# Controlling *Rhododendron* spp. in the Turkish Black Sea Region

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*Summary*

Rhododendrons (*Rhododendron ponticum* L. and *Rhododendron luteum* Sweet) dominate the understories of the mesic forests of the Black Sea Region (BSR) of Turkey. They dramatically reduce forest growth and regeneration and local plant diversity. This paper reports the results of a large rhododendron control experiment established on two different sites in the western and eastern BSR of Turkey 5 years after treatments (YAT). The paper also presents the second-year results of a second experiment in which the foliar herbicides of the previous experiment were tested on rhododendron at much lower rates on a western BSR site. Five YAT, grubbing and foliar spraying were still the best rhododendron control methods in the first experiment. Cut-stump spraying provided an intermediate level of woody control. Hand-cutting was ineffective on *R. ponticum* and did not significantly differ from the control treatment in rhododendron basal area 5 YAT. The performance ratings of foliar triclopyr ester and imazapyr for woody control in both experiments were rate dependent. At high rates ranging between 2.6 and 5.8 kg ae $ha^{-1}$, foliar imazapyr controlled both rhododendron species significantly better than foliar triclopyr ester in the first experiment, suggesting enhanced imazapyr translocation to the roots. Some off-target damage was observed in the beech overstory for imazapyr at high rates. The performance ratings of these foliar herbicides were significantly reversed in the second experiment 2 YAT, where much lower rates were used (0.3–2.0 kg ae $ha^{-1}$) than in the first experiment. Insufficient imazapyr accumulation in rhododendron roots might account for the poor impact of this herbicide. No beech damage was apparent from any of the herbicides in the second experiment. The low-rate foliar triclopyr ester is recommended for effective and cost-efficient rhododendron control.

## Introduction

Purple-flowered and yellow-flowered rhododendrons (*Rhododendron ponticum* L. and *Rhododendron luteum* Sweet or syn. *Rhododendron flavum* Don., respectively) have become pernicious woody weeds in northern Turkey (Saatçioğlu, 1957; Eyüboglu and Karadeniz, 1987). *R. ponticum* is also recognized as a serious invasive shrub in the UK (Tabbush and Williamson, 1987; Rotherham, 2002). Rhododendrons significantly decrease tree regeneration, growth and floristic diversity in Turkey and the UK (Atalay, 1992; Mitchell *et al.*, 1997; Rotherham, 2002; Eşen and Zedaker, 2004).

In efforts to control this invasive woody weed, foliar imazapyr and triclopyr ester have been


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tested on *R. ponticum* in Britain with successful results (Tabbush *et al.*, 1986; Clay *et al.*, 1992; Lawrie and Clay, 1993; Dixon and Clay, 2003). A recent large experiment in northern Turkey employed different woody control methods, including cutting, grubbing and foliar and cut-stump spraying of various formulations of imazapyr and triclopyr herbicides at two rates on *R. ponticum* and *R. luteum* in the western and eastern Black Sea Regions (BSRs) (Eşen and Zedaker, 2004). Two years after treatments (YAT), grubbing and foliar herbicide spraying were evaluated as the best woody control treatments for rhododendron. In addition, foliar-applied imazapyr achieved substantially greater woody control than foliar triclopyr ester on both rhododendron species.

Herbaceous weeds are well known to do the most significant damage to crop seedlings during the initial growing seasons (Bacon and Zedaker, 1987; Cain, 1991; McDonald *et al.*, 1994; Yildiz, 2000). Early results of herbaceous weed control studies are therefore a reliable basis for making management decisions. A similar approach for woody plants may, however, lead to erroneous decisions. With extensive root systems and considerable root and stump sprouting abilities, long-lived woody weeds, including rhododendron (Rotherham, 2002), have the potential to continue to adversely affect tree growth and regeneration throughout the whole tree crop rotation (Radosevich *et al.*, 1997). Therefore, long-term data are needed to make proper decisions for effective rhododendron control treatments.

The Turkish study on rhododendron control used herbicides at high rates (Eşen and Zedaker, 2004), and at the end of the study, further trials were recommended using reduced foliar herbicide rates for greater cost-effectiveness. This paper assesses the study of Eşen and Zedaker (2004) 5 YAT and a second experiment that was set up to compare the efficacies of imazapyr and triclopyr ester at lower rates than in the original experiment.

## Methods

### *Site description*

The first, larger, experiment was conducted on two separate typical rhododendron–beech sites in the mesic mountains of the BSR in Turkey (Figure 1, Eşen and Zedaker, 2004). The first site was located in the Sökü Forest Management Chiefship of the Zonguldak-Bartın Forest Management Directorate in the western BSR, whereas the second site was in the Üçyol Forest Management Chiefship of the Ordu-Akkuş Forest Management Directorate in the eastern BSR (Eşen and Zedaker, 2004). The second, smaller, experiment was laid out on another western BSR site within the jurisdictional boundaries of the Tatlıdere Forest Management Chiefship of the Bolu-Düzce Forest Management Directorate (Figure 1).

The soils of the experimental sites varied between clay and sandy loam. All study sites had a primarily closed eastern beech (*Fagus orientalis* Lipsky.) overstory with a dense, continuous rhododendron understory. The primary understory woody species on the western BSR sites was *R. ponticum*. *R. luteum* was the predominant shrub species of the eastern BSR site (Eşen and Zedaker, 2004). Mean *R. ponticum* density on the second experimental site was much greater (107 000 stems $ha^{-1}$) than that on the first experimental site (48 000 stems $ha^{-1}$) (Eşen and Zedaker, 2004).

### *Treatments*

All woody control (manual and chemical) treatments were originally carried out on both study sites in the first experiment in late August and early September 1997 (Table 1). The manual treatments were hand-cutting and grubbing for *R. ponticum* and only hand-cutting for *R. luteum*. The chemical treatments included foliar, cut-stump and resprout spraying of rhododendron stems with imazapyr and triclopyr ester herbicides (Eşen and Zedaker, 2004).

Rhododendron stems in the original experiment were first hand-cut nearly 10 cm above the root collar (Eşen and Zedaker, 2004). The cut-stumps of *R. ponticum* were then sprayed with two different formulations (undiluted and 1 : 1 (v : v) water diluted) of Garlon® 3A and Pathfinder® II (Dow AgroSciences LLC, Indianapolis, USA). The cut-stump treatments were applied using 700-ml polyethylene sprayers. Due to its smaller stem diameter and greater stem density (90 000 stems $ha^{-1}$) compared with those of *R. ponticum* (48 000 stems $ha^{-1}$), a different stump


*Figure 1*. Locations of three rhododendron control experiments (1: Düzce, 2: Bartın, 3: Ordu-Akkuş) in the BSR of Turkey.

treatment was used for *R. luteum* individuals. Hand-cut *R. luteum* stumps were allowed to sprout, and the sprouts were sprayed with Garlon 4 at 2.5 and 5 per cent (v : v) rates 1 year after cutting. The resprout formulations were mixed with X-77 surfactant at a 1 per cent (v : v) rate (Eşen and Zedaker, 2004).

The foliage of rhododendron individuals on both western and eastern BSR sites in the first experiment was sprayed with triclopyr ester (Garlon® 4, Dow AgroSciences LLC) to the point of run-off at 2.5 and 5 per cent (v : v) rates in a water carrier using an 18-L SPI® polyethylene plastic knapsack sprayer (Chemical Containers, Inc., Arcadia, USA) (Eşen and Zedaker, 2004). A 5500 adjustable conejet nozzle (Spraying System®, Co., Wheaton, USA) mounted on a 1- or 2-m spray wand (B and G Spraying System®, Co., Plumsteadville, USA) was utilized for foliar treatments. An isopropylamine salt of imazapyr (Arsenal® 250 SL, BASF Corp., Research Triangle Park, NC, USA) applied at 5 and 10 per cent rates was the other herbicide used for foliar treatments. The Arsenal and Garlon herbicide mixtures were added with a 0.25 and 2.5 per cent (v : v) X-77 surfactant, respectively (Eşen and Zedaker, 2004).

The foliar herbicides and application procedures in the second experiment were the same as those in the first experiment, except that the herbicide rates (medium and low) were considerably lower and a different surfactant, Citowett® (BASF Corp.), was used (Table 2).

### *Experimental design and analysis*

In the first experiment, a randomized complete block design with five blocks and an incomplete block design with four blocks were used for the western and eastern BSR sites, respectively. Within each block, all experimental plots measured 32 × 32 m. Each treatment plot was divided into strips; two 6-m-wide buffer strips were installed at each edge of the plot within which there were three 4-m-wide treatment strips

*Table 1*: Manual and herbicidal woody control treatments applied on *R. ponticum* and *R. flavum* (syn. *R. luteum*) in the western and eastern BSRs with associated use rates

| Treatment | Herbicide | Dosage (kg ae ha$^{-1\dagger}$) |
|---|---|---|
| | *R. ponticum* | |
| Foliar | Garlon 4 | 5.1 |
| | Garlon 4 | 2.6 |
| | Arsenal SL | 5.8 |
| | Arsenal SL | 3.0 |
| Cut-stump | Garlon 3A | 9.8 |
| | Garlon 3A | 5.4 |
| | Pathfinder II | 2.5 |
| | Pathfinder II | 1.3 |
| Hand-cutting | – | – |
| Hand-grubbing | – | – |
| Check | – | – |
| | *R. flavum* | |
| Foliar | Garlon 4 | 5.1 |
| | Garlon 4 | 2.3 |
| | Arsenal SL | 5.8 |
| | Arsenal SL | 3.0 |
| Resprout spray | Garlon 4 | – |
| | Garlon 4 | – |
| Hand-cutting | – | – |
| Check | – | – |

Reprinted copyrighted material from Eşen and Zedaker (2004, Table 1) with kind permission of Springer Science and Business Media. '–', No herbicide use data were available.
†Acid equivalent per hectare.

*Table 2*: Use rates of foliar triclopyr ester (Garlon 4) and imazapyr (Arsenal SL) treatments applied on *R. ponticum* in the western BSR

| Herbicides | Rate label | Rate (kg ae ha$^{-1\dagger}$) |
|---|---|---|
| Garlon 4 | Low | 0.6 |
| | Medium | 2.0 |
| Arsenal SL | Low | 0.3 |
| | Medium | 0.9 |

†Acid equivalent per hectare.

alternating with two 4-m-wide buffer strips. The buffer strips served to reduce erosion risk (Eşen and Zedaker, 2004) and to eliminate possible treatment contamination from neighbouring plots. Refer to Eşen and Zedaker (2004) for more detailed experimental information.

For the second experiment, a randomized complete block design with four replications was used. Within each block, each experimental plot measured 10 × 10 m, with 2-m-wide outer zones left as buffers.

In the first experiment, treatment effects were evaluated in three 2 × 2-m sampling quadrates, which were randomly established in the central area of each of the three treatment strips in each experimental plot. Similarly, three sampling quadrates were randomly laid out in each 10 × 10-m plot in the second experiment. All of the rhododendron stems in these quadrates were measured for groundline diameter (gld) to calculate live rhododendron stump basal area (SBA) before (in 1997) and after (in 2002) treatments in the first experiment (Eşen and Zedaker, 2004). These measurements were carried out in 2001 and 2003 for the second experiment. In both experiments, no significant differences ($P > 0.1$) were found among experimental plots for total live rhododendron SBA before treatments, and thus absolute SBA ($m^2$ $ha^{-1}$) values were used to examine the effects of treatments. Treatment effects in the first and second experiments were determined using analysis of variance. Treatment means were separated using Tukey's least square means.

## Results

Five YAT, hand-grubbing and foliar spraying provided the best and similar control of *R. ponticum* (Table 3). Mean rhododendron SBA was significantly less (at least fivefold) with these treatments, compared with hand-cutting and the control. The latter two treatments did not significantly differ from each other in controlling rhododendron. Similarly, foliar spraying had a considerably greater (almost 11-fold) *R. luteum* control, compared with hand-cutting, the least successful treatment. Cut-stump and resprout spray treatments were intermediate in controlling rhododendron (Table 3).

Within foliar treatments, imazapyr and triclopyr ester herbicides were significantly different from each other in controlling rhododendron 5

*Table 3*: Effects of various woody control techniques on the live SBA of *R. ponticum* and *R. luteum* on the western and eastern BSR sites 5 YAT in the first experiment

| | Live SBA (±SE) ($m^2$ $ha^{-1}$) | |
|---|---|---|
| Treatments | *R. ponticum* | *R. luteum*[†] |
| No woody control | 18.2 a[‡] (±4.2) | – |
| Hand-cutting | 15.3 ab (±3.5) | 11.9 a (±1.9) |
| Cut-stump herbicide spray[§] | 7.8 abc (±3.8) | 4.5 b (±2.1) |
| Foliar herbicide spray | 3.0 c (±0.9) | 1.1 c (±0.3) |
| Hand-grubbing | 0.9 c (±0.3) | – |

[†]No data were available for the control and hand-grubbing treatments.
[‡]Means within a column sharing the same letter are not significantly different (Tukey's least square means $P < 0.05$).
[§]Cut-stumps of *R. ponticum* were sprayed. Resprouts of *R. luteum* were sprayed.

YAT (Table 4). Imazapyr reduced rhododendron SBA substantially more than triclopyr ester (almost fivefold). No substantial differences were found for rate and herbicide × rate interaction effects on rhododendron (Table 4). Some off-target damage was observed in the beech overstory for the high-rate imazapyr.

In the second experiment, a significant herbicide main effect was found for mean rhododendron SBA 1 and 2 YAT, with no substantial rate main effect or herbicide × rate interaction effect (Table 4). Mean rhododendron SBA was significantly smaller with triclopyr ester (at least threefold) than with imazapyr both 1 and 2 YAT (Table 4). No damage on beech trees in the overstory was observed from any of the treatments 2 YAT.

## Discussion

As in the second-year results (Eşen and Zedaker, 2004), hand-grubbing and foliar spraying were still the best techniques to control rhododendron effectively 5 YAT. Rhododendron usually forms a very shallow root system in the soil (less than 30–45 cm) (Çolak, 1997). Therefore, it is not difficult to root out small rhododendrons by hand-pulling from the upslope direction (Çolak, 1997; Eşen and Zedaker, 2004).

The superior woody control performance of foliar imazapyr when compared with foliar triclopyr ester in the second-year results continued in the fifth year for the first experiment (Eşen and Zedaker, 2004), suggesting that imazapyr might be favoured for the long-term control of rhododendron at the range of rates used in the experiment. Foliar treatments killed all of the *R. luteum* stems that were treated; imazapyr reduced rhododendron stems to bare ground and left an almost barren site. The control success of imazapyr on *R. ponticum* was previously reported by UK researchers (Edwards *et al.*, 2000; Dixon and Clay, 2002, 2003). Eşen *et al.* (2002) conducted an herbicide uptake and translocation study in *R. maximum*, which shares many ecological and biological properties with *R. ponticum* (Eşen, 2000; Nilsen and Horton, 2003). In this experiment, foliar imazapyr was translocated to the rhododendron roots in significantly greater amounts than triclopyr ester in the 72 hours following treatment. Enhanced foliar imazapyr translocation to roots in *R. ponticum* was also reported in the UK, and disposal of treated stems 2 or more days after treatment was recommended (Dixon and Clay, 2002). The overstory beech damage from the high-rate imazapyr indicated that this herbicide should only be used at low rates on beech–rhododendron sites.

Although imazapyr, and then triclopyr ester, provided good regrowth suppression of *R. ponticum*, they left populations of standing dead stems, which decompose very slowly (Çolak 1997). This may pose management problems, especially for the artificial regeneration of beech.

Given the low gdl's (mean gld was 14 and 15 mm for *R. luteum* and *R. ponticum*, respectively)

*Table 4*: Effects of foliar imazapyr (Arsenal SL) and triclopyr ester (Garlon 4) herbicides on live rhododendron SBA 5 and 2 YAT in the first and second experiments in the BSR

| Treatment[†] | Live SBA (±SE) ($m^2$ $ha^{-1}$) | | | |
|---|---|---|---|---|
| | First experiment | | Second experiment | |
| | 5 YAT | | 1 YAT | 2 YAT |
| | *R. ponticum* | *R. luteum* | *R. ponticum* | |
| Garlon 4 | 5.2 a[‡] (±1.1) | 2.2 a (±0.6) | 2.0 b (±0.5) | 1.3 b (±0.5) |
| Arsenal SL | 1.1 b (±0.6) | 0.0 b (±0) | 7.2 a (±1.6) | 4.0 a (±0.9) |

[†]Herbicide main effect was significant ($P \leq 0.05$), but rate and herbicide × rate interaction effects were not significant ($P > 0.05$).
[‡]Means within a column sharing the same letter are not significantly different (Tukey's least square means $P < 0.05$).

and high stand densities of rhododendron, cut-stump herbicide treatment is not recommended for rhododendron populations in the BSR of Turkey, due to less long-term woody control, high costs and greater environmental hazard compared to foliar herbicide treatments (Zedaker, 1986; Eşen and Zedaker, 2004). Cutting was the least effective and most cost-inefficient rhododendron control method, and its efficacy seemed to decrease further over time (Table 3) (Eşen and Zedaker, 2004).

In the second experiment, the performance rating of foliar imazapyr and triclopyr ester significantly changed, compared with the first experiment (Table 4). The relative performance rating of triclopyr ester in controlling rhododendron clearly improved in the second experiment, compared with both the rating of imazapyr in the same experiment and its own rating in the first experiment. Lower rates and better performance yielded a substantial improvement in the cost-effectiveness of triclopyr ester in the second experiment. Oil-based or lipophilic herbicides, including triclopyr ester, can penetrate the waxy foliage of woody species, including rhododendron (Holloway 1970), much better than water-based or hydrophilic herbicides (Zedaker, 1986; Ross and Lembi, 1989; Bentson and Norris; 1991; Jackson *et al.*, 1998; Minogue and Quicke, 1999). Triclopyr ester was actually found to be absorbed by the foliage of *R. maximum* in significantly greater amounts than imazapyr (Eşen *et al.*, 2002). High herbicide rates and possible herbicide–surfactant antagonism at high rates may, however, curtail the efficacy of triclopyr ester in woody vegetation by inhibiting the translocation of the active ingredient from treated foliage to roots (Zedaker *et al.*, 1994; Forster, 1998; Jackson *et al.*, 1998). Reducing the rate actually increased triclopyr ester translocation from the treated foliage of 1-year-old red maple (*Acer rubrum*) and sweetgum (*Liquidambar styraciflua*) (Zedaker *et al.*, 1994). The reasons mentioned above might partially explain the poor efficacy of triclopyr ester on rhododendron in the first experiment.

Unlike triclopyr ester, rhododendron control by imazapyr was poorer in the second study, when its rates were reduced by more than 80 per cent on average (Tables 1, 2). Similar rate-dependent reductions of *R. ponticum* by this herbicide have been reported (Dixon and Clay, 2003). Although this water-soluble compound (Minogue and Quicke, 1999) has major difficulties in dissolving the hydrophobic foliage of *R. ponticum* (Holloway 1970; Eşen *et al.*, 2002), it is translocated effectively to the roots once it is in the plant (Eşen *et al.*, 2002). In the second experiment, the accumulation of insufficient quantities of the active ingredient in rhododendron roots might be responsible for imazapyr's reduced efficacy. Testing the oil-soluble formulation of imazapyr (i.e. Chopper®) (Minogue and Quick, 1999) on rhododendron at a rate between those used in the first and second experiments is recommended for future studies.

Significantly improved imazapyr control (two-fold) in rhododendron over time in the second experiment (Table 3) was previously observed during the first experiment (Eşen, D.E. and Zedaker, S.M.Z. unpublished data). This is probably due to the slow-acting nature of the herbicide (Clay *et al.*, 1992).

## Conclusion

Foliar applications and grubbing were the best methods for the long-term control of rhododendron in the BSR of Turkey. The cut-stump spray treatment was intermediate in controlling rhododendron, and hand-cutting was least effective. The performance ratings of foliar triclopyr ester and imazapyr for woody control were rate dependent. At high rates (2.6–5.8 kg ae $ha^{-1}$), foliar imazapyr controlled rhododendron better than foliar triclopyr ester, suggesting greater translocation of the former herbicide to rhododendron roots. However, at lower rates (0.3–2.0 kg ae $ha^{-1}$), foliar triclopyr ester demonstrated an enhanced efficacy on rhododendron compared with imazapyr, and is thus recommended for effective and cost-efficient rhododendron control. Insufficient accumulation of the active ingredient in rhododendron roots might be responsible for the poor impact of imazapyr. Some off-target damage was observed in the beech overstory for imazapyr at high rates, yet this disappeared when lower rates were used in the second experiment.

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