African Journal of Biotechnology Vol. 8 (8), pp. 1488-1496, 20 April, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Chemical effects on controlling of *Rhododendron ponticum* L. in western black sea forest region of Turkey

Erol Kirdar* and Murat Ertekin

Bartın University, Faculty of Forestry, 74100 Bartın, Turkey.

Accepted 12 March, 2009

***Rhododendrons* impair the natural and artificial regeneration and seedling growth in the pure and mixed forest stands in Turkey. To control the rhododendrons by employing the sprout-less herbicide applicator (SLHA) is the main goal of this study. Two studies were conducted in the western black sea region of Turkey. Each study area was selected from natural mixed stands of beech (*Fagus orientalis* L.) and each one contained 30 sampling plots; roundup ® (glyphosate) and Arsenal ® (imazapyr) herbicides were used in different concentrations. Measurements were performed after the treatment on dead, dying and active stumps; average stump height and diameter, weak/very weak and active re-sprouts, average sprout's diameter and height from every stump cut. Recovery or re-growth potential (vigor index) and basal area reduction of every stump were also calculated in every plot. The treatment efficacy was tested by using the vigor index values. Multiple variance analysis showed that SLHA treatment was very effective in reducing basal area of *Rhododendron ponticum* at the end of the second growing years after treatment. This means that the sprout-less herbicide applicator seems to perform well in reducing the rhododendron competition to the point of enhancing the establishment of commercial forest species. In addition, no mechanical problems were encountered in the study areas during the herbicide application process.**

Key words: Weed control, glyphosate, imazapyr, *Rhododendron ponticum*, beech.

INTRODUCTION

The forest area of Turkey contains 21.2 million ha. A total of 10.5 million ha (50%) of all forest areas are degraded and contain very low yield forests (Anon, 2006). A large area of the degraded forests (canopy closure below 70%) is occupied by rhododendron (*Rhododendron* L.), raspberry (*Rubus* L.) and bracken (*Pteridium aquilinum*). Forests in Turkey face serious problems related mainly to the presence of non-commercial shrub and weed species, especially the rhododendrons. It impairs the growth of the natural and artificial regeneration of commercial tree species in the pure and mixed stands and seedling growth (Ata, 1996). Rhododendrons threaten forest tree regeneration success and growth throughout the world (Cross, 1981; Phillips and Murdy, 1985; Coats et al., 1991; Gritten, 1995; Clinton and Vose, 1996; Eşen, 2000). Manual and many mechanical control techniques are costly and ineffective against rhododendrons in Turkey (Saatçioğlu, 1957; Varol, 1970; Suner, 1978; Çolak, 1997). The main crop trees are suppressed by the faster growing competitive species such as rhododendron. Rhododendrons are sturdy, fast growing and aggressive shrubs which affect the growth of commercial tree species in Turkey.

In addition, the mechanical control of rhododendrons brings about concerns for long-term soil productivity

*Corresponding author. E-mail: ekirdar@yahoo.com. Tel.: +90 3782277422. Fax: + 90 378 228 7205.

(Childs et al., 1989). Beside the site-degrading effects, mechanical control does not provide the desired level of control. Rhododendron roots and stem pieces are widely distributed by the mechanical tools such as the blades of bulldozers and in fact, may enhance the proliferation of this aggressive shrub. Environmentally friendly herbicides, when used appropriately, provide the safest, most effective, and most cost-effective means to control unwanted vegetation in forestry applications (Eşen, 2000).

Rhododendron has proved to resist foliar herbicide control, with great recovery ability after a few growing seasons of herbicide application (Lawrie and Clay, 1993). Imazapyr and triclopyr, two recently developed herbicides have showed benefit results for the obstruction of rhododendron (Clay et al., 1992; Lawrie and Clay, 1993; Tabbush et al., 1986; Eşen, 2000). Triclopyr ([(3,5,6-trichloro-2-pyridinyl) oxy]acetic acid) is a synthetic auxin-type post-emergence herbicide that is effective for woody control (Forster, 1998; Jackson et al., 1998; Eşen, 2000). Garlon 4 and Pathfinder are two oil-soluble commercial products of triclopyr formulated as a butoxyethyl ester, whereas Garlon 3A is formulated as a triethylamine salt and is water-soluble. Imazapyr (2-[4, 5-dihydro–4-methyl–4- (1-methylethyl)–5–oxo-1H–imidazol-2-yl]-3-pyridinecarboxylic acid) is a systemic herbicide (Nissen et al., 1995; Eşen, 2000). Imazapyr as Arsenal 50 is recommended for pre-planting control of woody weeds in forestry and has been shown to be effective for *Rhododendron ponticum* control within a short time of spraying (Dixon and Clay, 2002). Tyler et al. (2006) also state that postcut application of the herbicide or applying the herbicides Metsulfuron-methyl or Imazapyr can effectively reduce a *R. ponticum* stand. Lewis and McCarthy (2008) assessed the nontarget translocation of imazapyr (Arsenal), an herbicide commonly used to manage woody vegetation in forests, from injected tree-of-heaven (*Ailanthus altissima*) to neighboring noninjected stems.

Cut stem surface treatments of woody plants with undiluted or water diluted herbicides are common application methods that have been successfully used in the USA (Zedaker et al., 1987; Zedaker, 1988) to treat prominent woody non-commercial (weed) species (Eşen, 2000). The treatment crew included two pre-trained workers operating the cutting equipment and a sprayer operator. The first step is to mechanically cut the *rhododendron* stems approximately 10 cm above the ground and then immediately spray premixed formulations into the cut surface to the point of runoff using 700 ml polyethylene sprayers (Eşen and Zedaker, 2004). Cut-stump treatments have shown some success in rhododendron control, using foliar-applied imazapyr and triclopyr in the UK (Tabbush and Williamson, 1987; Clay et al., 1992; Lawrie and Clay, 1993; Palmer et al., 1988; Eşen, 2000). Eşen et al. (2002) pointed out that the foliar-applied Arsenal SL (Imazapyr) had significantly greater rhododendron control than foliar-applied Garlon 4 (Triclopyr ester). Increasing the rates did not enhance the herbicide efficacy.

Brief description of the sprout- less herbicide applicator

The sprout-less herbicide applicator (SLHA) is a modern clearing saw attachment. It has been used to control the different woody vegetations in Canada and parts of the USA (Mubareka, 2000). The sprout-less herbicide applicator is a circular device designed to fit on the bottom of the brush-saw blade. It can be installed on all popular brush saw models. The model used for the study consists of a solution reservoir and a valve system including a brass cover and aluminum rim as a valve seat. The SLHA is attached beneath the brush saw blade using a bushing and the existing bolt and nut (Desrochers, 1999). A set of gaskets consisting of textile and special paper is located between the brass cover and the reservoir. The gasket set is used to calibrate the unit. The highly concentrated herbicide solution is released through the gaskets only as a result of the combined high-speed rotation and the vibration generated by the cutting action of the saw blade. The released solution is directed towards the bottom of the saw blade, thereby a very thin layer of concentrated herbicide solution is transferred into the stump at the same moment. SLHA system does not produce a spray to apply the herbicide into the cut surface when the unit is properly calibrated. In addition, it does not produce mist or fog. Instead, the herbicide solution is released and immediately coated into the cut surface during the cutting action only. The required quantity of herbicide per unit area (hectare) is very small in comparison with traditional (manual) herbicide application methods. The flow rate of the herbicide solution is usually calibrated to last about 75 min. The refilling of the herbicide applicator is done at the same time of refilling the fuel tank of the brush saw.

MATERIALS AND METHODS

Site selection

Two areas were selected for this study, they were located in Dumanlı (41° 31′ N, 32° 24′ E) and Kozcağız region (41° 29′ N, 32° 27′ E) in Bartın located western black sea region of Turkey (Figure 1). Both regions are occupied by oriental beech (*Fagus orientalis* Lipsky.), hornbeam (*Carpinus* spp.), chestnut (*Castanea sativa*) and linden (*Tilia tomentosa*). Experimental sites were chosen at an altitude of 700 m in Dumanlı region and an altitude of 1100 m in Kozcağız region. The understory of the pure and mixed forest of oriental beech, especially a large area of degraded forests (canopy

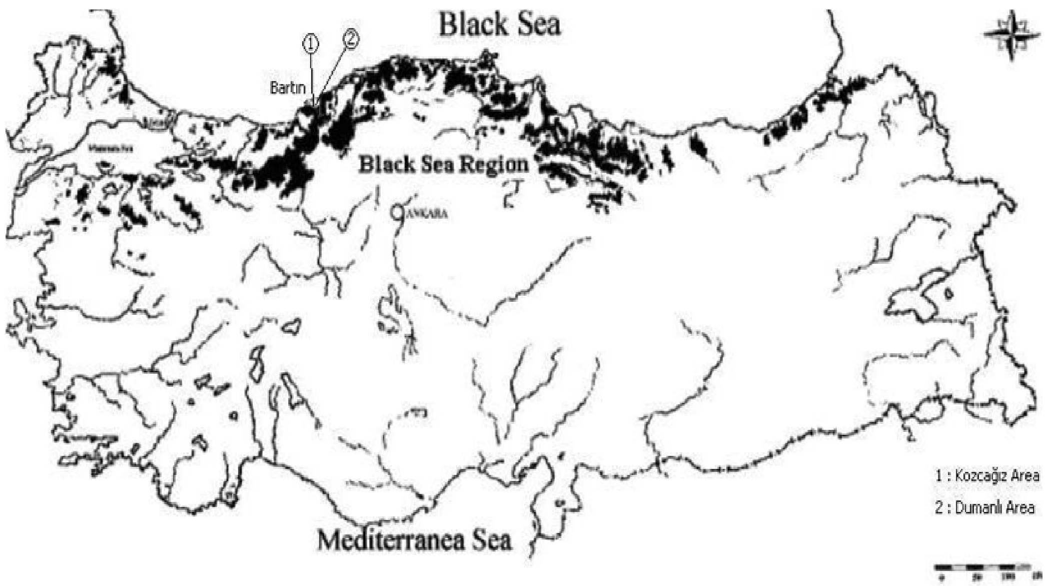

Figure 1. The general distribution range of the oriental beech and the locations of the experimental sites of *R. ponticum* in the western black sea regions in Turkey.

closure below 70%), was occupied by rhododendron, raspberry and bracken.

Western black sea region consists of mountains which are parallel to the sea. Steepness of theirs slopes were greater than 20%, which causes a sudden rise of the air fronts over the steep northern slopes of this mountain belt. Steepness of slopes of oriental beech sites causes high rate of soil erosion unless the soil is covered by vegetation (Eşen, 2000; Atalay, 1992). With its dense coverage both above and below ground, rhododendron reduces the impact of raindrops, providing a slow movement of the rain from the canopy to the soil. Therefore, the erosion rate is reduced (Eşen, 2000).

The treatment plots were conducted in both study sites which are located in Kozcağız and Dumanlı areas: in the forest stand with 85% crown closure (dense forest-crown closure over 70%) and in a forest stand with 20% crown closure (degraded forest-crown closure below 40%).

Experimental treatments and design

Mechanical (only brush saw cutting) treatment and sprout-less herbicide applications with different concentrations were used for this experiment on between 10th and 15th June, 2001 (Table 1).

Arsenal® 250 SL, an isopropylamine salt of Imazapyr and Roundup®, N-(phosphonomethyl) and glycine were used as herbicide for SLHA application. Roundup® at a proportion of 75% was used with water dilution. On the other hand, arsenal 250 SL was also used at the 10 and 15% rates, and as a mixture with roundup at 70% in diluted water for SLHA application. All treatments were carried out under a dense stand (crown closure: 85%) and a degraded stand (crown closure: 20%). Individual rhododendron stems were cut by sprout-less herbicide applicator from 5 - 10 mm above ground. All stumps exposed to herbicidal treatment were colored with special blue ink for easy identification.

The SLHA applicator has 110 ml reservoir tank to hold herbicide solution. Herbicide application rates changed from 0.80 and 5.50 l/ha according to stand conditions, work habits and the setup of the device itself. Roundup application used 5.50 l/ha (75% of the herbicide solution) and 5.13 l/ha. (70% of the herbicide solution). Arsenal application also used 1.1 l/ha (15% of the herbicide solution) and 0.80 l/ha (10% of the herbicide solution). Herbicide consumption on cut surface of stump varied between 0.055 and 0.088 ml according to stand density and stump hardiness.

Stumps of rhododendrons grown in degraded stands were thicker and bigger than those grown in dense stands. Initial density of *R. ponticum* also changed from 50,000 to 80,000 per ha in both Dumanlı and Kozcağız areas.

A randomized complete block design with 3 blocks (replications) was used for the *R. ponticum* site. Treatments were randomly assigned to 4 x 12 m experimental plots in each block (Figure 2).

Each block was divided into 5 plots. Treatments were applied only in 4 plots (treatment bands), which were separated by 2 m buffer bands. The last (fifth) plots were left as a no woody control (check) plot. The buffer bands served to reduce the risk of soil erosion, a problem in the BSR on intermediate to steep slopes (Çolak, 1997).

Efficacy assessment

The effect of treatments was assessed in 1 x 10 m permanent quadrates randomly installed in each of treatment plots for rhododendron. All measurements were performed in quadrates of plots. All of the stumps originating from one root system were counted and average stump diameter was measured. Diameter and height of the re-sprouts were also recorded to the nearest 0.1 mm. Then, the initial density was calculated per hectare before treatment

Table 1. Mechanical (SLHA without herbicide) and sprout-less herbicide applicator treatments (SLHA) and associated usage rates in western black sea region.

Canopy closure	Treatment	Herbicide	Rate (v:v:v)
85%	SLHA without chemical	---	---
	SLHA	Ru75+W*	82.5 ml+27.5 ml
	SLHA	Ru70+Ar10+W **	77 ml+11 ml+22 ml
	SLHA	Ru70+Ar15+W ***	77 ml+16.5 ml+16.5 ml
	NWC (Check)	---	---
20%	SLHA without chemical	---	---
	SLHA	Ru75+W*	82.5 ml+27.5 ml
	SLHA	Ru70+Ar10+W **	77 ml+11 ml+22 ml
	SLHA	Ru70+Ar15+W ***	77 ml+16.5 ml+16.5 ml
	NWC (Check)	---	---

The reservoir tank of SLHA takes approximately 110 ml herbicide solution.
NWC: No woody control.
*Ru 75+W: Roundup ® at 25% concentration in water,
** Ru70+Ar10+W: Roundup ® at 70% plus Arsenal ® at 15% plus water,
*** Ru70+Ar15+W: Roundup ® at 70% plus Arsenal ® at 10% plus water.

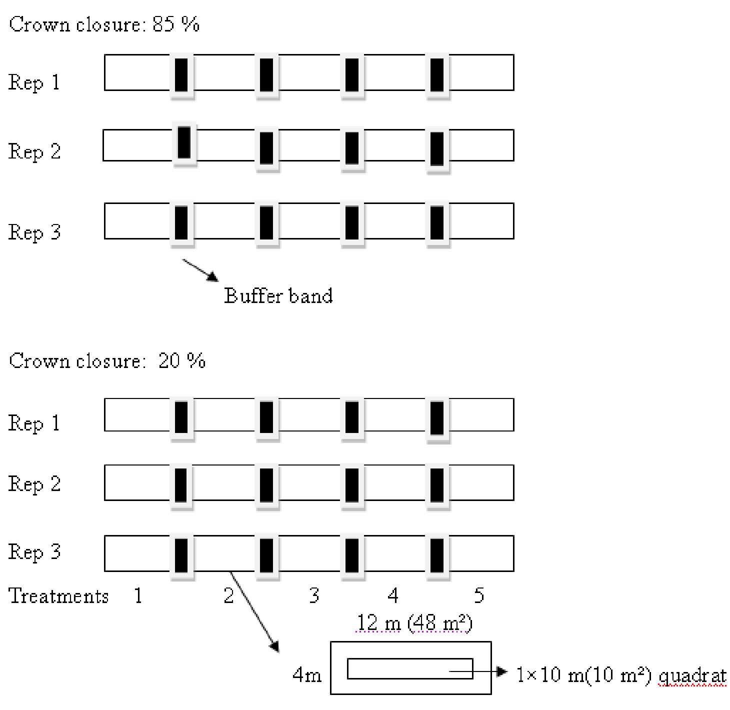

Figure 2. Scheme of randomized complete block design and a detailed sectioning of the sample plots of treatments in Kozcağız and Dumanlı areas.

[initial density (%) = (number of stumps in plots / number of plots) ×10,000/plot area]. The conditions of all re-sprouts were classified as dead, dying and active criteria in plots. Dying and active sprouts were also classified in accordance with 3 criteria. These are, very weak sprouts (do not have the ability to live), weak sprouts (may have a chance to live) and normal sprouts (growing normally and healthy). All the re-sprouts were counted in each plot for all types of sprouts originating from their respective stumps such as sprout origin (above ground level) and sucker origin (from the roots below the ground level around the stump). Final density was calculated by counting re-sprouts in plots per hectare after treatment [final density (%) = (number of re-sprouts in plots/number of plots) ×10.000/plot area]. Finally, the data were processed initially by using the excel spreadsheet program. From these data, % reduction in stump basal area (SBA) and average vigor index per treatment was calculated as fallows;

Vigor index (recovery potential indicator) = (quantity of normal sprouts × average height)/100

Average basal area reduction (%) = 1- (x/y) × 100

Stump basal area (cm^2) = π (stump diameter / 2)^2

X is the total live stump basal area after treatment and y is total live stump basal area before treatment.

Average vigor index is to be considered as a measure of the scale of the unwanted recovery in the quadrates of plots. It was calculated for each stump after treatment in the plots and then calculated per ha. The more and taller the re-sprouts of a stump are, the higher would be the vigor index value. The shorter the re-sprouts are the lower the vigor index value is. Vigor index value is usually close to 0.0 in herbicide treated sites (very weak possibility of re-growth of the sprouts from the stump cut), and usually higher than 1.0 in mechanically treated sites (strong possibility of re-growth of the sprouts from stumps cut). This means that the chance of developing a competition is many times greater in the mechanically treated sites compared to herbicide treated sites.

Statistical analysis

The vigor index (recovery potential indicator) was used to analyze the SLHA's effectiveness on rhododendron control. Means of treatments were subjected to analysis of variance using computer software package STATGRAFT and the LSD for all comparisons of pairs at $P < 0.05$ were calculated by using Tukey test.

RESULTS AND DISCUSSION

It was noted that the vegetation initial densities varied considerably between the dense forest sites and the degraded forest locations. The results indicate clearly that the initial density of rhododendrons increased significantly after mechanical cuttings. Final density was found 3 - 4 times higher than initial density in mechanical treatment. SLHA treatments showed high effectiveness to control the competition of rhododendron. Final densities were found much lower than initial densities in SLHA treated plots of both locations in Kozcağız and Dumanlı areas (Table 2).

The highest basal area reduction was found at 92% in the dense stands of Kozcağız site. It was treated with roundup (70%) plus arsenal (15%) (Ru70Ar15). It also shows the lowest final stem quantity of only 4000 stems/ha and lowest vigor index of 0.004 in first growing season. This is followed by roundup (70%) plus arsenal (15%) in Dumanlı site. Basal area reduction of stands treated with SLHA decreased ranging from 73 to 92%. On the other hand, basal area reduction of mechanically treated stands of Dumanlı and Kozcağız decreased ranging from 7 to 14% respectively. No woody control (NWC (check)) plots showed an increase in basal area which shows negative percentage figures ranging from -9 to -14%.

There were very significant difference among the treatments, crown closure and years. SLHA treatments were effective at 0.001 confidence level on controlling rhododendrons. Ru70Ar15 (Roundup at 70% plus arsenal SL at 15% plus water) and Ru70Ar10 (roundup at 70% plus arsenal SL at 10% plus water) treatments were more effective than Ru75 (roundup at 75% plus water). LSD Tukey tests were held on between mechanical and SLHA treatments (Table 3).

The average vigor index values were also determined in Kozcağız and Dumanlı areas for the first and second years. The average vigor index values obtained from the second year were higher than those from the first year. This means that some dying sprouts, which indicated live stumps, became active again during the second growing season (Table 4).

This also means that the dying stumps could be considered as a potential threat to the future of this area. This resulted in an increase in the vigor index values in the second year. The number of newly emerging sprouts and their growing speed from stumps of the mechanical treatment plots showed a significant increase at the end of the second years compared to the first year (Table 3). On the contrary, the quantity of new sprouts and their growing speed were not as high in the SLHA treated plots. The average vigor index values in degraded stands (crown closure: 20%) were higher than those in dense stands (crown closure: 85%). This means that the chance of developing re-sprouts of stumps in the degraded stands was higher than in the dense stands (Table 3 and 4). The highest values of the average vigor index were found in the mechanically treated plots. They were 3.070 and 4.175 at the end of the second growth season in Kozcağız and Dumanlı areas, respectively. The lowest values of the average vigor index were found in the treatment of Ru70Ar15 plots. They were 0.015 and 0.063 in Kozcağız and Dumanlı areas, respectively (Table 4). This means that the chance of developing a competition of rhododendrons again after treatment is at least 60 times lower (maximum 200 times lower) in SLHA treatment (Ru70Ar15) than the mechanical treatment.

Rhododendrons are very resistant to herbicide and have a very strong root system. It can easily multiply by vegetative mode and develop higher number of sprouts than resulting in an increase of the stem count. This was observed in particular in the mechanically treated sites.

Table 2. The average values of results of SLHA methods at the end of 2 growing season after treatments on *R. ponticum*

Study area	Stand canopy closure (%)	Treatment	Initial density (stems/ha)	Final density (stems/ha)	Basal area reduction (%)
Dumanlı	85	Mechanical[a]	53.000	194.000	7.26
		Ru75[a]	79.000	15.000	81.01
		Ru70Ar10[a]	56.000	7.700	86.25
		Ru70Ar15[a]	61.000	6.500	89.34
		NWC (Check)	58.000	58.000	-11.75
	20	Mechanical	61.200	214.000	10.37
		Ru75	59.000	15.700	73.39
		Ru70Ar10	50.000	8.000	84.00
		Ru70Ar15	77.100	9.450	87.74
		NWC (Check)	65.500	65.500	-14.50
Kozcağız	85	Mechanical	55.000	247.000	13.77
		Ru75	51.000	10.300	79.88
		Ru70Ar10	51.000	6.700	86.86
		Ru70Ar15	49.500	4000	91.92
		NWC (Check)	50.200	50.200	-9.85
	20	Mechanical	60.500	291.000	14.11
		Ru75	63.000	14.500	76.99
		Ru70Ar10	71.000	12.300	82.39
		Ru70Ar15	68.000	9.800	85.58
		NWC (Check)	65.700	65.700	-12.35

[a]Mechanical = SLHA without herbicide, Ru75 = Roundup ® at 75% concentration plus water, Ru70Ar15 = Roundup ® at 70% plus arsenal ® at 15% plus water, Ru70Ar10 = Roundup ® at 70% plus arsenal ® at 10% plus water.

They were heavily infested with sprouts of the rhododendron. Control of rhododendrons was more successful with SLHA in plots established in stands with 85% crown closure in comparison to plots established in stands with 20% crown closure. Ru70Ar10 and Ru70Ar15 treatments were relatively equal in their effectiveness statistically. Both of them have a greater effect than the treatment of Ru75. Eşen and Zedaker (2004) found that foliar-applied arsenal SL had significantly greater rhododendron control than foliar-applied Garlon 4. But increasing the mix percentage rates did not enhance the herbicide efficacy. This may also be explained by the results of Eşen et al. (2002), who found that higher herbicide rates did not significantly increase Imazapyr and triclopyr ester translocation to rhododendron roots. In this study, when arsenal was mixed with roundup, it was more effective than roundup alone. Increasing the proportion of arsenal from 10 to 15% did not statistically change recovery potential indicator of the rhododendron sprouts. Imazpayr as arsenal is more effective herbicide than roundup for controlling the *R. ponticum*. Dixon and Clay (2002), Tyler et al. (2006) and Lewis and McCarthy (2008) had assessed the same results in their researches.

Zedaker (1986) explained that the difficulty with foliar spray was the limited mobility with the knapsack spray equipment in very tall and dense stands. Therefore, good foliar coverage was difficult to achieve, resulting in greater chemical volume use and required extra application time. Opening a walking path in these stands usually overcame this difficulty, yet at a greater operational cost. In addition, the contamination risk of herbicide to the environment, wild-life and underground water is very high in foliar herbicide application system (Eşen and Zedaker, 2004). Eşen and Zedaker (2004) also stated that the ground line diameters were 1.4 and 1.5 cm for purple-and yellow-flowered rhododendrons, respectively and the high density per ha on the western site resulted in excessive chemical consumption and time. So, spraying the cambium of such small cut stems with squirt bottles was difficult and increased the waste of herbicides. Zedaker (1988) stated that normal cut-stump herbicide application system needed a sprayer to apply the herbicide into the cut surface. It is generally more cost-efficient when the stem diameters are big and the densities are low.

Table 3. The results of ANOVA and LSD Tukey tests according to vigor index values in both Kozcağız and Dumanlı areas.

Main effects	Kozcağız area		Dumanlı area	
	F-value	P- value	F-value	P-Value
Treatment (A)	417.21***	0.0000	257.96***	0.0000
Crown Closure (B)	25.05***	0.0000	23.67***	0.0000
Years (C)	261.22***	0.0000	201.00**	0.0000
Interactions				
A × B	18.76***	0.0000	16.20***	0.0000
A × C	217.36***	0.0000	131.82***	0.0000
B × C	13.90***	0.0007	16.65***	0.0003
A × B × C	11.93***	0.0000	12.37*	0.000
LSD Tukey results	Means		Means	
Treatments				
Ru70Ar15	0.017 a+		0.054 a+	
Ru70Ar10	0.032 ab		0.074 a	
Ru75	0.117 b		0.181 b	
Mechanical	1.468 c		1.913 c	
Crown closure				
85%	0.322 a		0.418 a	
20%	0.495 b		0.693 b	
Years				
1 year later after treatment	0.128 a		0.155 a	
2 years later after treatment	0.689 b		0.956 b	

+*Means in the column followed by the same letters are not significantly different ($p < 0.05$).*
***A significant difference ($p < 0.001$) was observed within treatments and their interactions.

Table 4. The values of average vigor index (recovery potential indicator of rhododendron sprouts) at the end of two growing seasons in both Kozcağız and Dumanlı areas.

Treatment	Kozcağız area				Dumanlı area			
	85% Crown closure		20% Crown closure		85% Crown closure		20% Crown Closure	
	FGS*	SGS**	FGS	SGS	FGS	SGS	FGS	SGS
Mechanical	0.355	1.960	0.490	3.070	0.476	2.393	0.607	4.175
Ru75	0.048	0.143	0.078	0.200	0.047	0.350	0.087	0.440
Ru70Ar10	0.016	0.033	0.022	0.055	0.008	0.107	0.011	0.175
Ru70Ar15	0.004	0.015	0.012	0.035	0.006	0.063	0.007	0.143

*First growing season, and **second growing season.

Mechanical cutting was ineffective in controlling the rhododendron (Saatçioğlu, 1957; Varol, 1970; Suner, 1978; Robinson, 1980; Palmer et al., 1988; Çolak, 1997). Varol (1970) said that the great sprout production observed after the mechanical cutting and than rhododendron populations will become dense again. A similar result was seen in some plots treated mechanically in this study.

The roots of rhododendrons generally grow in the upper 27 - 30 cm of the soil and rarely penetrates deeper than 45 cm. Fine roots are distributed mainly in the liter, humus, and near-surface layers of the soil, and roots generally grow uphill (Çolak, 1997). Root and stem parts left in the soil after grubbing may, however, minimize the long-term effectiveness of this manual technique (Eşen and Zedaker, 2004). However, *R. ponticum* grows to great heights (≥ 2 m); the ground-line diameters range from 0.8 to 7 cm and densities range from 46.000 to 79.000 plants/ha in their natural ranges in both sites. Eşen and Zedaker (2004) also stated that *R. ponticum* can grow higher than 2 m and sometimes up to 5 m in height. Ground line diameters can be more than 9 cm and their densities range from 48,000 to 90,000 plants/ha in the natural forests of Turkey.

Because of the above mentioned factors, grubbing process cannot always be carried out in northern Turkey. There is only one possibility to pull weak rhododendrons which are smaller than 1.0 m and thinner than 1.0 cm, individually in these areas. The traditional woody control of rhododendron is to cut them clearly from the ground level or if possible grubbing them using bulldozers on alternate-strips (bands). SLHA system has a great advantage to control the rhododendrons because it allows both clear cutting of rhododendrons from ground level on alternate-strips and herbicide application onto the cut stems at the same time. It did not need an extra sprayer to apply the herbicide into the cut surface of stumps. The consumption of herbicide was less per ha. It was found that SLHA effectiveness was very high in reducing the rhododendron density. It also indicates the differences between the SHLA (chemical) on rhododendrons with the non-chemical means on weed control. Also, no mechanical or gasket related problems were experienced during the application of herbicides.

Conclusion

The sprout-less herbicide applicator performs well in reducing the *rhododendron* competition to the point of allowing the establishment of commercial forests. Therefore, it is recommended to consider the SLHA system as a useful tool for plantation maintenance and establishment of a new forest. Tree planting could be carried out within a short time after the treatment due to confinement of the herbicide solutions to the stumps. It was found that there was no contamination to the workers or the environment while treating the stumps with the SLHA system. For longer lasting effectiveness and in order to control other species, which may be more resistant to the roundup (glyphosate) herbicide, it is recommended to use the formulation of roundup mixed with arsenal SL (imazapyr) and to increase the concentration of Arsenal such as 30 or 40%. Additional tests are recommended to confirm the initial findings.

However, there is sufficient evidence that the SLHA could be considered as a useful tool for forest establishment efforts in Turkey. On the other hand, since rhododendrons are very resistant to herbicide treatments and have a very strong root system, additional studies ought to be done with roundup mixed with higher arsenal concentration (such as Ru50Ar30 or Ru40Ar40).

ACKNOWLEDGEMENTS

We would like to thank to M. Aboud Mubareka who has helped us conduct this research and test this applicator together before the study in Turkey and his company of sprout-less vegetation control systems, Canada for their support in obtaining the device of the SLHA. We also appreciate Mr. Mubareka's help on the preparation of this manuscript.

REFERENCES

Anonymous (2006). Orman Varlığımız (In Turkish). The Existence of Turkey's Forest (In English). Orman Bakanlığı (Ministry of Forest), Orman Genel Müdürlüğü (General Directorate of Forestry), Ankara, Turkey, p.160.

Ata C (1996). Regeneration Problems of Mixed Stands, Regeneration Problems of Mixed Stands of Forest In Turkey, IUFRO, International Workshop Proceedings. Faculty of Forestry, Bartın, Turkey. p. 21-33.

Atalay I (1992). Kayın (*Fagus orientalis* Lipsky). ormanlarının ekolojisi ve tohum transferi yönünden bölgelere ayrılması (the ecology of beech forests and their regioning in terms of seed transfer). Ministry of Forestry. Res. Inst. of For. Trees and Seed Improvement. 5: 54-59.

Childs SW, Shade SP, Miles DWR, Shepard E, Froehlich HA (1989). Soil Physical Properties: Importance to Long-Term Forest Productivity. In: Perry DA, Meurisse R, Thomas B, Miller R, Boyle J, Means J, Perry DR, Powers RF (ed.). Maintaining the Long-Term Productivity of Pacific Northwest Forest Ecosystem. Timber Press, Portland, OR, pp. 53-66.

Clay DV, Goodall JS, Nelson DG (1992). The effect of imazapyr on R. ponticum. Aspects Appl. Biol. 29: 287-294.

Clinton BD, Vose JM (1996). Effects of *Rhododendron maximum* L. on Acer rubrum seedling establishment. Castanea 61: 38-45.

Coats KD, Emmingham WH, Radosevich SR (1991). Conifer-seedlings success and microclimate at different levels of herb and shrub cover in a *Rhododendron-Vaccinium Menziesia* community of South Central British Colombia. Can. J. For. Res. 21: 858-866.

Cross JR (1981). The establishment of Rhododendron ponticum in the Killarney oakwoods S. W. Ireland. J. Ecol. 69: 807-824.

Çolak AH (1997). Pembe Çiçekli Ormangülü'nün Silvikültürel Özellikleri Üzerine Araştırmalar (In Turkish). Investigations on the Silvicultural. Characteristics of Rhododendron *ponticum L* (In English), Doctorate Thesis, University of Istanbul, Turkey, p. 181.

Desrochers L (1999). The Sprout-Less Herbicide Applicator. Forest Engineering Institute of Canada field note (July 1999), Field Note No. Silviculture-117.

Dixon FL, Clay DV (2002). Imazapyr application to *Rhododendron ponticum*: speed of action and effects on other vegetation, For. Vol. 75(3): 217-225.

Eşen D (2000). Ecology and Control of Rhododendron (*Rhododendron ponticum* L.) in Turkish Eastern Beech (*Fagus orientalis* Lipsky.) Forests, Faculty of Virginia Polytechnic Institute and State University, Doctora Thesis (unpublished), Virginia, p.111.

Eşen D, Jackson ML, Zedaker SM (2002). Herbicide uptake and translocation in great rhododendron (*Rhododendron maximum* L.) Pop. Sum., 4 Intl. Conf. Forest Veg. Mgmt. Nancy, France. p. 390-392.

Eşen D, Zedaker SM (2004). Control of rhododendron **(***Rhododendron ponticum* and *R. flavum*) in the eastern beech (*Fagus orientalis* L.) forests of Turkey, New Forests, 27(1): 69-79.

Forster A (1998). Surfactant formulations to enhance triclopyr amine efficacy: Effects on adhesion, retention, and contact phytotoxicity on three hardwood species. M.S. Thesis, Virginia Polytechnic Institute and State Univ., Blacksburg, VA, USA. p. 140.

Gritten RH (1995). Rhododendron ponticum and some other invasive plants in the Snowdonia National Park. General Aspects and Special Problems. Plant Invasions. pp. 213-219.

Jackson M, Zedaker SM, Forster WA, Zabkiewicz JA (1998). Uptake and efficacy of triclopyr plus Silwet surfactant. Proc., Southern Weed Sci. Soc. 51: 134.

Lawrie J, Clay V (1993). Effects of herbicide mixtures and additives on Rhododendron ponticum. Weed Res. 33: 25-34.

Lewis K, McCarthy B (2008). Nontarget Tree Mortality after Tree-of-Heaven (*Ailanthus altissima*) Injection with Imazapyr, Northern J. Appl. For. 25(2): 66-72

Mubareka MA (2000). Sprout-Less Herbicide Applicator is the way of the future for pre-commercial thinning, News and Weather- Telegraph J. A 2, May 15.

Nissen SJ, Masters RA, Thompson WM, Stougaard RN (1995). Absorption and fate of imazapyr in leafy spurge (*Euphorbia esula* L.). Pesticide Sci. 45: 325-329.

Palmer CG, Reid DF, Godding DJ (1988). A review of forestry trials with a formulation of *triclopyr, dicamba,* and 2, 4-D. Asp. Appl. Biol. 16: 207-214.

Phillips DL, Murdy WH (1985). Effects of rhododendron *(*Rhododendron maximum *L.)* on regeneration of Southern Appalachian hardwoods. For. Sci. 31: 226-233.

Robinson JD (1980). *Rhododendron ponticum.* A weed of woodlands and forest plantations seriously affecting management Proceed. Weed Control in Forestry Confer. Brighton Crop Prot. Conf., pp. 89-95.

Saatçioğlu F (1957). Karadeniz Ormanları süceyrat problemi: Ayancık-Cangal bölgesinde mekanik metodla yapılan süceyrat mücadelesine ait 12 yıllık tecrübe denemeleri. I.U. Orman Fakültesi Dergisi (Woody Vegetation Problems in the Black Sea Forests: 12 Year Test Results on Mechanical Control of Woody Vegetation in Ayancik-Cangal). (Journal of the Faculty of Forestry, University of Istanbul) 7: 69-108.

Suner A (1978). Düzce, Cide ve Akkuş¸ mıntıkalarında saf doğu kayını meşcerelerinin doğal gençlestirme sorunları üzerine araştırmalar (Research on the Regeneration Problems of Pure Eastern Beech Stands in Duzce, Cide, and Akkus Localities). Ormancılık Araştırma Enstitüsü (Turkish Forest Research Institute). In: Teknik Bulten Serisi (Technical Bulletin). Ankara, Turkey No. 107, p. 7-55.

Tabbush PM, Turner DJ, Sale JS (1986). Chemicals for the forest: What about additivies? For. British Timber 15: 12-13.

Tabbush PM, Williamson DR (1987). Rhododendron ponticum *as a* Forest Weed. For. Commission Bull. 73: 1-7.

Tyler C, Pullin AS, Stewart GB (2006). Effectiveness of Management Interventions to Control Invasion by *Rhododendron ponticum*, Environ. Manage. 37(4): 513-522.

Varol M (1970). Ormangülleri ile mücadele (Control of Rhododendrons): Ormancılık Araştırma Enstitüsü Yayınları (Turkish Forest Research Institute Publications). Teknik Bülten Serisi (Tech. Bull.) 46: 1-57.

Zedaker SM (1986). Herbicides and application techniques for managing immature hardwoods. In: Smith HC, Eye MC (eds.) Proc., Guidelines for Managing Immature Appalachian Hardwood Stands. Soc. Am. Foresters Publ. 86(02): 240-250.

Zedaker SM, Lewis JB, Smith DW, Kreh RE (1987). Impact of harvest and site quality on cut-stump treatment of Piedmont Hardwoods. South J. Appl. For. 11: 46-49.

Zedaker SM (1988). Herbicide and nonchemical vegetation control during hardwood regeneration. In: Proc., Guidelines for Regenerating Appalachian Hardwood stands. USDA For. Serv., NE For. Exp. Sta., pp. 112-113.