of the young crop, but this has seldom been proven.

4. Secondly, no herbicide can be relied on always to give a complete kill of the weeds it is aimed to control. Often patches of weed survive, or one or two sprayed stumps sprout again; this is due in some cases to the inherent difficulty of spraying evenly where weed growth is patchy and irregular, and in other cases to the protection of small weeds by bigger neighbours so that the herbicide does not reach its target properly. Such missed areas may require 'spot' or local retreatment.

5. Thirdly, new vegetation will usually fill the gaps left by what has been killed; for example, grasses may increase rapidly when broad-leaved weeds such as bramble are treated. Before spraying, the likely consequences of removing any particular weed or group of weeds must therefore be carefully considered.

6. Lastly, for the best results, the use of herbicides must be fully integrated into the process of establishing a crop or removing an unwanted vegetation cover, and not treated as an isolated operation. Herbicides should never be treated as the *exclusive* way of treating weeds. Machine cutting is often cheaper and excellent results can be obtained by a combination of machine and chemical control, or of hand cutting and chemical control.

Careful Use of Herbicides

7. Before spraying, the wider consequences outlined above must always be considered quite as much as the narrower question of whether a particular material will do a particular job in given circumstances. It would be a disservice to suggest that in forestry there are no hazards associated with the use of herbicides. On the other hand, herbicides have been used with proper care on a prac-

* Throughout this leaflet, the term 'herbicide' is used in the sense defined in the *Weed Control Handbook* i.e., "a chemical which can kill or inhibit the growth of certain plants".

tical scale in British forests for the last ten years and it is important that the same care is always taken.

8. Herbicides should be considered as tools which can be properly used or abused. If the instructions for use are ignored, extensive damage to plants or discomfort to the user may follow. **IT IS ESSENTIAL TO READ ALL THE INFORMATION ON THE LABEL ON THE HERBICIDE CONTAINER AND TO OBSERVE STRICTLY THE INSTRUCTIONS AND PRECAUTIONS LAID DOWN.** Such instructions and precautions will describe both the protective clothing required by those handling the weedkiller, either in its concentrated form or when diluted, and also any potential direct risks to other crops, to farm animals or to wild life. Although the provision and use of protective clothing is not legally obligatory for any herbicide recommended here, *all users should always comply with all the recommenda-*

tions. SEE ALSO paras. 121–136 on safety and precautions.

GUIDES TO THE USE OF HERBICIDES

9. Tables 1–3 indicate which weedkillers are most appropriate for given weed types and what are the possible times of the year for their use.

Table 1 lists the chemicals mentioned in this leaflet and shows their relative value in particular situations.

Tables 2 and 3 list the main types of treatment and indicate the times of the year when they may be used, Table 2 for unplanted land and Table 3 for planted ground.

10. Recommendations giving full details of the treatments referred to in Tables 1–3 are arranged as shown in the Contents pages at the front of this leaflet.



PLATE 2. A plastic 4-5 gallon-capacity knapsack sprayer being filled with 2,4,5-T in oil. The tripod is made of three creosoted stakes supporting a platform. The height of the platform is such that a man can comfortably get into the knapsack harness while the knapsack is still on the platform. The spray solution passing into the knapsack is drawn by hose from a reservoir which may be up to 200 feet from the pump. (Yardley Chase Forest, Northants).

TABLE 1
SUMMARY OF CHEMICALS USED IN FORESTS AND FOR SCRUB CONTROL

		<i>Chemical</i>	2,4,5-T	2,4-D	2,4-D/2,4,5-T mixture	<i>Ammonium sulphamate</i>	<i>Paraquat</i>	<i>Diquat</i>	<i>Dalapon</i>	<i>Chlorthiamid</i>	<i>Maleic hydrazide</i>	<i>Dicamba</i>	
FOREST WEEDING	PRE-PLANTING	Woody weed foliage	g	g	g								
		Hardwood stumps	G		(g)	g							
		Hardwood Basal Bark or Frill Girdle	G		g								
		Rhododendron stump	T/g			G							
		Rhododendron re'grth	T/g			g							
		Grass and Broad- leaved herbs					g	(g)	(g)	T			
	Bracken											T	
	POST-PLANTING	Woody weed foliage	G	g	g								
		Hardwood stump and dormant shoot	G		g	(g)*							
		Hardwood basal bark and Frill Girdle	G		g	(g)*							
		Rhododendron stump	T			g*							
		Rhododendron re'grth	T/g*			G*							
		Grass and Broad- leaved Herbs					G	(g)	(g)	T*			
		<i>Calluna</i> (Heather)		G				(g)	(g)				
Mixed seedling woody and herbaceous weeds		g		g							t		
Bracken											t		
SPECIAL SITES	Poplar Plantations	g	g	g		G				T*			
	Road-sides	G	G	G							G		

Key.

t = in limited trials.
 T = in more than one year's trials but not yet unconditionally recommended.
 (g) = beyond trial stage but not generally used.

g = in use on moderate scale.
 G = widely used
 * = May cause some damage to crop close to treated weeds.

TABLE
TREATMENTS WHEN PREPARING GROUND

<i>Treatment</i>	<i>Chemical</i>	<i>Diluent</i>	<i>Method of Application</i>
Basal Bark or Frill to Standing Stems. Fresh-cut Stumps, and Stumps with Shoots. }	100% 2,4,5-T	Oil	Knapsack Sprayer or Can and Brush or Lance from Hose and Reel.
Fresh-cut Stump or Frill.	Ammonium Sulphamate	Water	Dry Crystals, or Plastic Watering Can and Rose or Brush.
Foliage Spray, Gorse, Coppice and Bramble.	50% 2,4,5-T	Water or Water + 10% Oil	Knapsack Sprayer or Mist-blower or Tractor, with Boom or Mist-blower.
Spray, Heather	2,4-D	Water.	Knapsack Sprayer or Mist-blower or Tractor, with Boom or Mist-blower, or Aerial Spray.
Grasses (to 3 weeks before planting).	Dalapon	Water	Knapsack Sprayer or Tractor with Boom.
Grasses and Herbs (to 3 days before planting).	Paraquat (Gramoxone)	Water	Knapsack Sprayer or Tractor with Boom.

- - - - marginal
 ——— satisfactory
 ≡≡≡ widely used

TABLE
TREATMENTS WHEN WEEDING AND

<i>Treatment</i>	<i>Chemical</i>	<i>Diluent</i>	<i>Method of Application</i>
Cut Stump and/or Basal Bark	100% 2,4,5-T	Diesel	Knapsack Sprayer or Can and Brush.
Cut Stump or Frill	Ammonium Sulphamate	Water	Crystals Can and Brush
Foliage Spray to Coppice, Bramble and Seedling Hardwood.	50% 2,4,5-T	Water	} Knapsack Sprayer, Mist-blower, Tractor and Boom or Aerial spray.
Foliage spray to Mixed Hardwood, Herbaceous Broadleaf Weeds.	50% 2,4,5-T and 2,4-D	Water	
Spray to Heather	2,4-D	Water	Knapsack Sprayer, or Mist-blower or Tractor and Boom
Grasses	Dalapon	Water	Knapsack Sprayer (and Dribble Bar) or Tractor and Boom.
Grasses and Herbs.	Paraquat	Water	Knapsack Sprayer (+ Cone) or Arbogard (Mark II).
Grasses	Chlorthiamid (Prefix)	None	Granules (By hand or tractor-mounted spreader).

- - - - marginal
 ——— satisfactory
 ═════ widely used

3

CLEANING AFTER PLANTING

<i>Post-planting</i>												<i>Remarks</i>
Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
=====			-----						-----			Do not spray within 10 days before bud break on crop trees.
-----		-----		-----		-----		-----		-----		May kill plants rooting close to treated stumps.
-----		-----		-----		-----		-----		-----		Bramble, broom and gorse Use only among conifers when not growing. Do not spray if foliage yellowing or autumn leaf-fall has started.
-----		-----		-----		-----		-----		-----		
-----		-----		-----		-----		-----		-----		Spray only conifers when not growing.
-----		-----		-----		-----		-----		-----		Grass must be actively growing.
-----		=====		=====		=====		=====		-----		Molinia Keep off all parts of crop trees. Grass must be green when sprayed.
-----		-----		-----		-----		-----		-----		
-----		-----		-----		-----		-----		-----		Provisionally recommended only among Corsican pine, Sitka spruce and hardwoods.

FOR RATES OF DILUTION SEE TEXT

Choice of Derivative and Formulation

11. Some herbicides are available in several different guises. Growth regulators like 2,4-D and 2,4,5-T are acids in their essential form but are almost always compounded and sold as one or other derivative, e.g. sodium salt, amine salt, butyl ester, even though all recommendations are in terms of the *equivalent amount of the acid*, sometimes abbreviated to "acid equivalent" or "a.e."

12. Each *derivative* may in turn be *formulated* in different ways, or may be available both formulated and unformulated. The formulation in this sense is the particular blend of surface active agents, emulsifiers, stickers, etc., used.

An unformulated ester contains no additives and does not mix readily with water. An emulsifiable ester contains additives which enable it to mix readily with water. Both formulations mix readily with oil. See also "Notes on materials", para. 137 *et seq.*

13. Both the derivative and the formulation may affect many important properties of the herbicide, in particular its ability both to contact and to penetrate the outer tissue of the plant, its ability to mix with the recommended diluent, its volatility and its cost. Very often a compromise has to be reached between the last factor, cost, and other properties. This compromise is relevant in woody weed control to the use made of various forms of 2,4,5-T.

14. For normal winter use, the unformulated butyl esters of 2,4,5-T have been used and have proved effective, though in very cold conditions, they have solidified in the drum; this can be overcome by warming, albeit sometimes a slow process. In very warm spells in the spring, or in the summer, damage has been observed apparently due to volatilization of both formulated and unformulated butyl esters of 2,4,5-T and their spread in warm, almost still, air. It is probable that such volatilization can be avoided by using the more expensive

but less volatile iso-octyl or nonyl 2,4,5-T esters; these are being tested (during 1968) for volatility under field conditions.

Naming of Recommended Herbicides

15. In the following paragraphs, the approved standard name for each herbicide is used. Details of proprietary brand names and manufacturers of most materials mentioned can be found in the current 'Agricultural Chemicals Approval Scheme—List of Approved Products'. This is published annually in February by the Ministry of Agriculture, Fisheries and Food and is available free of charge from the Ministry's Publications Department, Block C, Tolcarne Drive, Pinner, Middlesex. Suppliers of those materials *not* mentioned in the List of Approved Products are given in paras. 141–150 together with brief notes on all materials mentioned.

RECOMMENDATIONS—WOODY WEEDS

16. 2,4-D, 2,4,5-T, ammonium sulphamate or paraquat are recommended to control broadleaved woody and herbaceous weeds in forests. Table 4 sets out the relative susceptibility of common woody weeds to the first three of these materials and indicates the most effective means of control. Details of the timing and technique follow the table and are arranged in the following order:

Trees or shrubs with clearly defined stems or stumps.	Paragraph No.
Standing stems	21
2,4,5-T	24
Ammonium sulphamate	28
Stumps	
Hardwood standards and coppice (excluding <i>Rhododendron</i>)	30
2,4,5-T	34
Ammonium sulphamate	37
Rhododendron	40
Ammonium sulphamate	41
2,4,5-T	46
Foliage sprays to high cover	49
Other woody and herbaceous weeds	52

Foliage sprays after planting conifers	55
Foliage sprays before planting	61
Treatment of heather	63

TREES AND SHRUBS WITH CLEARLY DEFINED STEMS OR STUMPS

17. Table 4 sets out the relative susceptibility of the common hardwood species to 2,4-D, 2,4,5-T, and ammonium sulphamate. Most species are best controlled either by 2,4,5-T in oil applied to the stem of the standing trees or to the cut stumps, or by ammonium sulphamate applied to newly cut stumps or notched into the stem.

18. When considering these alternatives, it should be remembered that large standing dead trees are unsightly, especially if in an isolated or prominent position. Even small crops, so killed, can look extremely conspicuous when viewed from a neighbouring hill slope.

19. Coppice and scrub trees up to 25 or 30 feet tall, if killed standing, disintegrate slowly and do no damage to any undercrop. On the other hand, falling debris from larger trees may constitute a danger to passers-by. Land-owners or tenants who have used herbicides, or who have arranged their use to kill trees growing near public roads or footpaths, may be liable for any injury to passers-by or damage to their property from falling branches etc. Large trees near roads and footpaths should therefore never be killed standing.

20. In all stem and stump spraying operations, it may be necessary to add to the spray solution a marker dye to indicate which stumps were sprayed, to check that the right stumps have been treated, both at the time and within three or four days of spraying. Suitable spray markers are listed at the end of the leaflet in para. 149.

Stem Treatment of Standing Trees and Shrubs

21. Wherever old coppice or scrub woodland is unsaleable, it may be better to kill trees standing than to clear them. Alternatively, planting may have been planned to take

advantage of complete or partial over-head cover giving shade and protection against frost; as such crops develop and the cover has to be removed, it may be cheaper and otherwise preferable to kill it standing, rather than fell and risk damage to the young crop. The residual and slowly decreasing protection afforded by the dead stems can be of value silviculturally.

22. Stems may be killed by spraying the bottom 12 inches ("basal bark" spray) or a frill may be cut and herbicide run into the cut. Basal bark spraying may require up to twice as much spray solution for trees of a given size as treatment of cut stumps. Table 4 shows which species are best controlled with 2,4,5-T and which with ammonium sulphamate. The latter is usually more expensive to use and is only recommended where 2,4,5-T is ineffective. See Table 5 for comparative costs.

23. No direct spray of 2,4,5-T or of ammonium sulphamate must come in contact with the foliage of the young tree crop.

N.B. BOTH YOUNG AND ESTABLISHED TREES ROOTING IN SOIL SPRAYED WITH AMMONIUM SULPHAMATE MAY BE DAMAGED OR KILLED.

Stem Treatment Using 2,4,5-T

24. *Trees or Coppice Less Than 4 inches Diameter Breast Height.* (See Plates 3, 9, 10, 11).

The bark at the base of the tree should be sprayed using an *unformulated* low-volatile ester of 2,4,5-T at 1½-2 gallons of 100% ester diluted in 100 gallons of diesel oil, gas oil or paraffin. Spraying should saturate the bark to the point of run-off, over the full circumference of the stem, from a height of 12 inches to ground level; the bark should be dry at the time of spraying. The treatment can be applied at any season, although the most consistently good results have been obtained in the periods from January to May, and shortly after full

TABLE 4
THE EFFECT OF 2,4-D: 2,4,5-T AND AMMONIUM SULPHAMATE ON WOODY WEEDS

Herbicide — Method — Diluent — Species Timing — Placing —	2,4-D ¹	2,4,5-T ¹				Ammonium Sulphamate to Stump or Stem ⁴ —all Seasons
	Overall Spray	Overall Spray		Placed		
	Water	Water	Oil	Oil	Oil	
	Summer Foliage	Summer Foliage	All Season Shoot ⁵	Winter Stem	Winter Stump	
ALDER (<i>Alnus</i> spp.)	MS	S		MS	S	S
ASH (<i>Fraxinus excelsior</i>)	MR	MR	MS	MR	MS	S
BILBERRY (<i>Vaccinium</i> spp.)	MS					
BEECH (<i>Fagus sylvatica</i>)		MS	S			
BIRCH (<i>Betula</i> spp.)	MS	S	S	S	S	S
BLACKBERRY (<i>Rubus</i> spp.)	MR	S	S		S	
BLACKTHORN (<i>Prunus spinosa</i>)		S	MS	MS	S	S
BOX (<i>Buxus sempervirens</i>)		MS	S			
BRIAR (<i>Rosa</i> spp.)	MR	S	S		S	
BROOM (<i>Sarothamnus scoparius</i>)	S	S	S		MS	
BUCKTHORN (<i>Rhamnus cathartica</i>)		MS	S	MS		
HORSE CHESTNUT (<i>Aesculus hippocastanum</i>)		MS		S	S	
SPANISH CHESTNUT (<i>Castanea sativa</i>)		MS		S	S	S
DOGWOOD (<i>Theleycrania sanguinea</i>)		S	MS		MS	
ELDER (<i>Sambucus nigra</i>)	MS	S	S	S	S	S
ELM (<i>Ulmus</i> spp.)	MR	MS	S		S	
GORSE (<i>Ulex</i> spp.)	MR	S	MS ³		S	
HAWTHORN (<i>Crataegus</i> spp.)	R	MR	S	MR	MR	S
HAZEL (<i>Corylus avellana</i>)	MR	MS	MS	MS	S	
HEATHS (<i>Erica</i> spp.)	MS ²					
HEATHER or LING (<i>Calluna vulgaris</i>)	MS ²	MR				
HOLLY (<i>Ilex aquifolium</i>)	R	R			MS	
HORNBEAM (<i>Carpinus betulus</i>)		MS	MS	MS	S	
IVY (<i>Hedera helix</i>)	R	MR	S			
JUNIPER (<i>Juniperus communis</i>)	R	R				
LIME (<i>Tilia</i> spp.)		MS				

TABLE 4—*contd.*
 THE EFFECT OF 2,4-D: 2,4,5-T AND AMMONIUM SULPHAMATE ON WOODY WEEDS—*contd.*

Species	Herbicide —	2,4-D ¹		2,4,5-T ¹			Ammonium Sulphamate to Stump or Stem ⁴ —all Seasons
	Method —	Overall Spray	Overall Spray		Placed		
	Diluent —	Water	Water	Oil	Oil	Oil	
	Timing Placing —	Summer Foliage	Summer Foliage	All Season Shoot ⁵	Winter Stem	Winter Stump	
FIELD MAPLE (<i>Acer campestre</i>)			MS	MS	S	S	
OAK (<i>Quercus</i> spp.)	R		MR	MS	MS	MS	
WILD PEAR (<i>Pyrus communis</i>)			MS			S	
POPLAR (<i>Populus</i> spp.)	MS		S	S	S	S	
PRIVET (<i>Ligustrum vulgare</i>)			MS	MS			
RHODODENDRON (<i>Rhododendron ponticum</i>)	R		MR	MS ⁶	MR	MR	S
ROWAN (<i>Sorbus aucuparia</i>)	MS		MS		MS	MS	
SNOWBERRY (<i>Symphoricarpos</i> spp.)	S		MR		MR	MR	
SYCAMORE (<i>Acer pseudoplatanus</i>)			MS		MS	S	
WILLOW (<i>Salix</i> spp.)	S		S	S	MS	MS	S

Notes.

S = *Susceptible*: Consistently good control by suggested technique at the lower of the application rates recommended below.

MS = *Moderately Susceptible*: Good control with the higher of the rates recommended below.

MR = *Moderately Resistant*: Some effect from the higher rates of applications but recovery rapid.

R = *Resistant*: No useful effect at the highest rate quoted.

Recommended rates of application of 2,4-D and 2,4,5-T are:—

Overall Summer foliage sprays—2 to 4 lb acid equivalent per acre.

All season shoot sprays—4 to 6 lb acid equivalent per acre.

Basal bark and cut-stump treatments—15 to 20 lb acid equivalent per 100 gallons oil.

1. Growth-regulating herbicides are most concisely prescribed in terms of the parent acid whichever derivative is used and however this is formulated (e.g. 2,4-dichlorophenoxyacetic acid as the sodium or potassium salt, amine, emulsifiable ester, etc.). In the text, full details of the appropriate formulations and their rates of applications are given; to do so here would make the table unmanageable.

2. For best control of heather, apply 2,4-D at 5 lb acid equivalent per acre. See paras. 63–66.

3. Foliage sprays to gorse in the winter may be applied in water as a cheaper alternative to oil.

4. Frill girdle or basal bark.

5. Susceptible evergreen species will usually succumb if sprayed at any time of year.

6. See paras. 41–46. Use 25 lb acid equivalent per 100 gallons of oil.

leaf development in summer. About 1 fluid ounce of spray solution is required per inch of stem diameter; i.e. 1 gallon of spray solution will treat about 160 inches of stem diameter or 50 trees 2-4 inches diameter at breast height. Trees with moss-covered bark may require about twice as much spray as those with clean bark.

25. Trees or Coppice More Than 4 Inches Diameter at Breast Height.

It is more effective and economical to treat larger stems or moss-covered stems by "frill" girdling, followed by application of chemicals to the frill rather than to apply a basal-bark spray. A "frill" girdle is prepared as near ground level as is convenient, and consists of a ring of downward-sloping overlapping cuts made with a light axe or bill-hook. The cuts must penetrate to the cambium, and if possible into the outer sapwood. See Plate 11, page 49.

26. Unformulated 2,4,5-T ester at 1½-2 gallons of concentrate per 100 gallons of diesel oil or gas oil should then be poured or sprayed into the *fresh* cuts. This treatment is most effective applied shortly after full leaf development, but it can be applied at all seasons with useful results. The volume applied must be sufficient to wet the full circumference of the girdle, especially the upper surfaces. The simplest way of achieving this is to wet the bark just above the frill and allow the solution to run down into the cuts. As a general rule about 1/6th fluid ounce is required per inch of stem diameter, i.e. 1 gallon of spray solution will treat about 900 inches of stem diameter or about 110 trees averaging 6 inches breast height quarter girth. Sprays to the base of the stem or to frills may be applied using knapsack sprayer working at low pressure. Frill-girdles also can be treated using a pressure oil-can, or simply a can with a spout.

27. Trees may also be girdled using a "tree injector" (Plate 10). Cuts made by the injector must penetrate to the cambium and should be about 4 inches apart, centre to centre. Where coppice stools are being treated, at least one cut must be made in each stem.

Stem Treatment Using Ammonium Sulphamate—All Sizes of Tree

28. Species such as ash and hawthorn (i.e. those relatively resistant to 2,4,5-T) should either be frill-girdled, by the method described above, and the frill wetted to run-off with a solution containing 4 lbs of ammonium sulphamate per gallon of water, or notches may be cut into the base of the stem. The notches should be no more than 4 inches apart edge to edge and should each receive about half an ounce of dry crystals of ammonium sulphamate. (One heaped teaspoonful of crystals weighs approximately half an ounce). Alternatively, if trees are frilled, crystals may be spread round the frill at the rate of half-ounce (one teaspoonful) per four inches of frill. Notches are best suited to trees over six inches in diameter at the base.

29. Ammonium sulphamate corrodes metal rapidly (see footnote). When applying it in solution, it is essential to use either sprayers made entirely of plastic and stainless steel or plastic cans. Dry crystals should be measured out with a plastic teaspoon.

Stump Treatment

Hardwood Standards and Coppice excluding Rhododendrons

30. Hardwood stumps can readily be sprayed to prevent growth of unwanted coppice-shoots. The treatment is easy to apply and can result in considerable savings in the cost of subsequent weedings; the cost of cleaning

Footnote. Sodium benzoate may be added at the rate of ½ ounce per gallon of solution to cut down the rate of corrosion of brass or copper by 90% or more. Nevertheless corrosion still takes place and ammonium sulphamate and inhibitor must not be left in contact with brass or copper any longer than is essential. Sodium benzoate has no effect on the rate of corrosion of steel.

operations at the time of brashing and firrs thinning will also be reduced.

31. Stump sprays are best applied before planting, soon after the standing stems have been felled. Alternatively they may quite well be applied after planting, though more care will be required in placing the sprays.

As the volume of spray required is proportional to the surface area of the stump, the lower a stump is cut, the less the area of bark that has to be treated. Leaving high stumps can add 20% or more to the cost of materials.

32. There is nothing that will effectively and quickly rot the stump once it has been killed. If stumps have to be removed, it is usually better to winch the stem and stump out together and then cut off the stump, rather than fell the tree and be faced with the task of winching or digging out the stump. It has been claimed that it is easier to winch out a stump that has been killed with 2,4,5-T or ammonium sulphamate, than stumps which have some live roots.

33. Machines, such as the "Stump-gobbler", have recently been introduced which will grind away large stumps. Though effective, at present (Summer 1968), they are not widely available.

Stump Treatment Using 2,4,5-T

34. Susceptible species should be sprayed or brushed with a low-volatile unformulated ester of 2,4,5-T at 1½-2 gallons of ester per 100 gallons of diesel oil (see Table 4). A marker dye 'Waxoline Red O.S.' (oil soluble) may be added at 1 lb per 200 gallons of oil, if it is necessary to trace which stumps have been treated. The herbicide should wet the heartwood and saturate the bark and sapwood surface and in particular the bark at the root collar and just above ground level.

35. 2,4,5-T can be applied at any season, but stumps should not be treated when wet with rain. Spraying volumes will vary greatly

according to the diameter and number of stumps per acre. On average about 1/20th pint of spray per inch of stump diameter is required i.e. 1 gallon of spray will treat about 150-200 ins. of stump diameter or 25-35 tree stumps averaging six inches in diameter. Stumps which have re-sprouted, producing coppice shoots, can also be killed by spraying the bark and bases of the young shoots as well as the bark on the stump. This is also recommended as a "spot" treatment for any sprouts appearing in the season following 12 months after spraying of newly-cut stumps.

36. The most widely used equipment for the application of 2,4,5-T sprays to stumps has been a knapsack, operated at low pressure (5 lb-10 lb per square inch) so that the drift and "bounce" of droplets are minimised. The most recent equipment operates at the lower pressure. See also paras. 97-109.

Stump Treatment Using Ammonium Sulphamate

37. For satisfactory control, no more than two days must elapse after cutting before stumps are wetted with a solution containing 4 lb of ammonium sulphamate per gallon of water. This should be applied liberally to the stump, including cut surfaces. If the interval between cutting and spraying is increased, the control is less certain. Stumps may be treated by spraying or by brushing with a distemper or large paint brush (see paras. 34-35 above).

38. Alternatively, it will be easier and cheaper to apply dry crystals to the cut surface, at the rate of about half-an-ounce per inch of stump diameter. In this case, retention of crystals will be improved if the stump is cut so as to leave a horizontal or V-shaped surface. Ammonium sulphamate should not be applied to stumps if heavy rain is expected within a few hours of application.

39. If ammonium sulphamate is applied to the soil around stumps, young or old trees

rooting in the soil so treated may be damaged or killed. Foliage sprayed with ammonium sulphamate will be scorched.

Stump Treatment of Rhododendrons

40. Afforestation of areas covered with dense rhododendrons is expensive, principally because the rhododendrons have to be cleared by machine or by hand. There is nothing that can yet be recommended to kill such standing cover. Once it has been cut however, regrowth can be prevented or killed using ammonium sulphamate or 2,4,5-T.

Ammonium Sulphamate on Rhododendron Stumps.

41. If stumps can be treated within two days of cutting, they should be sprayed or painted liberally with a solution of ammonium sulphamate so as to saturate the stump surface and bark. A better control of regrowth is obtained if the ground surface within 1-2 foot radius of the stump is also sprayed; but see also para. 39.

42. It may not always be possible to spray stumps immediately after cutting, and regrowth may occur. In these circumstances, the regrowth, the stump and the ground around should all be sprayed; but see also para. 37.

43. Ammonium sulphamate may be applied at 4 lb per gallon of water, using either a plastic watering-can fitted with a fine rose, or paint-brush and plastic pail. When regrowth is being sprayed, a non-ionic wetter (see para. 150) should be added to the spray solution at the rate of 1 tablespoonful (1 fluid ounce) per gallon of spray solution.

44. In areas cleared of dense rhododendron, stumps and regrowth have been killed very successfully using a mist-blower (motorised knapsack sprayer—see Plate 1) applying 20 gallons per acre of a solution containing 4 lb of ammonium sulphamate per gallon of water. (68 lb of sulphamate+17 gallons of water make approx. 20 gallons of spray solution.)

However, severe corrosion of the metal parts of some powered spraying equipment has been reported following extensive spraying with ammonium sulphamate and this technique can only be recommended tentatively.

45. Areas treated with ammonium sulphamate can be planted twelve weeks after spraying.

2,4,5-T on Rhododendron Stumps and Regrowth

46. Rhododendron is best treated after cutting and before planting. In unplanted areas, freshly cut stumps should be sprayed to run-off with a solution containing 2-2½ gallons of unformulated ester per 100 gallons of oil. This should be applied to all accessible stump surfaces, both freshly-exposed wood and bark down to soil level.

47. Stumps with up to 3 or 4 years regrowth may be sprayed with a solution containing 5 gallons of emulsifiable concentrate per 100 gallons of water. All surfaces, especially bark and stump, must be well wetted, but it is wasteful to spray foliage to run off; an even, light coverage on leaves is sufficient.

48. 2,4,5-T should only be used on rhododendron in planted areas (a) if the conifer crop is resistant and dormant, (b) alternatively, if it is certain that no spray will reach the tree by mis-direction of the nozzle, by drift or by volatilization. These hazards are particularly serious in hardwood crops and in all crops during the period when shoots are growing rapidly, i.e. May and June. Treatments in planted areas should be by the same methods as are recommended above for pre-planting treatment.

Foliage Spraying of Standing Trees and Shrubs (High Cover) with or without a Conifer Undercrop

49. Sprays can be applied to the foliage of high cover; the kill is less complete than where the bases of stems are sprayed, as the upper foliage often protects the lower parts of the crown so that the lower parts survive. It is obviously difficult to spray the foliage of

high cover from the ground, and the most effective method is to spray from a helicopter or fixed-wing aircraft, using 5 pints of 50% 2,4,5-T as an emulsifiable ester in 10 gallons of water per acre.

50. Where a conifer undercrop has been planted, the incomplete control achieved with aerial spraying of high cover has seemed adequate to release the crop. On frosty or exposed sites, the cover left has given some valuable protection. However, much the same effect can also be achieved by basal bark spraying and avoiding selected stems. Where there is an undercrop, foliage spraying of high cover must be restricted to the period from mid-August to early-September (or earlier when the undercrop has ceased growing), if the undercrop is not to be damaged and a good kill of the overstorey obtained. If the undercrop is not dormant at the time of spraying, it is likely to be damaged.

51. If no undercrop is present, the spray is best applied between late June and late July, using a mixture of 5 pints of 2,4,5-T ester, 2 gallons of diesel oil and 8 gallons of water. It is essential to mix oil and herbicide together first and to add the water to this mixture. See also sections on Protection of neighbouring crops and Aerial Spraying, paras. 129 and 106 respectively.

OTHER WOODY AND HERBACEOUS BROADLEAVED WEEDS

52. Species with numerous small stems cannot easily be controlled by sprays to the stem or stump. Instead, the foliage has to be treated. Weeds in this category are most troublesome in young crops, when especial care has to be taken that the sprays are put on at the right time of year and that the correct formulation, rate of dilution and diluent are used. Foliage sprays to control weeds should not be applied among young hardwood crops unless the individual trees can be protected from the spray.

53. Coppice stools producing new shoots in

the year following cutting are not adequately controlled by sprays to the foliage of the shoots. In this condition, the leaf area is too small to absorb the quantity of herbicide necessary to kill the stump. Such stumps should be treated with 2,4,5-T in oil. See para. 34 above.

54. After foliage spraying, it is important that treated growth should not be cut until it is dead, or until it is clear that the plant has completely recovered.

Foliage Sprays to Woody and Herbaceous Weeds in Young Conifer Plantations

55. If herbicides are applied as placed sprays, they must be directed onto the weeds and entirely avoid crop trees; if applied overall, crop and weeds alike are sprayed. If 2,4,5-T or 2,4-D comes into contact with actively growing forest trees, either will damage the crop by causing shoot and foliage distortion or death of individual trees. Placed sprays can be used only if the proper materials, equipment and skilled staff are available. For placed spraying, low volatile esters must be used, equipment must be able to deliver at low pressure (5-10 lb p.s.i.) and staff must be able to spray accurately, consistently to avoid young trees. Spraying should be avoided in late May and early June when crops are particularly susceptible, and in spells of very hot weather at other times. Post-planting sprays *must* be diluted in water.

56. Overall sprays of 2,4-D or 2,4,5-T, or a mixture of 2,4-D and 2,4,5-T, can be applied for *selective* control of herbaceous and young broadleaved woody weeds in young *conifer* crops, providing spraying is **confined to that period in late summer when conifer shoots have ceased elongation and buds have formed**. The following species are relatively resistant to sprays applied from *mid-August onwards*: Scots pine, Corsican pine, Norway spruce, Sitka spruce, Douglas fir, *Abies grandis*, *Abies procera*, Western red cedar and Lawson cypress. However, *Pinus radiata*, *Pinus pinaster*,



PLATE 3. Sweet chestnut sprayed with 2,4,5-T solution containing $1\frac{1}{2}$ gallons of unformulated 2,4,5-T ester per 100 gallons of oil. The spray had been applied by knapsack to individual stumps. (Bedgebury Forest, Kent).

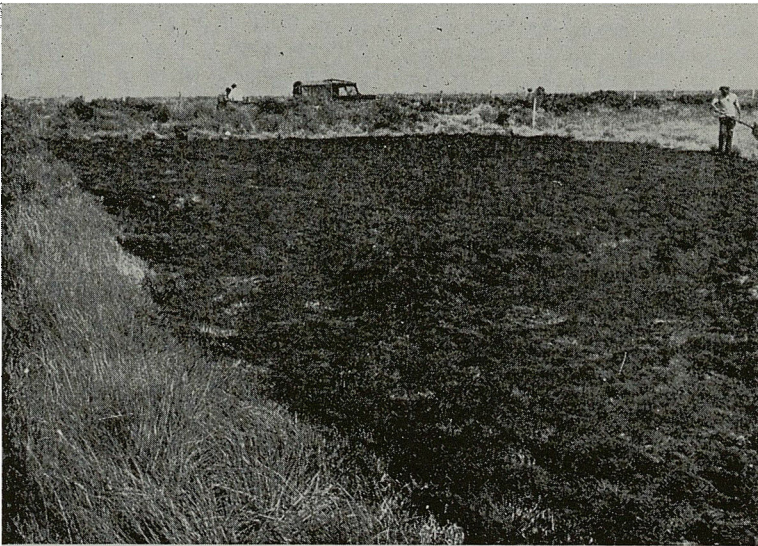


PLATE 4. Control of Purple moor grass, *Molinia caerulea*. The dark strip, centre and right-hand, had been sprayed with paraquat in July; the dried-out treated grass strip was burned while the adjacent grass was still green. Photo taken in August. (Aeron Forest, Cardigan).

Lodgepole pine and larch should not be sprayed while less than 12 feet high. The foliage of Western red cedar and Lawson cypress may be distorted and thickened but the height growth of the young trees is normally not checked.

57. Larch plantations often become filled with dense bramble and may be almost impenetrable just before brushing and first thinning. Bramble developing at this and later stages in larch or other conifer plantations can be controlled by spraying in late summer (Plate 5). If spraying is a preliminary to a thinning, 12-18 months should elapse between spraying and thinning to allow the bramble to break down. Paths may have to be cut through the bramble to get in to spray. If a mist-blower is available, paths can be 20-40 feet apart as a mist-blower can reach 10-20 feet on either side of each path; if only a knapsack and lance is available, paths may have to be cut every 6 or 8 feet.

58. In all selective sprays in young crops, care should be taken to avoid the crop trees as far as possible, spraying up to them but not giving them the full force of the spray. This will ensure that damage is kept to a minimum.

Choice of Chemicals

59. Where the prime object is control of *woody* species, use an emulsifiable low-volatile 2,4,5-T ester at 3-5 pints per acre of a concentrate containing 5 lb of 2,4,5-T (acid equivalent) per gallon diluted in water and applied as an overall spray. *Complete* coverage of foliage by the spray is essential and the spray volume required may range from 10-15 gallons per acre for mistblowers to 30-60 gallons per acre for knapsack sprayers, depending on the equipment used and the density of the growth treated.

60. For control of herbaceous weeds or a mixture of woody and herbaceous weeds, use a proprietary mixture of emulsifiable low-volatile 2,4-D and 2,4,5-T esters at 2-3 pints

per acre diluted as indicated in para. 59 and applied as an overall spray, as for 2,4,5-T.

Foliage Sprays to Woody and Herbaceous Weeds Before Planting

61. With modern techniques of cultivation, there is usually little call for the selective control of weeds before planting a forest crop. Species like bramble and gorse take at least 12-18 months to break down after spraying; if planting takes place before the woody tissues have decayed, there is still the expense of cutting the dead wood away by hand or by machine to get in. However, where necessary, herbicides can be applied to vegetation before an area is planted. Treatments are similar to those described in the previous section (paras. 56-60), except that, firstly, sprays should be applied between the time when leaves are first fully expanded in June and mid- or late August. Secondly, the rate of application is higher; 5 pints of 2,4,5-T or 3½ pints of a mixture of 2,4-D and 2,4,5-T are suitable. Equipment suitable for medium volume application of these materials is described below (paras. 92-128).

62. Where it is decided to apply a low-volume spray using a mist-blower, a better kill is obtained if the ester is first diluted in 3 gallons of diesel oil and this is added to 12 gallons of water to make the required 15 gallons of spray solution per acre. If an aircraft is used, the same procedure should be followed but using 2 gallons of diesel oil and 8 gallons of water. *This oil mixture must only be used on unplanted ground.*

Heather

63. Heather, *Calluna vulgaris*, and heaths, *Erica* species, can be controlled on unplanted areas by spraying at the rate per acre of 8 pints of 2,4-D ester containing 5 lbs 2,4-D (acid equivalent) per gallon diluted according to whether high or low volume spraying equipment is available. Sprays may be applied any time between early June and the end of August.

64. When the ground has been planted with conifers, the rate of 2,4-D ester should be reduced to 5 to 6 pints per acre and the spray applied in the second half of August or very early in September, otherwise the planted crop will suffer damage. Ground planted with hardwoods should not be sprayed against heather.

65. Tall "leggy" heather is often difficult to control, whereas short, leafy heather is killed most readily. The difference in response is probably related both to the leaf area available to absorb the herbicide and to the length of woody stem between leaf and root through which the herbicide has to be translocated. The more leaf and the shorter the stem, the better the kill.

66. Where plantations are to be fertilized with phosphatic fertilizers, with or without nitrogen as well, it is worthwhile deferring spraying for one or two growing seasons after application so that the heather can form more foliage in response to the fertilizer and so increase the area of leaf available for absorption and translocation of the 2,4-D.

Heather and Bees

67. Bees are attracted to heather when in flower. Ideally for the bees, sprays should be applied when the heather is *not* in flower, but in practice, this is often out of the question if heather is to be sprayed while it is still susceptible and after the crop has hardened up sufficiently. In such circumstances, any beekeepers with hives on or near the sprayed area should be notified well beforehand. Bees will normally avoid areas sprayed with 2,4-D. Nevertheless, 2,4-D can cause some mortality in bees if a thousand acres or more are sprayed at one time and bees in the locality have no alternative nectar sources.

CONTROL OF PERENNIAL GRASSES AND OF GRASSES MIXED WITH BROAD-LEAVED HERBACEOUS WEEDS.

68. Competition by perennial grasses in

young plantations is a common condition and often retards crop growth. Grass weeding by hand is expensive, and the chemicals *dalapon* and *paraquat* reduce weeding costs. Both may be applied before or after planting though with *dalapon*, application after planting, is restricted to a particular period if the crop is not to sustain damage. *Paraquat* has been more widely used than *dalapon*. *Chlorthiamid* has also been used but on a small scale.

69. Both *dalapon* and *paraquat* act by penetration through leaves of grasses, but *dalapon* is also taken up through grass roots. *Dalapon* is best applied in water as a spray to actively growing grasses; it acts fairly slowly and may persist in the soil for two-three weeks.

70. *Paraquat* may be applied to green grass whether growing or dormant, but should not be put onto bare soil as it will be inactivated rapidly. The effect of *paraquat* is apparent within two or three days and sometimes within a day in the summer, but in the winter two weeks may pass before any effect can be seen. *Paraquat* is inactivated within a short time of reaching the soil and has no effect at all on roots or rhizomes unless translocated down from the shoots.

71. Grass species vary in sensitivity to *dalapon* and *paraquat* sprays. Thus, *Molinia*, *Nardus*, *Agrostis*, *Deschampsia* species and *Holcus lanatus* are susceptible or moderately susceptible, while *Calamagrostis epigeios*, *Agropyron repens* (couch) and *Holcus mollis* are more difficult to control.

Dalapon has little effect on broadleaved weeds, but *paraquat* is effective in the summer against most broadleaved herbaceous species, killing top growth but having relatively little effect on perennial root-stocks and rhizomes which usually sprout again soon after treatment.

72. PARAQUAT MUST NOT BE APPLIED THROUGH A MISTBLOWER EXCEPT WHERE THE OPERATOR CAN AVOID OR CAN BE PROTECTED FROM



PLATE 5. Dense bramble in an experiment. Foreground sprayed with a low volatile ester of 2,4,5-T formulated as an emulsifiable concentrate. The rate of application was 2 lb 2,4,5-T (acid equivalent) per acre. The spray was applied in the summer by mistblower. Background, Control, unsprayed. (Swaffham, Thetford Chase Forest, Norfolk).

INHALING DROPLETS OF PARAQUAT SPRAY. THIS TECHNIQUE IS NOT RECOMMENDED.

Grass Control Before Planting

Dalapon

73. Dalapon can be applied up to 3 weeks of the date of planting without risk of damage to the crop, but it must be put on while the grass is growing fairly vigorously. A more complete kill of rough deep swards is obtained if, before spraying, they are burned, grazed or mown down to encourage fresh growth. Best results are likely if the spray is applied not more than six weeks before planting.

74. Sprays may be applied in September or October for autumn planting, or in March or early April for spring planting, using 15 lb of dalapon (commercial product) in 30-40 gallons of water per acre. Do not spray immediately before or after rain. Knapsack sprayers can be used although they are rather slow; large areas are best treated using a tractor-mounted boom-sprayer.

Paraquat

75. Paraquat may be used to kill grasses up to three days before planting. For each acre to be treated, $\frac{1}{2}$ to 1 gallon of commercial concentrate containing paraquat (i.e. 1-2 lb active ingredient) should be diluted in 50 gallons of water and sprayed on vigorous grasses. The higher rate will be necessary in thick grass mats, or where the less susceptible species listed in para. 71 predominate. The grass must be green when treated; paraquat has no effect on any parts of the grass above ground which are dead and dried at the time of spraying. Such dead grass if plentiful can effectively screen the live parts and protect them.

76. Sprays of paraquat in the late summer, autumn or winter on green grasses have also been remarkably effective and have killed some species (e.g. *Festuca* and *Dactylis*) better than when these have been sprayed in

the spring or early summer. On the other hand, *Molinia* and some *Agrostis* species appear to be best controlled by sprays in July or August and often survive autumn spraying.

77. Both paraquat and dalapon may be sprayed on to strips or patches. Young trees may then be planted in the middle of the treated areas. This will substantially reduce the cost of chemical required per acre planted.

Chlorthiamid

78. Chlorthiamid granules ('Prefix') have been used on ground before planting. Late autumn or winter applications in 30-inch wide strips at 55 lb granules per treated acre have given one season's control and have not damaged Corsican pine planted eight weeks after treatment. This treatment has not yet been widely tested and can only be recommended for small-scale trial with resistant species. (See para. 81 below).

Grass Control in Planted Areas

Dalapon

79. Dalapon can be used to control grasses without damage to the young crop, provided that spraying is restricted to periods when the crop is dormant, and that the application rate does not exceed 12 lb dalapon (commercial product) per acre. Best results have been obtained spraying during the period *mid March to late April*, using dalapon at 12 lb of commercial product in 30 to 40 gallons of water per acre sprayed. The treatment is best applied in strips 3 feet wide along each row, directing the spray to minimise the wetting of the crop plants. This can be done with a lance fitted with a single jet spraying one strip eighteen inches wide along the two sides of each row, or a short boom with two jets arranged to spray both sides of a row close up to the trees. If the kill of grasses in the first year after spraying is incomplete, or there is much germination of grass seeds already in the soil, it may be necessary to repeat the treatment. A lower rate of 6 lb

dalapon (commercial product) per acre may suffice if regrowth is weak, otherwise the rate previously recommended should be used.

Paraquat

80. Paraquat may also be used in young plantations at $\frac{1}{2}$ gallon of commercial product (1 lb active ingredient) in 30–40 gallons of water per sprayed acre, but only where both foliage and bark of the trees can be effectively protected from direct contact with the spray. This treatment has proved effective and relatively inexpensive, and is now widely used in grassy areas.

Chlorthiamid

81. Chlorthiamid is chiefly available as a granule under the brand name of "Prefix", for patch or strip application to grass and herbaceous broadleaved weeds. It has been quite widely tested but is not, so far, used on a large scale. The recommended rate is 1/5 oz per square yard (55 lb of 7½% granules per treated acre). It should be applied in March and April and can then only be provisionally recommended for use in young plantations of Corsican pine, Lodgepole pine, Sitka spruce, oak, beech and sycamore. Young Norway spruce and Scots pine have often survived and grown well, but there have been instances of damage. It is difficult to ensure an even spread of the small quantity of granules required for each tree over the correct radius. Failure to do so usually results in over-dosing some part of the treated patch. If the over-dosed area happens to be near the young tree, this may be damaged or even killed. It is probable that damage reported on Norway spruce and Scots pine has originated in this way.

82. The granules are usually applied to circular patches 1 ft. 8 in. in radius (corresponding to 1 sq. yard). However, in some Corsican pine areas in East Anglia, where tractors can easily straddle planted rows, two strips 30 in. wide have been treated at one pass, with a row of trees down the centre of

each strip. This treatment has been accurate and results have been good.

Grass Control in Fire-breaks

83. Paraquat may be sprayed onto fire-breaks at $\frac{1}{4}$ – $\frac{1}{2}$ gallon of commercial product in 20–60 gallons of water per acre. Sprays applied between mid-July and mid-August can be expected to leave the grass dry and inflammable within a few days of spraying. The treated area should be burned off while the adjacent grass is still green. See Plate 4. This technique is used mainly in areas where *Molinia caerulea* is dominant.

Mixed Herbaceous Vegetation in Planted Areas Paraquat and Diquat Mixtures

84. While paraquat is more effective in vegetation dominated by grasses, a mixture of paraquat and diquat at the same rate as for paraquat by itself ($\frac{1}{2}$ gallon of commercial product in 30–40 gallons of water per acre) may be preferable where there is a substantial proportion of broadleaved weeds present. Neither bark nor foliage of young trees must come into contact with the mixture.

BRACKEN

85. Bracken constitutes a major weed problem in plantations in many hill areas. Of the many chemicals tested, dicamba has shown most promise in controlling this weed economically. However, it can at present only be recommended if applied before planting; dicamba applied after planting for bracken control may cause too much damage to the crop.

86. Dicamba is provisionally recommended for unplanted land at 4 lb per treated acre, applied in March–April in strips 3 ft. wide with 3 ft. between adjacent strips. Such treatment has given good to complete control of bracken for two to three years following treatment. Treatment at 2 lb per acre has reduced the vigour of bracken for one to two years but is not so reliable. Crops planted in the autumn following treatment benefit from control of bracken for one or two years after planting.



PLATE 6. Grass-weeding young Corsican pine using "Arbogard" shield. Twin jets either side of shield swing in arc while spraying, so that a patch around the tree approximately a square yard in area is sprayed, while the shield remains stationary. (Alice Holt Forest, Hampshire).



PLATE 7. Detail of "Arbogard" shield shown in Plate 6. Note tree and actual jets of spray, just above shield.

TABLE
COMPARATIVE COSTS OF TREATING WOODY WEEDS

<i>Type of Growth</i>	<i>Treatments</i>	
	<i>Method of Application</i>	<i>Chemical</i>
Stumps (See also note (v) for Rhododendron)	Sprayed to run-off	a. 2,4,5-T
		b. Ammonium sulphamate (species resistant to 2,4,5-T only).
Stems whether under 4 in. and given 'basal bark' spray, or over 4 in. and frill girdled.	Sprayed to run-off	a. 2,4,5-T
		b. Ammonium sulphamate (Species resistant to 2,4,5-T only).
Over 4 in. and notched.	Dry crystals in notch	Ammonium sulphamate
Young woody regrowth & bramble. (See note (v) for Rhododendron)	Overall spray	2,4,5-T
Heather	Overall spray	2,4-D

- Notes:*
- (i) All costs of materials have been calculated on the basis of prices for purchases of large quantities of the herbicides: to get an idea of the cost where small quantities are purchased, it is suggested that the prices given be increased by about 30%.
 - (ii) All costs of application exclude all overheads. In all cases a range of figures is given; the actual direct cost depends on the size of the area (large areas are usually relatively cheaper to treat than small ones), and on the ground conditions.
 - (iii) No charge has been made for water. Nevertheless in some areas the cost of carrying water to the site will add appreciably to the cost of treatment.

5

USING 2,4-D, 2,4,5-T OR AMMONIUM SULPHAMATE (IN 1968)

Rate of Dilution	Typical volume used per planted Acre	Costs (Spring 1968)				
		Materials Per Acre	Application (including 40% labour on-cost)			
			Knapsack Medium Volume	Tractor Medium Volume	Mist-blower Low Vol.	Aircraft Low Volume
1½ gallons unformulated ester in 100 gall. of diesel oil.	25-40 galls. of solution	£3.5— £5.5	£2—£3	£2.5— £4	Not Applic.	Not Applic.
4 lb. per gallon of water.	„	£7— £11.10	„	„	„	„
1½ gallons unformulated ester in 100 gall. of diesel oil.	35-50 galls. of solution	£4.10— £6.10	£2.10—£3.10 for trees under 4" £3.10—£5 for trees frilled	Not	Applicable	
4 lb. per gallon of water.	„	£2.10— £3.15				
(Not diluted; applied dry)	50-100 lb dry crystals	£3.15— £7	£3.10—£5 for notching trees			
2½-5 pints of emulsifiable ester (50% a.e.) in either 40-75 gallons of water (high vol.) or 10-20 galls. of water (low vol.).	40-75 10-20	£1—£2	£4.10—£6.10	£1—£2	£2.15-£3	£2-£3.10
6-8 pints emulsifiable ester (50% a.e.) in 40-60 galls. of water (high vol.) or 10-20 galls. of water (low vol.).	40-60 10-20	£1—£1.5	£1.15—£2.10	£1.5-£1.10	15s-£1.10	£2-£3.10

(iv) In 1968 there is little difference in price between unformulated and formulated ester per lb of active ingredient. 2 gallons of 50% emulsifiable concentrate will contain the same quantity of 2,4,5-T as 1 gallon of unformulated ester and may be used instead, wherever the unformulated ester is recommended.

(v) Rhododendron stumps and regrowth may be sprayed with 2,4,5-T at 2½ gallons unformulated ester in 100 gallons of diesel oil per acre. The volume required for stumps may be up to 40-60 gallons per acre depending on the height and density of weed. The cost of materials ranges from £7—£36 per acre.

TABLE
COMPARATIVE COSTS OF TREATING

<i>Type of Growth</i>	<i>Method of Application</i>	<i>Date of Application</i>	<i>Chemical</i>
POST-PLANTING Grasses and herbs.	Square yard patch per tree using shield.	When grass is green.	Paraquat
Grasses.	As above	Mid March to late April.	Dalapon
PRE-PLANTING Grasses and herbs.	Strips 3 ft. wide, 3 ft. untreated between.	When grass is green.	Paraquat
Grasses.	As above.	Sept./Oct. or Mar./Apr.	Dalapon

Notes (i) to (iii) of Table 5 apply equally to this table.

* When spraying by mistblower, the whole area is treated and the cost of dalapon per acre has to be doubled.

6

PERENNIAL GRASSES AND HERBS

<i>Dilution rate per acre sprayed</i>	<i>Cost (Spring 1968)</i>			
	<i>Material per Acre planted at 6' x 6'</i>	<i>Application (including 40% labour oncost)</i>		
		<i>Medium Volume</i>		<i>Low Volume Mistblower</i>
		<i>Knapsack</i>	<i>Tractor</i>	
$\frac{1}{2}$ gall. in 40 galls. water	14s.	£1 15s.	£1	Not applicable
12 lb in 40 galls. water.	13s.	£1 15s.	Not applicable	„
$\frac{1}{2}$ gall. in 40 galls. water	£1 8s.	£3	15s.	„
15 lb in 40 galls. water.	£1 12s.	£3	15s.	£2—£3*

87. Dicamba has little effect on established grass under bracken. Following treatment of the bracken, any perennial grass may be expected to spread. Trees may be planted three to four months after treatment. In practice, this means in the autumn of the year of treatment, or the following spring.

88. Paraquat applied in May or June at 1-2 lb per acre (4-8 pints of formulation) will defoliate bracken but only affects the fronds which have emerged at the time of treatment.

POPLAR PLANTATIONS

89. Poplars in the first two to three years of growth following planting can be seriously checked by weed competition. The best means of overcoming this is to lay a mulch of cut vegetation in a two- to three-foot radius around each plant. Such mulches not only control weeds but also provide a source of nutrients. Black polythene sheet has been used but is costly and difficult to fix down securely. Straw may be used but is also costly.

90. Paraquat at 1 lb per acre (4 pints of formulation per acre), applied as a medium-volume spray, may be used as an alternative to a mulch, but poplar growth is not quite so good on sprayed plots as on those mulched with cut vegetation. Sprays should be repeated whenever weed growth requires.

COST OF TREATING WOODY WEEDS

91. Tables 5 and 6 give the relative costs of materials and application by the various techniques outlined in this section.

The costs of application exclude all overheads and are based on actual costs, except for the upper limit for aircraft application which is based on a quotation for a series of isolated 50 acre blocks to be sprayed with 2,4-D.

EQUIPMENT

92. For most operations described in the preceding paragraphs, choice of the most suitable equipment has to take into account

the scale and duration of work, accessibility to machines and, if aerial spraying is possible, availability of landing strips. The notes that follow describe equipment and opinions of late 1968 and will become somewhat out of date as manufacturers improve equipment, and advances are made in techniques leading to a higher or more effective rate of work. A booklet describing methods and equipment developed by Forestry Commission Work Study teams is in preparation but is unlikely to be available before the end of 1969.

Distribution of Materials

93. The method of bulk distribution of spray solution can have a big effect on working costs, and specifically on the amount of time lost in operations such as walking back to refill an empty sprayer. How and where spray solutions are distributed depends very much on local conditions, but everywhere the most economical system is likely to be a compromise between low-cost bulk movement and bulk storage and the need to reduce 'on-site' lost time by having materials well distributed in small lots.

94. Bulk storage of oil in tanks such as illustrated in Plate 8, by economies in purchasing covers the cost of the storage tank and its installation after the tank had been filled three times and the contents used. However, provision then has to be made for distribution to the spray location from the bulk store. The cost of weedkillers in 45-gallon drums is normally less than when in 5 gallon drums. However, the larger drums are too heavy to be manhandled easily and provision has to be made for emptying them, for example by a pump like that illustrated in Plate 8.

Knapsack Sprayers

Knapsack sprayers for medium volume applications

95. There are three main designs of manually operated knapsack sprayers:

- (i) sprayers into which air is pumped before

- use (Pressurised knapsack sprayers);
- (ii) sprayers pumped intermittently as a man works; (Plate 2);
- (iii) sprayers emptying by gravity either into a perforated ("dribble") spray bar or into a lance carrying a small pump and shield ("Arbogard") (Plates 6 and 7.)

The pumped sprayers can be used for placed sprays such as basal bark and stump sprays, and for spraying a patch round each tree in young plantations. The "Arbogard" is designed for patch spraying and has the advantage that a constant, predetermined volume of spray solution is automatically applied to each patch. Lances with Shield attached (e.g. the "Politec") and suitable for patch spraying can also be attached to pumped knapsacks.

96. Lightweight plastic knapsack sprayers with a capacity for 4 gallons of spray (Plate 2) have been shown to be cheaper to use than sprayers with 2-3 gallon capacity as less time is spent walking back to refill them; however, when full, the operator is carrying 50 lb on his back which can be particularly strenuous on rough ground.

Knapsack Accessories

97. Knapsack delivering spray under pressure should have:

- (i) a trigger on-off tap on the lance;
- (ii) a pressure gauge (available, if not constantly in place) on the lance to check on the working pressure;
- (iii) an adjustable pressure control valve;
- (iv) jets which operate efficiently at 5-10 pounds per square inch working pressure, spreading a fan of spray droplets (e.g. "Floodjets" or "Polijets"). Jets giving a hollow cone or fan and requiring 20-30 lb p.s.i. working pressure may be used, but are less satisfactory as they create more fine droplets which are likely to drift. For basal bark spraying, an adjustable jet capable of giving any pattern from a pencil-wide stream to a wide hollow cone, facilitates treatment, especially of coppice stems.

Knapsack mistblowers for low-volume treatments

98. Mistblowers deliver a small volume of liquid as small droplets in a large volume of air to a distance of fifteen feet or more. Mistblowers are well suited to overall foliage treatments at a low volume of spray per acre, but are not suitable for placed applications such as stump or basal bark sprays.

Tractor-mounted equipment

99. Tractor-mounted or Land Rover-mounted spray equipment has so far found little place in forest weeding. Tractors fitted with agricultural spray booms have occasionally been used to spray grass before planting, while recently four hoses and lances have been run from a tractor-mounted sprayer for applying sprays in young plantations. A tractor-mounted granule spreader used for chlorthiamid ("Prefix") granules has been used successfully in young Corsican pine plantations on flat areas in East Anglia. However, the scope for any of these systems is limited to relatively flat areas.

Sledge-mounted equipment

100. A pressure hose, live reel and pump mounted on a sledge has recently been developed. In this arrangement, known as "Pharos" (Pressure Hose And Reel On Sledge), spray is pumped from a portable storage tank on the ride side through 500 feet of main line which then divides to 2 or 4, 125 feet side lines, each of which terminates in a standard spray lance and jet. "Pharos" sprayers were first available commercially in 1968.

Hoses used on spray equipment

101. All rubber hoses through which spray solutions pass must be made of oil-resistant rubber, even if the diluent is water, as the rubber may pick up oily components from the concentrate. Such hoses should be used exclusively for herbicides. If used for other forms of crop-spraying, and in particular pre- and post-emergence oil sprays in forest

nurseries, it is essential for hoses (and containers also) to be thoroughly washed out, first with oil and then with detergent and water. Hoses have retained growth-regulating herbicides even though well washed out with water, and have subsequently released them with devastating effect into oil intended as a post-emergent spray to conifer seedlings.

CLEANING OF EQUIPMENT

102. All equipment must be cleaned thoroughly, immediately after use. This is particularly important after using 2,4-D or 2,4,5-T. With these materials, spraying equipment should be cleaned immediately after use by pouring a volume of diesel oil into the tank and recirculating it through the sprayer, pump and spray lines, and back into the tank. This oil should then be sprayed out onto waste ground and replaced by a large volume of water containing a wetter or detergent. This should again be circulated thoroughly through the sprayer, and sprayed out onto waste ground. Finally, all parts should be washed through with clean water.

103. If equipment used for applying growth-regulating herbicides is not washed out meticulously after use, subsequent sprays may be contaminated and may cause substantial damage. Failure to clean equipment properly is known to have resulted in crop damage and financial loss on farms, forests and in forest nurseries.

104. Equipment which has been used for ammonium sulphamate solution must be washed and sprayed out thoroughly with clean water immediately after use, and metal parts thoroughly smeared with light engine oil.

105. ALWAYS SPRAY OR POUR WATER OR OIL USED FOR WASHING OUT SPRAY EQUIPMENT ONTO WASTE DRY GROUND WHERE IT CAN PERCOLATE INTO THE SOIL. NEVER WASH OUT NEAR WELLS. NEVER POUR WASHINGS INTO DRAINS, DITCHES OR STREAMS!

AERIAL SPRAYING

106. Aerial spraying is unique in being the only operation in weed control which is always carried out by contractors who normally have little contact with forestry. Because of this, aerial spraying requires particular care in planning and special organisation. The particular features of aerial spraying are listed below.

107. The volume per acre is low compared with most other spray techniques, therefore in order for the herbicide to be distributed evenly over all parts of the target, droplets have to be small. While the larger droplets will fall to the ground quickly, the smaller ones will drift down slowly. The optimum droplet diameter for spraying is 350 microns (0.35 mm) achieved by spray pressures between 25 and 35 p.s.i.

108. The aircraft, whether fixed wing or helicopter, has to fly several feet above the highest part of the crop and creates considerable turbulence. There is therefore plenty of opportunity for the wind to pick up the smaller droplets and carry them onto adjoining areas.

109. Winds at ground level are, on average, least at dawn and at dusk. The first two or three hours after sunrise and the last hour or two before sunset are times when the risk of drift is least. Wind speeds of up to 10 knots are normally acceptable when spraying. Spraying may also proceed in stronger winds up to 15 knots, if clearly blowing away from all susceptible crops.

110. Aircraft work quickly but are expensive. Aerial spraying contractors usually have a full programme and have to work one job in with another. The weather is usually the decisive factor, in particular, wind speed and direction. Supervisors and ground markers must be prepared to turn out early or late and must expect last-minute alterations of plan and in particular, delays.

111. At the present time, there is no evidence that helicopters have any technical advantage

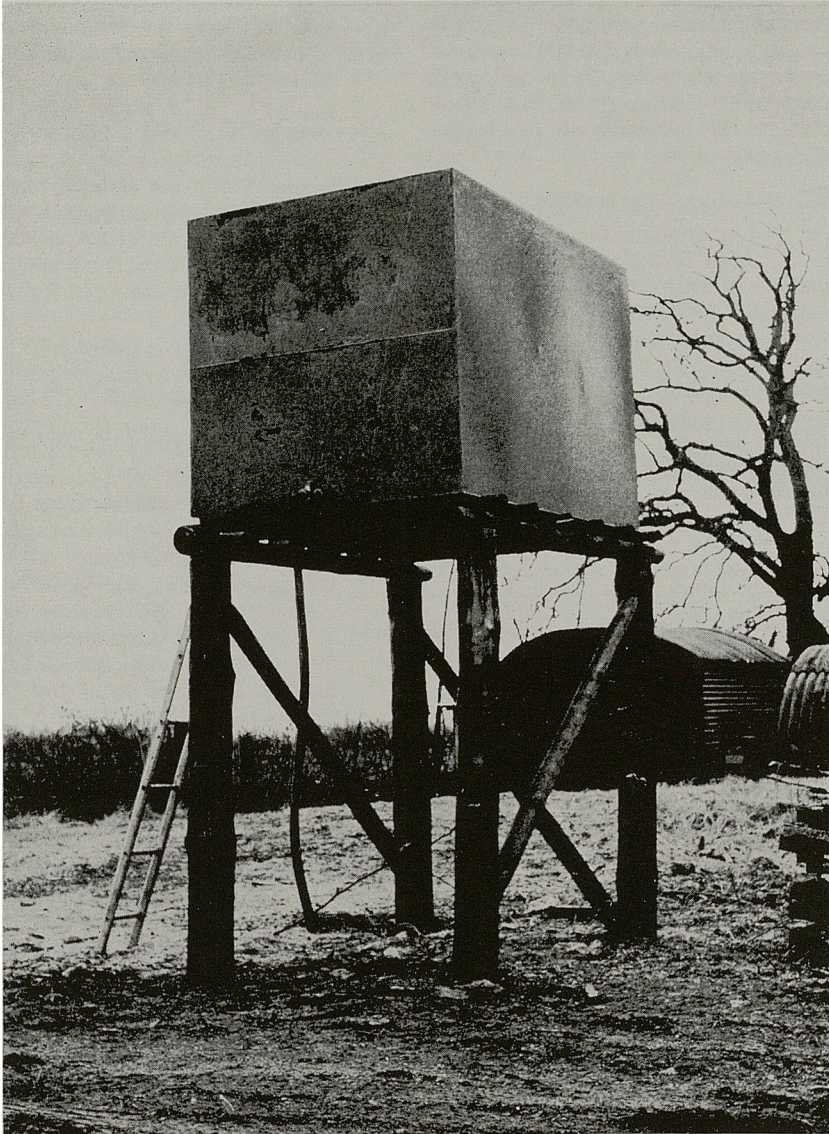


PLATE 8. A 600-gallon tank for diesel oil on a locally-made base of creosoted posts. The tank is sufficiently high to empty itself by gravity into tanks on any transporting vehicle.

over fixed-wing aircraft. Which is chosen will depend on the distance of landing facilities from the area to be sprayed and the consequent cost per acre sprayed. In flat country and where convenient landing strips are near at hand, fixed-wing aircraft are likely to be cheaper than helicopters.

Selection of area and preliminaries

112. Any area for spraying should be decided 6–9 months ahead of the spray date so that preliminary enquiries can be made and requests to tender or firm negotiations started at least 3–4 months before the date of spraying. Terms should have been agreed two months ahead of the operation.

Buffer Zone

113. It may be desirable to leave a boundary strip for example to conceal the brown foliage of treated weeds in an area of high amenity, or to leave a safety margin between the sprayed area and susceptible crops. At least 400 yards should separate greenhouses and orchards from the nearest area aerially sprayed.

Nature Reserves and Sites of Special Scientific Interest

114. The Nature Conservancy Regional Officer for the locality must be informed at the very first opportunity if land including or adjacent to nature reserves or Sites of Special Scientific Interest (S.S.S.I.s) are to be sprayed from the air.

The Spray Contract

115. When arranging an aerial spraying contract, the following points should be taken into account.

- (i) *Rate and formulation of material to be used.* Often there is only one formulation commercially available. However, where there is any choice, the less volatile materials should be selected if high temperatures are possible in the few days following spraying. See para. 11.

- (ii) *Limits of period* during which sprays may be applied.

- (iii) *Third-party claims.* It must be clearly agreed both who is responsible for claims by third parties in the event of damage to neighbouring crops and the procedure to follow should a claim be made. (Should any claim be received, all staff must clearly understand that nothing other than a bare acknowledgement of receipt of the claim should be made until the claim has been fully investigated.)

- (iv) *Responsibility for spraying.* It must be clearly agreed who has the final decision if spraying conditions are marginal. Normally, the pilot should carry this responsibility as he will have infinitely more experience of spraying than any forester. However, the forest owner or his agent may wish to have the last word in certain circumstances.

- (v) *Services required,* e.g. location of and access to landing strip; supply of water diluent; storage tanks or bowsters; refilling procedure; radio contact between landing strip and spray area; ground markers, how many, where and how controlled.

Arrangements after signing the contract and before spraying

Supervision of Operation

116. One supervisor (and a deputy if possible) should be nominated to be in charge of the ground operation, and his duties and responsibilities should be clearly defined. Because of the likelihood of short-notice changes of plan, this man should be freed from other definite commitments during the period when spraying is likely to take place. He must also be free to take part in any planning discussions beforehand.

Training of Marker Men

117. If ground markers are required, the distance between consecutive flight paths, likely

directions of flight and any special arrangements must be discussed with the contractor and a procedure agreed, sufficiently before the event, for the men involved to be instructed and rehearsed.

For even spray distribution, the aircraft must fly uniformly-spaced parallel courses over the whole area. Ground markers can be of the greatest assistance, but the men handling the markers must be clearly instructed so that there is an unambiguous indication of the next line of flight *immediately* one line is finished. Markers must be clearly visible from the air from all angles. Men handling markers must know what to do if an aircraft runs out of spray, part way down a run.

Survey of Adjacent Crops

118. Where blocks of forest near farm land are to be sprayed, details of all crops should be noted in a zone $\frac{1}{2}$ – $\frac{3}{4}$ mile around the perimeter of the area to be sprayed, paying particular attention to orchards, seed crops especially crops of the cabbage tribe, (*Brassicacae*), glasshouses, the location of farms running pedigree stock, Nature Reserves, Sites of Special Scientific Importance and beehives. A map on the scale 1:10,000 (6 inches to the mile) is ideal for recording such details. As part of the pre-spray routine, most contractors carry out a survey from the air or by Land Rover. However, it is in everyone's interest for local forest staff to supplement the contractor's survey information from local knowledge.

Informing Neighbours

119. It should be agreed with the contractor who will be responsible for informing neighbours and other interested parties such as shooting tenants and beekeepers and the nature of information given. Normally, the approximate date of spray and the chemical to be used should suffice. See also para. 67.

120. A meeting between the contractor and the forester or other member of the staff who

is to be responsible for ground operations should be planned for 10–14 days before the expected date of spraying, to go over the details of the final arrangements. The survey of adjacent crops should have been completed by this date and a list made of neighbours who have been informed that spraying is likely.

SAFETY PRECAUTIONS

PROTECTION OF THE OPERATOR

Recommendations made under the Pesticides Safety Precautions Scheme

121. The requirements set out in the recommendations sheets issued under the Pesticides Safety Precautions Scheme (P.S.P.S.) administered by the Ministry of Agriculture, Fisheries and Food, are given below. These requirements are also printed on all containers in which these herbicides are sold.

Paraquat: (P.S.P.S. Recommendation Sheet 331 of 1.12.67). Wear Rubber Gloves and face shield when handling concentrate. Wash concentrate from skin or eyes immediately. Avoid working in spray mist. Wash hands and exposed skin before meals and after work.

Diquat: (P.S.P.S. Recs/312 of 1.11.67). As for Paraquat except that no reference is made to a face shield.

2,4,5-T: (P.S.P.S. Recs/169 of 24.1.67). Wash concentrate from skin or eyes immediately. Wash hands and exposed skin before meals and after work.

2,4-D: (P.S.P.S. Recs/165 of 24.1.67). As for 2,4,5-T.

Dalapon: (P.S.P.S. Recs/282 of 1.8.67). Dalapon is irritating to the eyes and can be to the skin. Remove heavily contaminated clothing immediately. Wash splashes from skin or eyes immediately. Wash hands and exposed skin before meals and after work.

Ammonium sulphamate: (Unnumbered sheet dated 8.2.65). Wash concentrate from

skin or eyes immediately. Avoid working in spray mist. Wash hands and exposed skin before meals and after work.

Dicamba: (P.S.P.S. Recs/203 of 1.2.67). Wash concentrate from skin or eyes immediately. Wash hands and exposed skin before meals and after work.

Chlorthiamid: (P.S.P.S. Recs/202 of 1.2.67). Wash hands before meals and after work.

Oil diluents: No sheets are issued covering the use of oils as diluents. However, Ministry of Agriculture advisory leaflets draw attention to the risk of dermatitis if working with oil, especially diesel oil for long periods. For this reason, it is recommended that protective gloves are used when working with 2,4,5-T in oil.

Implementation of Recommendations

122. None of these recommendations come within the scope of the Agriculture (Poisonous Substances) Regulations, and so cannot be enforced by processes of law. Nevertheless, it is considered to be an unavoidable duty of a good employer to implement the P.S.P.S. recommendations as regards his employees. How this is done depends on local circumstances, and in particular on the length of time any man will be working with a particular material.

Protective Clothing

123. Recommendations for protective clothing are given in Table 7.

They are made on the assumptions:

- (i) that workers concerned are likely to remain on such work for several days at a time;
- (ii) that the vegetation sprayed at medium volume rates is likely to be treated by knapsack and lance operating at low pressure and spraying at up to knee-height. In such circumstances, spray solution can be transferred back to the operator as he walks; hence the need for

oil-proof (and water-proof) trousers and boots; paraquat is sprayed onto grasses not more than 9 inches tall and water-proof trousers are not essential if wellington boots are worn;

- (iii) that low-volume sprays are applied by aircraft or mistblower, and droplets are likely to cover the vegetation at least up to waist height and sometimes higher. In gusty winds, occasional swirls of droplets may envelop the operator. These can, and should, be minimised by working so that the spray blast is directed down wind from the position of the operator;
- (iv) the equipment is maintained in good order with a well fitting leak-proof filling lid and joints that do not leak, and that care is taken in filling not to get spray solution outside the container wiping off splashes that may run down and drip onto the operator;
- (v) finally, while for operations such as handling concentrates, protective clothing is obligatory for the safety or well-being of the operator, for other operations it is intended to reduce the risk of discomfort. As some of the protective clothing can itself be uncomfortable—for example on difficult terrain in hot weather, it is important to distinguish between what is essential and must be worn in all conditions, and what a supervisor may allow to be taken off at his discretion. Table 7 is laid out with this distinction in mind.

124. For all compounds, the P.S.P.S. recommendations sheets lay down that splashes of any concentrate must be washed from the skin or eyes immediately. It follows that if concentrates are to be handled in the forest, *washing water must be taken there too*. If this is impracticable, goggles must be worn to protect the eyes and a waterless skin cleanser and paper towels must be instantly available.

TABLE 7
PROTECTIVE CLOTHING WHEN USING HERBICIDES IN THE FOREST

CLOTHING	AMMONIUM SULPHAMATE solution			DALAPON IN WATER		PARAQUAT AND/OR DIQUAT IN WATER		2,4,5-T, 2,4-D OR 2,4-D/2,4,5-T MIXTURE IN WATER		2,4,5-T IN OIL	
	Crystals	Medium vol.	Low vol.	Medium vol.	Low vol.	Medium vol.	Medium vol.	Low vol.	Medium vol.	Low vol.	
BOOTS Oil-resistant Wellington	N	E	E	E	E	E	E	E	E	E	
TROUSERS Oil and thorn-proof	N	E	E	E	E	E	E	E	E	E	
JACKET Oil-proof and thorn-proof	N	D	E	D	E	D	D	E	D	E	
GLOVES P.V.C., polythene or rubber protective	E	E	E	E	E	E	E	E	E	E	
FACE SHIELD	N	N	D	N	D	E/N(1)	N	D	N	D	
RESPIRATOR (3)	N	N	D	N	D	N	N	D	D	D	
WATER-PROOF HAT	N	N	D	N	D	N	N	D/E(2)	N	D/E(2)	

KEY TO TABLE 7

E = **essential**. Laid down under the Pesticides Safety Precautions Scheme or considered necessary in relation to working conditions in forestry.

D = **discretionary**. Must be available. Such items may reduce discomfort of the operator and so should be freely available but the final choice may rest with him after fair trial.

N = **not considered necessary**.

Notes.

(1) Face shield essential when handling paraquat concentrate but not otherwise.

(2) Waterproof hat must be worn by ground markers during aerial spraying.

(3) For all low volume sprays using water as diluent, a respirator or face mask designed to intercept droplets is quite adequate. For sprays using oil as diluent, a respirator designed to intercept vapour is necessary if the smell of the oil causes discomfort.

It is also stated that in all circumstances workers should wash before meals and after work. Soap and water must be available at such times, or a waterless skin cleanser and paper towels. A source of supply of suitable materials is given in para. 151.

125. Respirators are mentioned in Table 7 because some workers have experienced discomfort when working with diesel oil for long periods. The requirement "avoid working in spray mist" for paraquat and ammonium sulphamate can also be met, as far as the nose and mouth is concerned, by wearing a respirator or a mask capable of filtering out all fine droplets. However, it should not be necessary to create a spray mist; both materials, ammonium sulphamate and paraquat, should be applied to low-growing vegetation by knapsack operating at 10 lb pressure or less. Ammonium sulphamate solution may be applied to frills from a container emptying solely by gravity. By keeping the spray nozzle down, working at low pressure, and keeping upwind of the spray nozzle, operators run no risk of working in a spray mist.

126. The requirement of a face shield when handling paraquat concentrate can be met by using goggles such as are listed in para. 151, provided means are instantly to hand to wipe off splashes from skin of the face and mouth. Otherwise a face shield should be worn.

127. The requirement to wear gloves when handling paraquat concentrate can be met by use of heavy P.V.C. gloves. Such gloves are also suitable when working with 2,4,5-T in oil. Thin rubber, unlined gloves are too easily torn to make them a practical proposition when using herbicides in forest conditions. However, it is vital that the lined gloves recommended are examined regularly and frequently to see that they are sound and clean. They achieve the exact opposite of what is intended if the lining absorbs any herbicide and holds it against the operator's skin. Another alternative is thin polythene gloves which are used once and then thrown away.

128. Barrier cream rubbed into the skin and hands and wrists reduces the risk of dermatitis and is recommended when using oil for long periods, especially by operators whose skin is easily inflamed.

PROTECTION OF NEIGHBOURING CROPS.

129. Both 2,4-D and 2,4,5-T can cause serious damage if spray is allowed to drift onto nearby susceptible crops. The risk is greatest with low-volume overall sprays, using a "mist-blower" or aircraft, but precautions must be taken during any spraying operation. Particularly vulnerable crops are in orchards, glass-houses and field crops being grown for seed.

The main points to observe are:—

- (i) Avoid spraying in areas immediately adjoining susceptible agricultural or other crops.
- (ii) For safety when aerial spraying, do not spray within 400 yards of a susceptible crop; this untreated strip should be dealt with by other methods.
- (iii) Always use low-volatile ester formulations to reduce risk of damage by vapour drift.
- (iv) Do not spray on very windy days. When there is a slight wind, spray downwind rather than upwind.
- (v) Keep the spray nozzles as near to the target as consistent with good distribution.

PROTECTION OF LIVESTOCK

130. Plants, in particular ragwort, (*Senecio jacobea*), which are normally unpalatable and which are poisonous to livestock may become palatable following foliage spraying. All livestock must be excluded from sprayed areas where such weeds may be growing for 3 to 4 weeks after spraying.

PROTECTION OF WILD LIFE

131. As far as is known, none of the substances used as recommended here will have



PLATE 9. Oak coppice, shortly after spraying with 2,4,5-T in oil ($1\frac{1}{2}$ gallons unformulated ester in 100 gallons of oil) as a basal bark spray. (Brechfa Forest, Carmarthen).

any direct ill-effect on mammals or birds. Some indirect effects are inevitable—such as the destruction of food plants on which some animals and insects may rely, but these plants would almost certainly have been suppressed in the course of normal forest growth; the use of herbicide will only have hastened an inevitable process. Should rare plants be known to be present in an area to be treated, they should be screened or their locality left unsprayed.

132. Any small patches of dense scrub which can be left in areas to be treated are likely to provide nesting sites for more birds than might at first be expected from the small area involved. Such areas are likely to provide a more valuable cover if they adjoin broad rides or fields.

PROTECTION OF WATER SUPPLIES

133. In all spraying operations, the greatest care must always be taken to avoid polluting water-courses or drinking-water supplies either when spraying or when cleaning up afterwards. Particular care must be exercised with overall sprays of 2,4-D or 2,4,5-T in areas where the water supply of farms or hamlets may come from the nearby stream.

Although the risks of poisoning human beings or animals by contaminating drinking water with any of the herbicides recommended here are negligible, such materials can make the water taste unpleasant. Therefore on no account must any herbicide be sprayed onto any open water surface, nor must water used to wash out containers or spray equipment ever be poured into streams or down drains.

134. The consequences of accidental spillage, leaking drums and carelessness when disposing of or washing out containers could be serious and lead to far higher local concentrations of herbicide than could possibly result from spraying. It is essential therefore to ensure that accidents and carelessness are kept to the absolute minimum.

135. *With proper care*, herbicides may be used in ground-water catchment areas (i.e. areas where part of the precipitation may percolate through permeable strata below the rooting depth of plants into wells and bore-holes to supply water for domestic or industrial needs), though if these are rented or leased from water authorities, their agreement must always be obtained beforehand. Studies have shown that all the herbicides recommended here break down in the soil and neither accumulate nor are likely to be leached from the soil. (Audus, 1960; Burschel, 1963). Other studies have shown that the oils used to dilute 2,4,5-T or 2,4-D are unlikely to penetrate more than a few inches into the soil and do not themselves constitute a threat to ground-water supplies (Linden et al., 1963).

136. In surface-water catchment areas (i.e. localities where run-off drains into water reservoirs or into streams supplying farms or hamlets with water), herbicides should not be used without the prior agreement of the local water authority. Where overall foliage sprays are applied, it is recommended that not more than one five hundredth of the total relevant catchment area be sprayed in any one week.

NOTES ON MATERIALS

2,4,5-T (2,4,5-trichlorophenoxyacetic acid)

137. The ester formulations of the growth regulating compound are available as:—

- (a) Unformulated 2,4,5-T esters: these usually contain about 10 lb per gallon (80%) 2,4,5-T (acid equivalent) and are somewhat cheaper than emulsifiable esters, but can only be used diluted in oils such as vaporising oil, diesel oil or gas oil. Unformulated esters should normally be used only for application to stumps, stems and frill girdles. If unformulated esters cannot be obtained, use twice as much emulsifiable concentrate containing 5 lb of 2,4,5-T (acid equivalent) per gallon. Waxoline Red O.S. dye may be added to 2,4,5-T



PLATE 10. Tree injector. This tool consists of a chisel cutting blade held rigidly in position to a tubular reservoir containing herbicide. In operation, the lever projecting upwards from the tube reservoir pivots at the base and operates a small pump so that a measured volume of weedkiller spurts down the blade into a newly-made cut. The tool seems best suited for treating single stems rather than multi-stemmed coppice stools.

in oil if it is necessary to mark the sprayed stems or stumps. See also para. 111.

- (b) Emulsifiable low-volatile 2,4,5-T esters: these are prepared so that the oily 2,4,5-T readily breaks up into very fine droplets to make a uniform milky suspension in water. They are normally used in water for foliage spraying of weed growth. Most ester formulations available contain 5 lb 2,4,5-T (acid equivalent) per gallon. See also para. 111.

2,4-D (2,4-dichlorophenoxyacetic acid)

138. In forestry, this compound is mainly of value for spraying foliage of heathers (*Calluna* and *Erica* spp.). For this purpose, the low-volatile nonyl ester of 2,4-D is suitable. Formulations used should contain 5 lb acid equivalent per gallon and be prepared for emulsification in water.

Mixtures of 2,4-D and 2,4,5-T

139. 2,4-D is particularly effective and relatively cheap for use against herbaceous species, but it is less active than 2,4,5-T against most woody species. Mixtures of the esters of each material are available; they are prepared for emulsification in water and should normally be used as foliage sprays. The ratio of 2,4-D to 2,4,5-T in such mixtures is usually 2:1.

Ammonium Sulphamate (A.M.S.)

140. This is highly soluble, crystalline solid which kills many woody species. A better kill is obtained if about 1 tablespoonful of non-ionic wetting agent (see para. 97) is added to each gallon of spray solution. When spraying randomly distributed stumps, a dyestuff such as either 'Methyl Violet 5807' or 'Hexacol Violet B.N.P. Extra' should be added to indicate which stumps have been sprayed. Of the two, the former is probably the better marker.

Chlorthiamid

141. This material is available as a granule containing 7½% active ingredient. It is marketed as "Prefix" by Messrs. Shellstar Ltd., 70 Brompton Road, London S.W.3.

Paraquat and Diquat

142. Both these compounds are formulated as a liquid for diluting with water. The concentrate contains 2 lb active ingredient per gallon. They corrode mild steel and galvanized steel and should not be stored in containers made of these metals. Polythene or P.V.C. containers are unaffected.

Dalapon

143. This is manufactured as the sodium salt, usually contains about 85% active ingredient. It is available commercially with or without a wetter. If the latter is purchased, it is advisable to add ½% of non-ionic wetter (para. 150) to the dalapon solution before spraying.

SOURCES OF SUPPLY

144. Currently approved brands of emulsifiable esters of 2,4-D and 2,4,5-T, separately and in mixture, can be found in the List of Approved Products prepared under the Agricultural Chemicals Approved Scheme by the Ministry of Agriculture, and issued annually free of charge. Copies can be obtained from the Ministry of Agriculture, Publications Department, Block C, Tolcarne Drive, Pinner, Middlesex.

145. Ammonium sulphamate is not mentioned in the List of Approved Products, because it is not in general use in agriculture. The names of some suppliers are therefore given below.

146. **Unformulated Esters of 2,4,5-T** may be obtained from:—

Shellstar Ltd., 70 Brompton Road, London S.W.3.

Plant Protection Ltd., Fernhurst, Haslemere, Surrey.

Agricola Chemicals Ltd., 30/32 Grays Inn Road, London W.C.1.

147. Ammonium Sulphamate from:—

Albright and Wilson Ltd., 69 Cabinet Chambers, Basinghall Street, Leeds 1.

148. Sodium Benzoate (corrosion inhibitor for use with ammonium sulphamate in brass or copper spraying equipment) may be obtained from many local chemists.

Marker Dyes

149. Waxoline Red O.S. to be added to 2,4,5-T in oil for stump spraying can be obtained from: I.C.I., Southern Region Sales Office, 81 High Holborn, London W.C.1.

'Methyl Violet 5807' to be added to the ammonium sulphamate for stump spraying can be obtained from: Hopkins & Williams, Freshwater Road, Chadwell Heath, Essex, and 'Hexacol Violet B.N.P. Extra' from L. J. Pointing & Sons Ltd., Dyestuffs Manufacturers, Hexham, Northumberland.

Wetting Agents

150. Several non-ionic wetting agents are suitable for adding to dalapon or ammonium sulphamate solution. These include 'Nonidet' made by Shellstar Ltd., and 'Agral 90' made by Plant Protection, Ltd.

PROTECTIVE CLOTHING

151. Descriptions, with approximate retail prices at July 1968, and suppliers follow:

Oil-proof and thorn-proof jacket and trousers (£6. 15s.).

Abridge Overalls Ltd., Victoria Road, Burgess Hill, Sussex.

Oil-proof Wellington boots: Semperit "Oil Boy" green, lined (65769 08—Mens) (£2. 7s.).

Semperit Rubber Mfg. Co. Ltd., Renwick Road, Barking, Essex.

Gloves

Plastochrome lined (blue) 540 with 2 inch cuff (49/- per dozen pairs).

James North & Sons Ltd., P.O. Box No. 3, Hyde, Cheshire.

Unlined Poligloves, disposable (250 pairs for 39/-).

Formpress Ltd., Sedgewick Hill, Murray Street, Manchester 4.

Eyeshield/goggles

Panoramette P.V.C. goggle (7/9d. each).

Pyrene Panorama Ltd., Hanworth Air Park, Feltham, Middlesex.

Eyeshield Type 6638 (£1. 10s. 9d. per dozen pairs).

Industrial Glove Co. Ltd., Nailsea, Somerset.

Face shield.

Clearways' Lightweight eye and face shield. Safety Products Ltd., Holmthorp Avenue, Redhill, Surrey.

Barrier Cream:

Rozalex No. 10 (7 lb £1. 10s. 8d.)
or

Rozalex Waterless Skin Cleanser (7 lb 15/-)

Both from Rozalex Ltd., Industrial Estate, Winsford, Cheshire.

Paper Towels (interfolded) (£3. 10s. for 1 case of 18 x 200 towels).

Jeyes-Parazone Sales Ltd., River Road, Barking, Essex.

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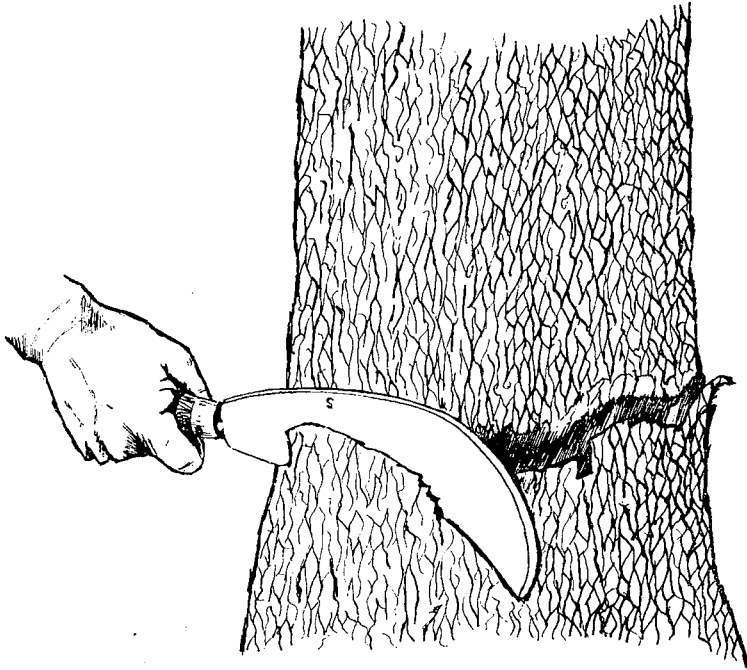


PLATE 11. Frill-girdling an oak with a bill-hook prior to the application of a herbicide.

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