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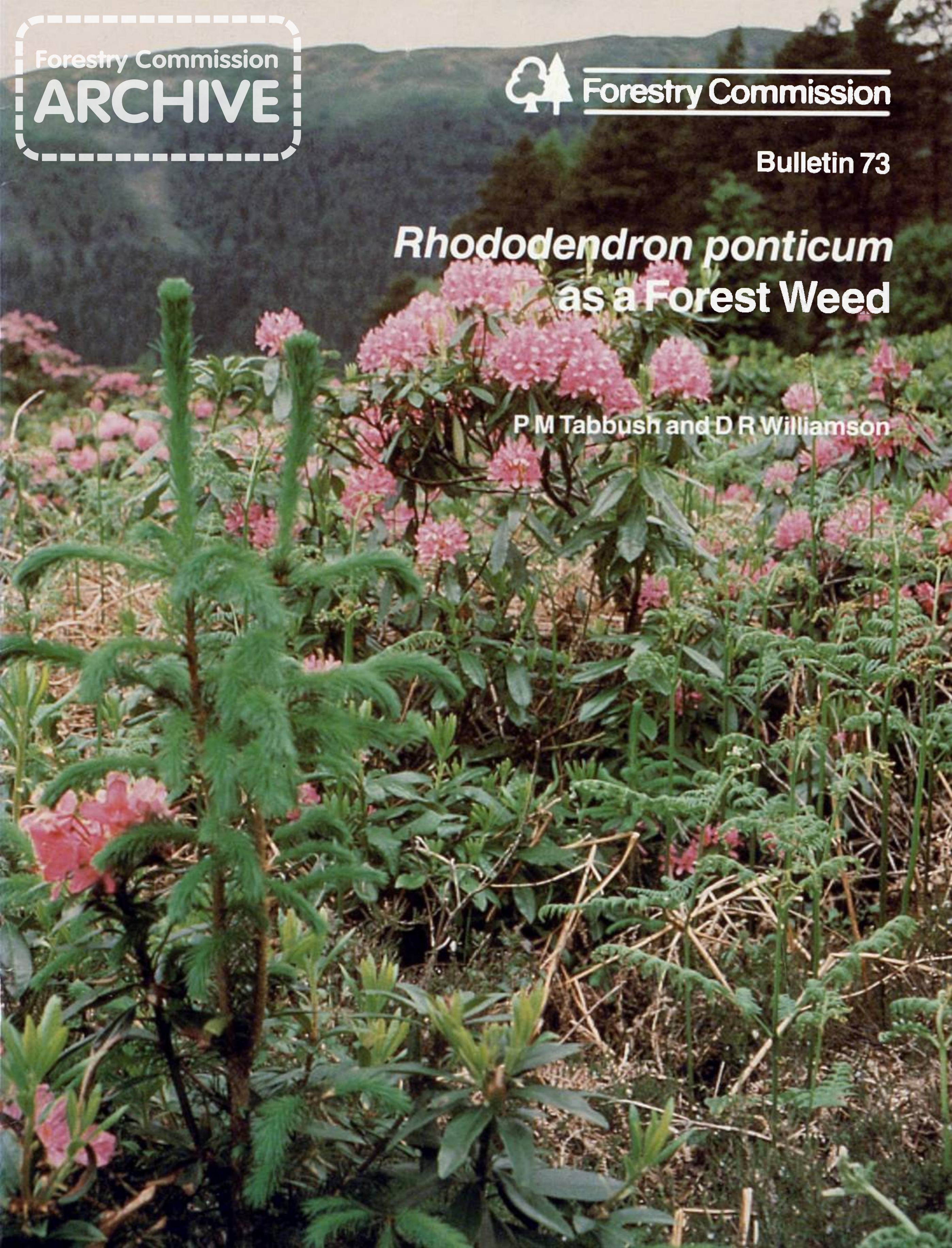
P M Tabbush and D R Williamson



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Rhododendron ponticum as a Forest Weed

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Silviculturists,
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Introduction

Rhododendron ponticum L. is an evergreen shrub which forms dense thickets up to 5 metres in height. The large purple blooms appear in spring and are an attractive sight which has become commonplace especially on forested slopes in the west of the British Isles. Foresters are familiar with it as a most intractable weed, indeed control may be so costly that it cannot be justified purely in terms of benefits to wood production. Because of its dense shade, acid litter and toxic foliage, invasion is accompanied by severe impoverishment of the native flora and fauna.

R. ponticum is an introduced species which has proved very successful under British conditions, and it is established and spreading in most parts of the British Isles. The first recorded introduction was in 1763, but the major invasions have their origin in the 19th century when *R. ponticum* was commonly used as a rootstock for grafting more attractive but less vigorous species and varieties. Neglect of grafted bushes leads to the rootstocks developing shoots and flowers of their own and, in this way, *R. ponticum* has often escaped from ornamental gardens associated with large Victorian estates which have fallen into neglect. It has also been planted as an ornamental shrub in its own right and is widely used to provide low cover in shelterbelts and game coverts.

Biological Characteristics

The genus *Rhododendron*, along with *Erica*, *Calluna* and *Vaccinium*, belongs to the family Ericaceae, the members of which have simple leaves, small seeds, and a mainly northern temperate or mountainous distribution. A knowledge of the biology of *R. ponticum* is essential to an understanding of its success as an invading species in the UK and for devising means for its control.

Natural distribution

R. ponticum has its main and most continuous natural distribution in the region of the Black Sea (Bean, 1976) but it is also native in parts of Portugal and southern Spain. Fossil evidence, however, shows that the present stands are remnants of a much wider distribution, stretching as far north as Ireland, which became fragmented by climatic change. The Atlantic race is known as subspecies *baeticum*, and is only distinct from the typical Black Sea *R. ponticum* in that the axis to the inflorescence is always hairy, especially near the apex, while that of the eastern race is usually glabrous, but not invariably so.

The introduced British population contains a number of hybrids, and this might have some bearing on its invasive vigour. Characteristics of *R. maximum* and *R. catawbiense* have been noted in some areas whilst in others typical *R. ponticum* or ssp. *baeticum* or hydbrids between them are to be found. However, the British population is usually referred to loosely as *R. ponticum*.

Seed production and dispersal

Seedlings do not usually produce flowers until they are 10–12 years old (Shaw, 1984). Each inflorescence produces about 5000 tiny oval seeds with a frill of hairs at both ends. A bush may produce one million seeds each year. Maturation takes about 6 months, the seeds ripening by December, but dispersal, mainly by wind, does not take place until February or March. The seeds are similar in size to those of other ericaceous species with an average weight of only 0.063 mg (Cross, 1975); they are some of the smallest found in the plant kingdom. The frill of hairs is thought to have more effect in assisting dispersal on the coats of animals in the relatively windless conditions under a forest canopy than in assisting wind dispersal, but in theory seeds of this size can be dispersed by wind over distances of at least 100 m, and updraughts and eddies can carry small quantities of seeds for a kilometre or more.

Germination and seedling establishment

Seeds germinate under favourable conditions in about 5 or 6 days. Light is essential although the amount required is low (2–5 per cent of full daylight). Seeds will therefore germinate on a shaded forest floor but not when buried under soil or vegetation. They have a short period of viability after release, and in experiments all imbibed seeds were non-viable after 160 days (Cross, 1981). Seeds therefore do not persist in the soil from one year to the next.

These somewhat unusual seed characteristics leave the young seedlings in a vulnerable position; they are on the surface, small and therefore with small reserves of water and energy, and susceptible to drought until the roots penetrate mineral soil. The characteristics of a safe site for gemination are demanding, and this is of key importance in understanding the conditions favourable for spread. Seeds generally become successfully established on a carpet of moss less than 1 cm in depth. Deeper moss allows the seed to become shaded, and even if germination does occur the roots fail to reach the soil and the seedling is susceptible to drought. Moss carpets of this nature can be created by ground disturbance, by trampling or scuffing by grazing animals, by burning, and indeed by the activities of man engaged in forest operations including scrub clearance. Factors favourable to mosses such as high humidity and rainfall, rocky slopes, disturbance of the forest floor by grazing animals also favour the spread of *R. ponticum*. Bare soil, that is without moss covering, is hostile for seedling establishment because the unprotected surface can dry out very rapidly. There is also some evidence that large drops of water from the tree canopy can uproot and destroy the small vulnerable seedlings.

Seedling survival

At the end of the first growing season the cotyledon stage seedlings are small (2–5 mm across), with a simple root system and they remain susceptible to desiccation. However, they contain a substance (andromedo toxin) which is highly toxic (Forsyth, 1954) and are generally avoided by grazing animals; although slugs eat newly germinated seedlings (Cross, 1973). Cross (1975) gives a list of organisms that have been found on *R. ponticum* but none seems to damage the species enough to exert a controlling effect. The main destructive agent is therefore desiccation and it follows that seedlings are most likely to survive in moist, sheltered micro-sites where the roots have access to mineral soil.

Vegetative propagation

According to Shaw (1984) rhododendron is not able to sucker, that is it does not produce adventitious buds on its roots. Thus pulling bushes out of the ground prevents regrowth and new bushes do not arise from buried pieces of root. Shoots will grow readily from buried pieces of stem, however, and the disturbance caused by pulling up bushes may produce a seedbed which subsequently becomes colonised by rhododendron seedlings.

Individual bushes spread readily by layering, procumbent branches producing roots at the point of contact with the soil, so that it rapidly becomes impossible to distinguish the original plants. Cutting and burning tend to create favourable sites for seedling germination, and these are readily colonised if a source of seed remains. Buds are readily produced at the base of the stem in response to cutting or fire, and it is difficult to destroy established bushes without the additional use of herbicides.

Shade tolerance

The compensation point (at which photosynthesis is sufficient to replace reserves used in respiration) for *R. ponticum* is at less than 2 per cent of full daylight, but a level of 5–10 per cent is required for satisfactory growth. The plants possess characteristics which adapt them to shade, for example low metabolic rate, resistance to disease and the ability to increase specific leaf area in response to a reduction in light intensity (Cross, 1973). Since rhododendron is evergreen it can make use of improved light levels following leaf fall in deciduous woodland; Cross (1975) found an 89 per cent increase in dry weight over the winter months for 5-year-old seedlings growing in an oakwood. Some conifers, particularly Western hemlock, Douglas fir, Grand fir and also Sitka spruce, cast such a dense shade as fully stocked pole-stage stands that *R. ponticum* is killed (Miller, 1954). However, if gaps and rides still harbour flowering bushes any thinning of the canopy will result in rapid reinvasion.

Distribution and spread in Britain

R. ponticum is now distributed throughout the British Isles (Perring and Walters, 1962). There is evidence (Shaw, 1984) that the rate of invasion has increased sharply during the last 15–20 years. This is probably due in part to changes in the pattern of land management, and in part to the natural exponential population increase of an invading species.

The distribution is not limited by temperature despite its southern origin; in Turkey and continental Russia it endures lower temperatures than are ever experienced in the British Isles. However, a combination of wind and low temperature probably limits its range in the mountains, and in Snowdonia it does not produce much seed above about 300 m elevation (Shaw, 1984), although in Ireland, Cross (1975) reports it growing at 530 m on Torc Mountain.

Although it is favoured by moist, acid soil conditions, it grows and flowers on a wide variety of soils. Cross (1975) described a stand growing on a thin soil over limestone with a pH of 6.4. In general, however, growth is poor at a pH greater than 5.0, with low levels of iron and manganese in foliage.

Rhododendron spreads extremely rapidly along avenues of disturbed ground with mossy habitats, especially power-lines, water courses and forest roads. The lack of alternative suitable sites may restrict distribution to these habitats for some time, but the increase in seed production means that sooner or later fire, forest clearance or overgrazing will allow the invasion of surrounding areas. Belts of dense woodland which are sufficiently broad (e.g. 100 m) can present a barrier to spread, but narrower belts allow some wind-borne seed to be carried over or through. Such belts can, however, reduce the rate of spread.

Summary of Biological Characteristics

A combination of the following characteristics has led to the success of *R. ponticum* under British conditions:

- prolific seed production and effective dispersal;
- unpalatability to grazing animals;
- low incidence of pests and diseases;
- shade tolerance;
- tolerance of a wide range of climatic and edaphic conditions;
- vegetative regeneration from buried stem fragments and ability to advance by layering.

To these we may add that the dense tangles of woody material are expensive to clear, and costly herbicide treatments are generally required for effective control.

The following factors tend to limit its spread and might be exploited for control:

- short life of seed;
- susceptibility of seed and seedlings to drought;
- slow early growth of seedlings and length of time to reproductive maturity;
- inability to sucker.

Control

Strategy

Rhododendron clearance is generally accomplished through a combination of physical and chemical means and these are described below, but the most efficient approach can only be determined after a thorough survey of the area in question.

Robinson (1980) described a planned approach to control, drawing on experience gained in 1344 ha of forest at Clogheen in Ireland. Initially the area was surveyed in detail, on a sub-compartment basis, classifying the rhododendron according to percentage ground cover and mean height:

Ground cover classes		*Height classes*	
A	None	1	< 1 m
B	< 5%	2	1–2 m
C	5–20%	3	> 2 m
D	21–50%		
E	51–80%		
F	81–100%		

These classes are used to determine the priority areas and also the appropriate control methods. For example, sparse cover (classes B–D) allows relatively easy access and in height class 1 the problem is easily dealt with using a hand-held sprayer. If the area is left, however, it will quickly become too high to spray and too dense for acccess, and so classes B_1–D_1 have priority over F_3. The dense cover in class F_3 must first be cut and either the freshly cut stumps treated or the regrowth sprayed after 1–2 years. This is very costly, but the operation will not become more costly if delayed, and it should not be tackled until treatment has been completed in the freshly invaded areas which can be tackled much more cheaply. If resources are not available to treat the more difficult areas then at least spread will be prevented so long as the programme is sustained.

A survey of Benmore Forest (Argyll) was carried out in 1981 (C. M. A. Taylor, personal communication) using Robinson's classes. The classification was extended to recognise five categories of forest: 1. establishment phase (0–15 years); 2. maintenance phase (16–35 years); 3. matured stands (36–55 years); 4. overmature stands (> 55 years); 5. bare land.

Clearly, the most immediate threat is posed to the youngest trees in category 1. However, stands programmed for clear felling will soon be recruited to category 1, and there is an opportunity to treat these bushes before felling while access is relatively easy. Stump treatment may be especially appropriate here.

In the Benmore survey over 50 per cent of the affected area fell into Robinson's class B (< 5 per cent cover), and this, together with areas being felled and restocked, was given the first priority for treatment. It was recognised that the eventual eradication of rhododendron would be very costly, but that the cost could be spread over many years. The principal aim was to *contain* the infestation within the existing area, gradually reducing the affected area when resources became available.

Physical control methods

Physical methods for destroying rhododendrons may be employed either to the exclusion of chemicals or to facilitate their use. Bulldozing, winching, chopping or cutting are expensive, because of the dense tangle of irregular woody stems, and it is this cost which makes rhododendron such a formidable weed to control.

The first Forestry Commission attempts to control rhododendrons by physical methods were at Glengarry (Highland), and were reported in the Journal of the Forestry Commission No.21 (1950). Attempts were made to cut groups or strips of dense rhododendron by hand, heaping the cut material on top of the uncut, with the intention of establishing evergreen conifers which would cast dense shade and ultimately exclude rhododendron from the whole area. This system showed promise (Miller, 1955) because it involved clearing only part of the area and the ability to dispose of the cut material without burning greatly reduced the cost. Miller concluded that the uncut strips did not need to be narrower than about half the height of the rhododendrons. However, if establishment of the conifer crop is delayed, the rhododendron re-asserts itself. Sitka spruce is now recommended rather than the Douglas fir, Western hemlock and Grand fir recommended by Miller because of its ease of establishment, rapid early growth and comparable ability to cast dense shade.

On suitable ground, heavy machinery can be used and this was also investigated in the 1950s. A great variety of machines fitted with pushing/cutting blades were tried but none proved very successful, partly because of the spread and irregular angles of old stems, and also because of the great volume of debris which tended to build up in front of the blade (Wood *et al.*, 1967). Wood and his co-authors stressed that no method of machine or hand clearance is likely to leave an old rhododendron site free from further infestation, largely because of regrowth from stem fragments and recolonisation by seeds from surrounding mature bushes. However, at Benmore and Carradale in west Scotland rhododendron was eradicated on some sites by pulling maiden plants of 'considerable size' out by hand. Winching out whole bushes has also been shown to prevent regrowth (Miller, 1952-4), and this supports Shaw's view (Shaw, 1984) that *R. ponticum* is unable to produce true suckers from roots.

Chemical control methods

Background

The first Forestry Commission experiments involving the use of herbicides on rhododendron were at Bramshill (Hampshire), Wareham (Dorset) and Ringwood (Dorset) forests, and were reported by Holmes (1957). Various herbicides were applied in the following ways:

a) foliage treatment of seedlings (2–4 years old);
b) foliage treatment of regrowth appearing on cut stumps within 1 or 2 years of cutting;
c) treatment of freshly cut stumps after clearance of large bushes;
d) basal bark treatment of large bushes;
e) over-all foliage spraying of large bushes.

MCPA, 2,4–D (ester and amine), 2,4,5–T (ester and amine), ammonium sulphamate (AMS), sodium chlorate and sodium arsenite were tried but only AMS and 2,4,5–T showed promise. AMS produced 100 per cent control in treatments a, b and c but otherwise treatments were unsuccessful, although 2,4,5–T butyl ester in diesel or paraffin appeared to have potential. This was investigated further (Aldhous and Hendrie, 1966) and 2,4,5–T ester was found to be effective at a rate of 1.0 to 1.5 kg in 100 litres of diesel oil as an overall spray to foliage, stems and stumps. Aldhous (1969) made specific recommendations for the treatment of rhododendron and Brown (1975) metricated the prescriptions, and added the recommendation that 1.0 g of sodium benzoate per litre of AMS solution should be added to reduce corrosion of brass sprayer parts.

New herbicides, such as glyphosate, triclopyr and hexazinone have been developed since the early 1970s, prompting a renewed research programme. Robinson (1980), working in Ireland, found that hexazinone was ineffective, but glyphosate and triclopyr were effective when applied as foliar sprays in mid-July to 0.5-1.5 m tall bushes under pole-stage Scots pine. The herbicides were mixed with water and applied by knapsack sprayer. For glyphosate, 100 per cent control was achieved at 3.96 kg ae ha^{-1} with percentage kill falling to 50 per cent at 1.98 kg ae ha^{-1}. Triclopyr was tried at 3.6 kg ae ha^{-1} only and this proved to be 100 per cent effective. In a further experiment under similar conditions, 10 l ha^{-1} of 36 per cent ae glyphosate (3.6 kg ae ha^{-1}) was applied bi-monthly from July to March and this indicated that July-September was the optimum period for application. Preliminary trials were carried out by the Forestry Commission at Benmore Forest (Argyll) in August 1981 using an ultra low volume applicator (ULVA) to apply glyphosate and triclopyr to rhododendron seedlings on a roadside embankment. Total volume rate sprayed was 30 l ha^{-1} for glyphosate and 19 l ha^{-1} for triclopyr at 3.6 kg ae ha^{-1} and 3.0 kg ae ha^{-1} respectively. In both cases good control was achieved.

Recent experiments

In 1982 three experiments were carried out to test a variety of chemicals, but with particular emphasis on the use of glyphosate using either the ULVA or medium volume applicators with or without 'mixture B' (Tabbush and Sale, 1984).

'Mixture B'

Rhododendrons have glossy, waxy foliage and this presents a serious obstacle to herbicide uptake. Aqueous formulations of herbicides, such as 'Roundup', tend to penetrate bark or leaves slowly, but once within the plant translocate freely. On the other hand, some herbicides which dissolve in oil enter plants rapidly but are then relatively immobile (Turner and Loader, 1974). It follows that oil soluble herbicides are likely to be more effective as foliage sprays, whilst aqueous herbicides are ideal for cut stump treatment.

'Mixture B' is a 1:1 mixture of two non-ionic surfactants ('wetters'), one water-soluble and the other oil-soluble. In the early experiments (Tabbush and Sale, 1984) it also contained four parts paraffin but this was later found to be unnecessary. The 1:1 mixture is normally added as 2 per cent of the total spray volume, to herbicide which has previously been diluted with water. The resulting micro-emulsion of oil-soluble surfactant dispersed in a continuous phase of aqueous herbicide can react with leaf waxes to provide a continuous aqueous pathway for the herbicide from the surface to the interior of the leaf. In studies with radioactively-labelled herbicides (Clipsham, 1984) 'mixture B' was found to increase substantially the rate and amount of uptake of glyphosate from drops placed on the surface of rhododendron leaves.

Ultra low volume

The experiment using ULV equipment at Benmore (Argyll) involved a range of dilutions and volume rates, applied to 1–2 m tall bushes in mid-July. Percentage kill after one year was greatly influenced by volume rate and 36 l ha^{-1} proved to be insufficient in the absence of 'mixture B', even at the lowest dilution rate (1 'Roundup': 3 water) which corresponds to a rate of 9 litres of 36 per cent ae glyphosate product per hectare. At a volume rate of 54 l ha^{-1} only the highest dilution rate (1:7) gave a poor result.

When 'mixture B' was added the 36 l ha^{-1} volume rate gave an improved result at the lower dilution rates. At 36 l ha^{-1} with a dilution of 1:5 and including 'mixture B', only 6 l ha^{-1} of product were used, but the level of control was not significantly less than for any other treatment, so this represents the cheapest effective treatment tested.

Medium volume

Using a spot-gun to apply 300 l ha^{-1} to experimental plots of 1 m tall regrowth at Dyfi (Gwynedd), 11 l ha^{-1} of 'Roundup' was insufficient unless 'mixture B' was added. Triclopyr ester at 4 kg ae ha^{-1} was more effective than glyphosate at 4 kg ae ha^{-1}. Fluroxypyr ('Starane') was effective at 4 kg ae ha^{-1} but not at 2 kg ae ha^{-1}. Hexazinone at 4 kg ai ha^{-1} was ineffective, as were soil injection treatments of tebuthiuron, buthidazole and hexazinone.

At Bramshill (Hampshire) applications were made at medium volume using a knapsack sprayer to 2 m tall bushes, again in mid-July. Hexazinone, tebuthiuron and buthidazole gave very poor results, glyphosate at 4 kg ae ha^{-1} achieved 68 per cent kill when 'mixture B' was added, but only 50 per cent without. Ammonium sulphamate gave 98 per cent control when applied 'to run-off'. Triclopyr at 4 kg ae ha^{-1} gave 78 per cent control with no additive; fluroxypyr at 4 kg ae ha^{-1} gave 73 per cent control.

An experiment at Quantock Forest (Somerset) in 1984 explored a range of foliage treatments applied in June and August to 3-year-old regrowth, using glyphosate and triclopyr ± 'mixture B'. In all cases June application was more effective than August. There was a significant improvement in control as both glyphosate and triclopyr rates were increased to 4 kg ae ha^{-1}. 'Mixture B' increased the effects of both herbicides.

In the same year, an experiment at Benmore (Argyll) showed that foliage application of 40 per cent AMS in water was more effective when applied April-August than at other times of year.

Spraying 'to the point of run-off'

In recognition of the practical difficulties involved in controlling rates of application in thickets of uneven height and distribution, herbicide was applied by knapsack sprayer 'to the point of run-off' in an experiment at Lammermuir Forest (East Lothian) in 1983. The site had been cleared of 5 m tall rhododendron under birch and oak 2 years previously, and the regrowth was less than 1 m tall. Spraying a plot of known area with 100 per cent rhododendron cover required 840 l ha^{-1} of water 'to the point of run-off'. Four dilutions of 'Roundup' (0.5, 1.0, 2.0 and 2.5 per cent) were applied in the same way in late August, and these resulted in 21.5, 95.0, 98.0 and 99.8 per cent control respectively.

Cut stump treatment

In an experiment in 1984 at Benmore (Argyll) five dilutions (0, 25, 50, 75 and 100 per cent) of 'Roundup' (36 per cent ae glyphosate) product in water, were applied to freshly cut rhododendron stumps using a paint brush. Treatments were applied at 2-month intervals from May 1984 to March 1985. All control treatments re-grew vigorously by the assessment date in July 1985, but suppression was between severe and total in all the herbicide treatments, regardless of date of application. There was no evidence that higher rates were better than the lowest rate, i.e. 25 per cent 'Roundup' in water.

Summary of Recommended Treatments

Current recommendations for chemical control are given in detail in the Forestry Commission publication 'The use of herbicides in the forest', and these are kept up-to-date as far as possible.

To select the appropriate method it is only necessary to distinguish two situations.

a. Seedlings or 1 to 3-year-old regrowth <2 m in height, readily treated using a hand-held sprayer.

b. Large bushes which must be cut down and the stumps either treated when freshly cut or allowed to regrow to allow foliage treatment.

Recommended treatments are as follows.

Foliage sprays

Glyphosate

Rate: 10 litres 'Roundup' (36 per cent ae glyphosate) per treated hectare or 8 litres 'Roundup' with 'High Trees Mixture B' as 2 per cent spray volume.

Date: May-August. Best results are to be expected in June/July.

Method: Glyphosate (with or without 'High Trees Mixture B') is approved by the Pesticides Registration and Surveillance Department (PRSD) of the Ministry of Agriculture Fisheries and Food for use through most types of spraying equipment.

Triclopyr

Rate: 8–10 litres 'Garlon 4' (48 per cent w/v triclopyr) per treated hectare. There is, as yet (July 1987), no PRSD approval for the addition of 'mixture B' to triclopyr.

Date: May-August. Best results are to be expected June-July.

Method: Triclopyr must be applied at a minimum volume rate of 200 l ha^{-1}, and this effectively confines its application to knapsack sprayers with conventional 'poly-tip' nozzles.

Ammonium sulphamate (AMS)

Rate: 40 per cent solution of AMS in water. Note that a spray 'to the point of run-off' might work out at a total volume rate of 850 l ha^{-1}, containing 340 kg of product.

A non-ionic wetter should be added at 6 ml l^{-1} of spray solution.

Date: Most effective June-August.

Method: Plastic watering can or Tecnoma T16P semi-pressurised knapsack sprayer. (AMS is corrosive to metal and this sprayer minimises contact with metal parts.)

General advice on foliage sprays

Translocation within rhododendron stems seems to be particularly poor in a tangential direction, so that spraying part of a bush results in the death of that part only. It is important to ensure full coverage of all the foliage. It is usually necessary to re-treat small pockets of regrowth for 2–3 years following the initial spraying.

Rates expressed on a per hectare basis can be converted to a spray concentration by spraying a test plot of known area 'to wetness', weighing the sprayer before and after and calculating the volume of spray used per hectare. The specified rate can then be made up to this volume and spraying 'to wetness' should then give the desired rate of product per hectare.

Stump treatments

Glyphosate

Paint (with a paint brush) all freshly-cut stump surfaces with a 25 per cent solution of 'Roundup' in water.

Triclopyr

Apply undiluted 'Garlon 4' or in a dilution of paraffin, diesel oil, TVO or water at 800 ml 'Garlon 4' to 10 litres of diluent, using a knapsack sprayer at low pressure with a solid stream jet.

Ammonium sulphamate

Apply as a 40 per cent solution as for 'foliage sprays'.

General advice on stump treatment

Surfactant additives are not appropriate for cut-stump application.

Treatment is effective at any time of year except during sap-flow in spring.

It is important to ensure that all surfaces are treated and, as for foliage sprays, to re-treat any pockets of regrowth for 2–3 years after the initial treatment.

Crop tolerance

Rates are generally so high for effective control of rhododendron that trees will be damaged if sprayed. The emphasis is therefore on treatment before planting.

Ammonium sulphamate retains its herbicidal activity in the soil, where it is also mobile, so that trees a few metres away from a treated stump may sometimes be damaged. Three months should elapse between treatment and subsequent planting.

Triclopyr persists in soil to some extent and a minimum of 8 weeks is required between application and planting.

Glyphosate is rapidly broken down on contact with soil and does not leach through soil, has no residual action, and planting may take place immediately after spraying.

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