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COLLEGE OF AGRICULTURAL & LIFE SCIENCES
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Protecting human health by controlling invasive woody shrubs in the Kickapoo Valley

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Objectives:

1. Confirm that maintaining woody invasive populations at <10% cover will reduce tick populations
2. Determine distance from high use area required to suppress invasive shrubs to minimize harm from ticks.
3. Train citizens in the Kickapoo Valley about ticks, diseases transmitted by ticks, and their relationship with Japanese barberry, and provide management recommendations to limit tick impacts to human health.

Summary

Forest understories dominated by Japanese barberry (*Berberis thunbergii*) have been shown to support higher abundance of blacklegged ticks (*Ixodes scapularis*) and higher prevalence of Lyme-infested blacklegged ticks than uninfested areas. Where barberry infestations occur in areas used by people for work or recreation, land managers may be inclined to mitigate people's exposure to the ticks by managing the barberry. In cases where infestations are too large to manage, land managers need to know to what extent they need to manage the barberry to reduce tick exposure, which includes understanding which barberry management techniques are most effective at both controlling the barberry and reducing tick habitat. We studied four barberry management techniques at two sites in Onalaska and Spring Green, Wisconsin with high (>50%) Japanese barberry cover. In April 2021, we established large plot replicates of the following barberry control treatments: (1) Mechanical removal followed by cut-stump herbicide treatment with glyphosate (Roundup); (2) Mechanical removal followed by flame treatment; (3) Foliar herbicide treatment with metsulfuron methyl (Escort); and (4) Foliar herbicide treatment with glyphosate (Roundup). Temperature and relative humidity sensors were installed in each treatment at both sites to document microclimatic conditions that impact tick survival.

Initial results from the 2021 growing season show that foliar treatments provided greater than 90% barberry control at both sites, while the treatments with mechanical removal provided from 60-80% control. All treated areas had microclimatic conditions less suitable for ticks than areas where the barberry was left unmanaged. In fall 2021 (6 months after treatment) all treatments provided significant control of Japanese barberry. Foliar treatments were the most effective (over 90% barberry control at both sites, while the treatments with mechanical removal were between 60 and 80% control. Similar results were observed one and two years after treatment with foliar remaining the most effective, followed by mechanical followed by herbicide to the cut stump, then mechanical followed by direct flame.

Impacts were observed from treatments, especially in areas of high density like Taliesin. At this location foliar application reduced diversity and cover of desirable plants the year after treatment. This reduction mostly disappeared after two years though. In lower density infestations like Onalaska, impacts were minimal the year after treatment and continued to be minimal.

While all treatments reduced Japanese barberry and environmental conditions conducive to ticks, foliar applications were the most effective approach. However, they had a higher impact on non-target species, especially in high density situations. Newer infestations, with lower densities should be prioritized as risks to desirable plants are minimized with this approach.

Index of Ratings and Results

Results

Barberry control:

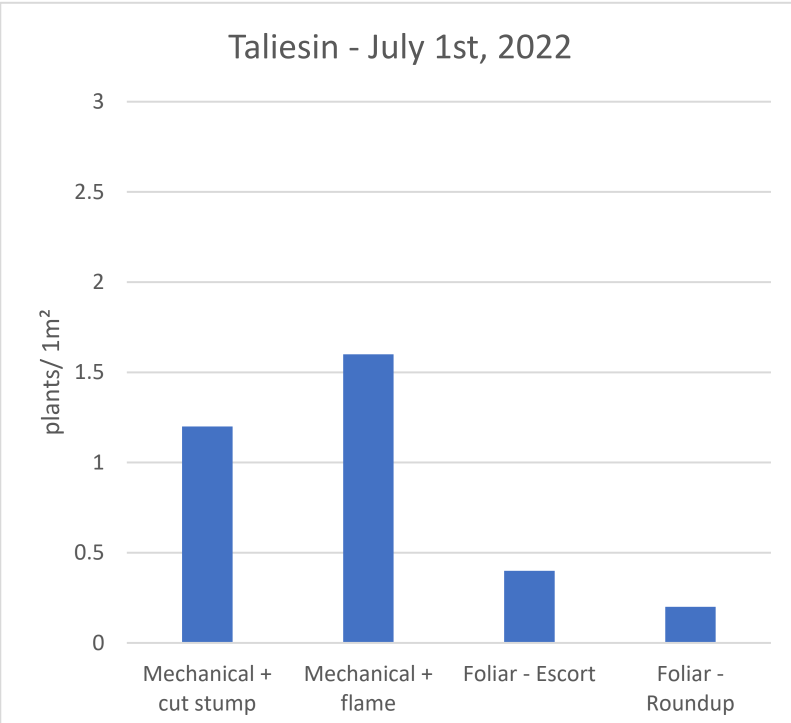
In fall 2021 (6 months after treatment) all treatments provided significant control of Japanese barberry. Foliar treatments were the most effective (over 90% barberry control at both sites), while the treatments with mechanical removal were between 60 and 80% control (see Figure 1).

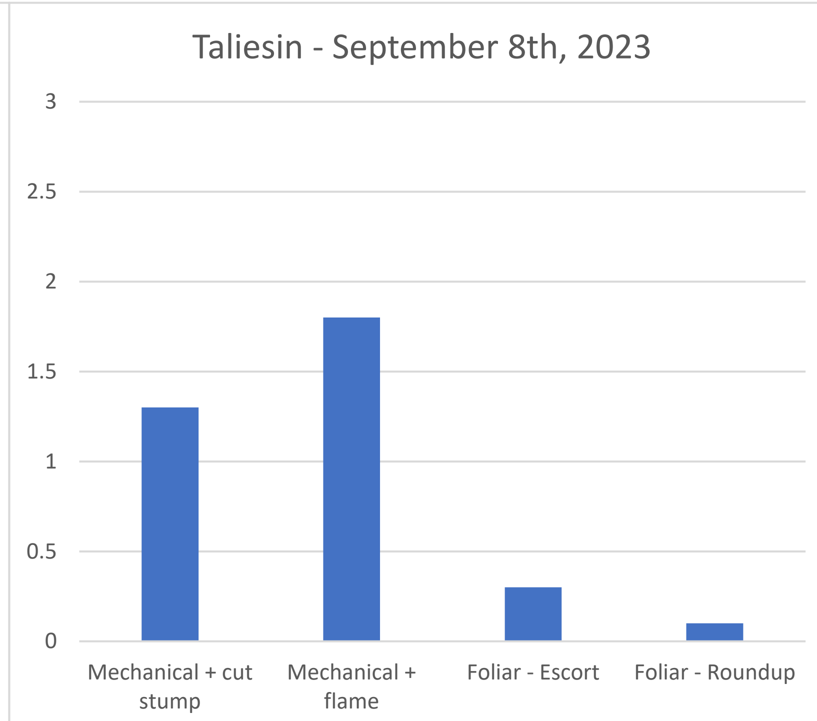
Thirteen months after application, all treatments showed low barberry density with all treatments at both sites having <2 plants m^{-2}. The foliar treatment with glyphosate had the lowest cover at both sites (<5%) but did not differ from escort at Taliesin and was similar to all treatments at Onalaska. The mechanical+flame application, while having an impact on Japanese barberry, did not have long lasting, consistent control and had the highest density and cover at both sites. When comparing species richness, Taliesin had reduced richness (native forbs, total natives, total richness) from foliar treatments while Onalaska had no differences in species richness. Mechanical and either burning or herbicide tended to have less impact at Taliesin suggesting that this approach limits off target damage. The majority of the injury and reductions in cover were observed with the foliar treatments to native forbs and non-native woody species.

Two years (27 months) after application, differences were still evident among treatments. At both sites, the foliar applications maintained high levels of control (< 1 plants/m2, 4% cover), while mechanical and cut stump applications were intermediate (< 2 plants/m2, 37% cover) and the mechanical and directed flame the worst (< 2.5 plants/m2, 48% cover). Differences in species richness dissipated after two years at Taliesin as no differences were observed. Similarly, few differences in cover were observed among treatments at either site. Non-native woody cover was elevated with the mechanical and cut stump treatment at Taliesin, while fern cover was reduced from foliar applications of roundup. Bareground remained elevated with foliar treatments at both site as it was >60%.

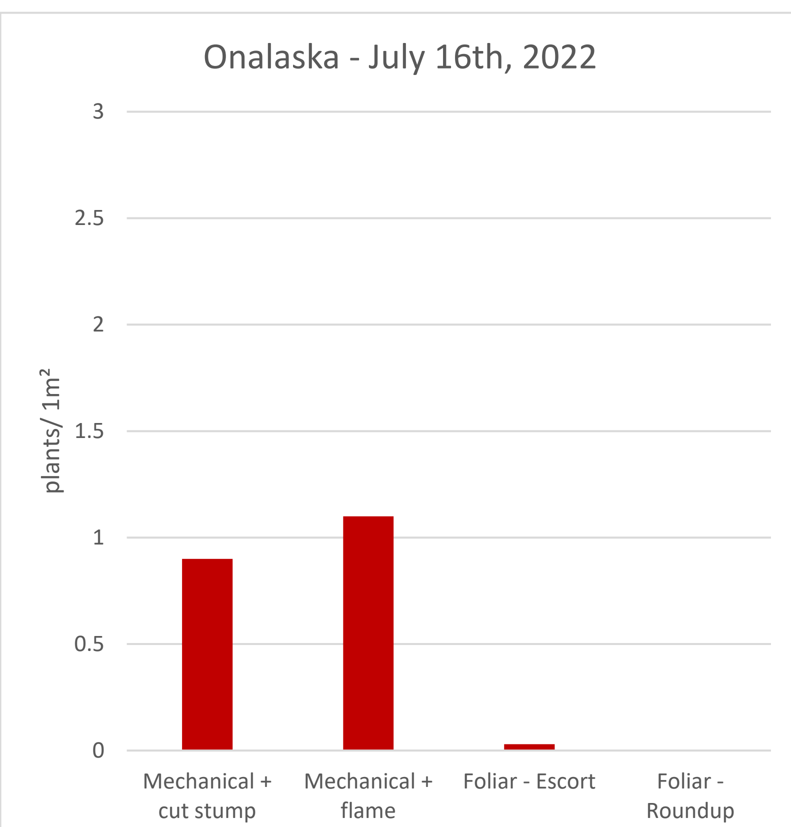
Results suggest that foliar treatments are the most effective but provide the most off-target injury. Targeting areas with lower density like Onalaska would be beneficial at minimizing the impact to non-target species.

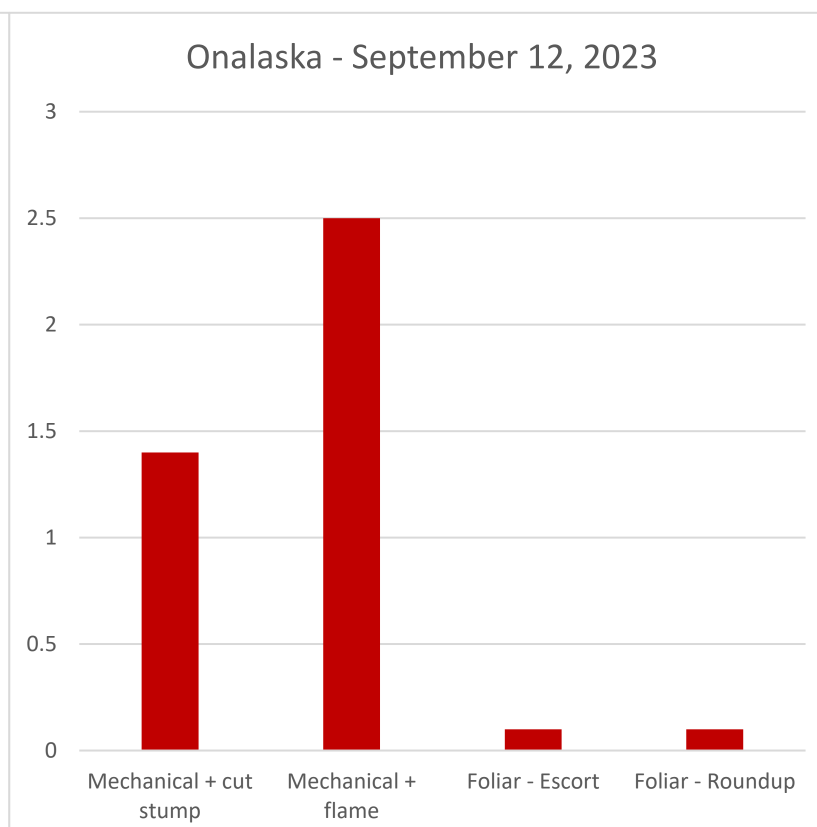
Japanese Barberry Densities





Bars labeled with the same letter do not significantly differ (P=0.05, LSD)





Bars labeled with the same letter do not significantly differ (P=0.05, LSD)

Figure 1: Japanese barberry control 6 months after treatment (front) with herbicides compared to areas not treated (back).

Treatment costs:

Treatment costs were calculated based on labor hours and product costs (propane for propane torch, fuel for brush cutters, and herbicide), but they do not include the cost of equipment (propane torch, brush cutter, backpack sprayer, or personal protective equipment). Management of heavily infested forests are expensive, with the most inexpensive treatments still costing in excess of $200 per acre. This emphasizes the need for early detection and rapid management. Treatments involving mechanical removal of barberry cost 4-6 times as much as foliar-only treatments, mostly due to labor costs.

Two years after application, neither site saw a significant difference in the overall number of native species found, among all treatments. This suggests that while more expensive options may provide immediate protection for desirables, it may not be needed. Table 1 and Figure 3 show each treatment's cost per acre, averaged across sites.

Table 1: Japanese barberry control cost per acre, averaged across both sites.

Treatment	Rate	Average total cost per acre ($)	Average product cost per acre ($)	Average labor cost per acre ($)	Average labor time per acre (hours)
Mechanical + cut stump	15% v/v	1,395 a	24 b	1,371 a	49 a
Mechanical + flame	2.5-10s @ 400,000 BTU	1,286 a	55 a	1,231 a	44 a
Foliar- Escort	1.5 oz wt/100 gal	221 b	3 c	218 b	8 b
Foliar- Roundup	15% v/v	267 b	8 c	259 b	9 b

Note: Numbers with the same letter are not significantly different (P=0.05, LSD).

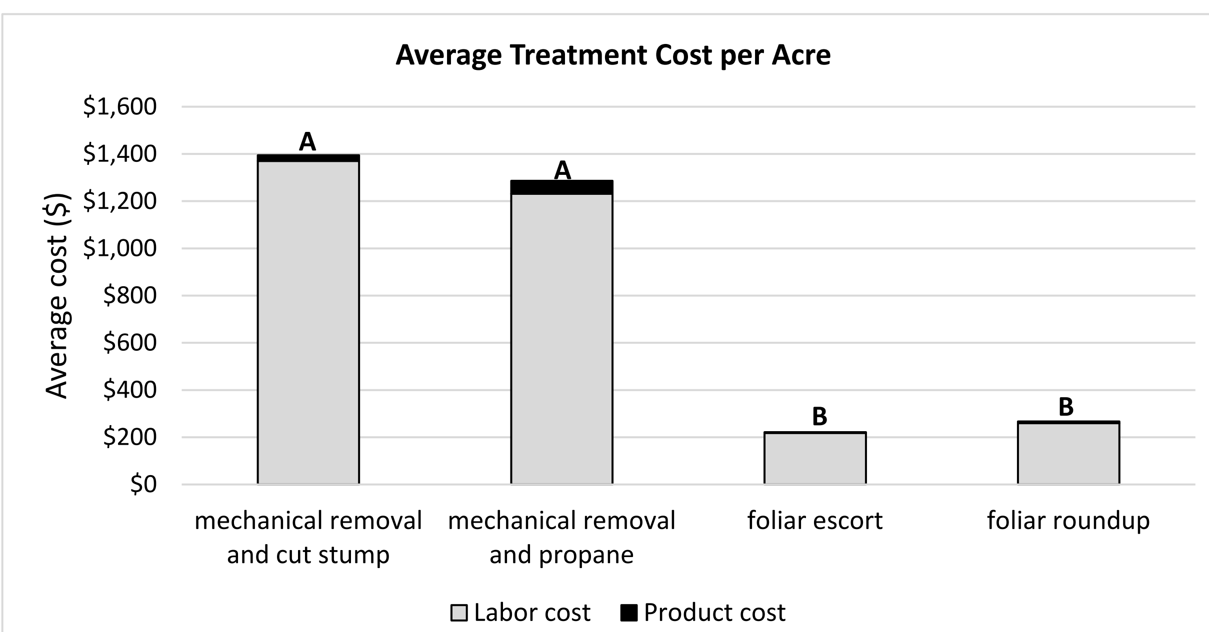


Figure 3: Average treatment cost per acre. Bars labeled with the same letter are not significantly different (P=0.05, LSD).

Tick Counts:

Tick drags yielded low tick numbers at both sites, making analysis difficult. The temperature and relative humidity data provides a good proxy for tick numbers because of the impact of microclimatic conditions on tick survival.

Temperature and relative humidity:

While control of barberry is important to mitigate numerous ecological impacts, the decision for which method to use should also consider impacts to tick habitat. Previous research has shown that ticks, particularly larvae and nymphs, are susceptible to desiccation. The vapor pressure deficit (VPD) has been shown to be a good proxy for determining suitable tick habitat. The VPD is the difference in water vapor pressure in the air compared with water vapor pressure when air is saturated at that temperature. As the rate of water evaporation increases with increased VPD, we can expect greater tick desiccation with higher VPD.

The temperature and relative humidity sensors recorded data half-hourly for the full months of April – October. We used this data to calculate the half-hourly VPD in each treatment for each month. Initial analysis (August data shown in Figure 4) shows that all treatments are making the environment less suitable (drier, higher VPD) for ticks vs. not controlled barberry areas. This is similar to results from Connecticut (Williams and Ward 2010) that showed lower VPD in not controlled barberry infestations compared to areas with low barberry cover and areas with previously high barberry cover that had been controlled. While differences in VPD may exist among different treatments, all treatments showed reductions in suitable tick habitat.

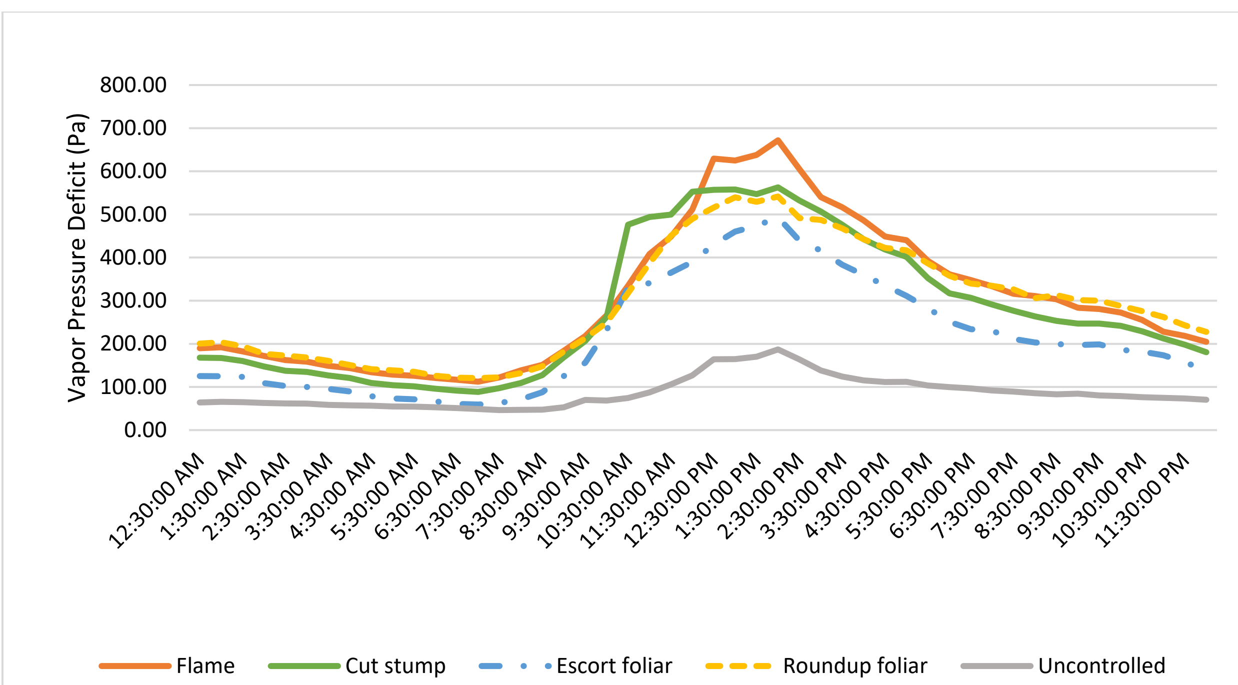


Figure 4: Half-hourly vapor pressure deficit for August 2021 at Taliesin.

Taliesin

9 Days Before Treatment – April 26th, 2021 (1/2)							
Treatment	Barberry Cover (%)	Other Shrub Cover (%)	Forb Cover (%)	Grass Cover (%)	Fern Cover (%)	Bareground /Litter Cover (%)	Canopy Cover (%)
Mechanical + cut stump	58 -	2 -	1 -	1 -	1 a	36 -	63 -
Mechanical + direct flame	65 -	4 -	2 -	1 -	1 a	28 -	46 -
Foliar – escort	72 -	3 -	1 -	1 -	1 a	23 -	63 -
Foliar – Roundup PowerMax	60 -	2 -	2 -	1 -	0 b	35 -	46 -
Statistics[1]							
Least Significant Difference (LSD) P=0.05	28.5	2.33	1.1	0.58	0.58	29.91	29.136
Standard Deviation	14.26	1.17	0.55	0.29	0.29	14.97	14.583
Coefficient of Variation (CV)	22.38	45.16	39.02	31.49	43.3	48.82	26.92
Treatment Prob(F)	0.6787	0.3396	0.4547	0.4547	0.0161	0.6755	0.356

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

9 Days Before Treatment – April 26th, 2021 (2/2)				
Treatment	Barberry < 2.5 ft Density (#/m²)	Barberry 2.5-6 ft Density (#/m²)	Barberry > 6 ft Density (#/m²)	Total Barberry Density (#/m²)
Mechanical + cut stump	0.4307 -	0.5107 -	0 -	0.941 -
Mechanical + direct flame	0.319 -	0.4307 -	0.048 -	0.7973 -
Foliar – escort	0.702 -	0.4307 -	0 -	1.1323 -
Foliar – Roundup PowerMax	0.367 -	0.4147 -	0.016 -	0.7977 -
Statistics				
LSD P=0.05	0.42275	0.38466	0.04795	0.53037
Standard Deviation	0.2116	0.19253	0.024	0.26547
CV	46.54	43.1	150	28.95
Treatment Prob(F)	0.2212	0.9247	0.1416	0.4289

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[1] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

63, 12 Days After Treatment (DAT) – July 7th, 2021			
Treatment	Barberry Cover (%)	Barberry Injury (%)	Barberry Control (%)
Mechanical + cut stump	17 -	90 -	89 -
Mechanical + direct flame	20 -	80 -	75 -
Foliar – escort	12 -	98	90 -
Foliar – Roundup PowerMax	1 -	100 -	99 -
Statistics[2]			
LSD P=0.05	22.52	41.63	17.63
Standard Deviation	11.27	20.83	8.82
CV	92	22.67	9.98
Treatment Prob(F)	0.2682	0.6594	0.074

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

166, 115 DAT – October 18th, 2021			
Treatment	Barberry Cover (%)	Barberry Control (%)	Barberry Mortality (%)
Mechanical + cut stump	9 ab	83 b	22 b
Mechanical + direct flame	14 a	73 b	25 b
Foliar – escort	2 bc	99 a	93 a
Foliar – Roundup PowerMax	1 c	99 a	95 a
Statistics			
LSD P=0.05	7.98	14.08	23.51
Standard Deviation	4	7.05	11.77
CV	61.49	7.95	20.05
Treatment Prob(F)	0.0228	0.0105	0.0003

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[2] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

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188, 137 DAT – November 9th, 2021							
Treatment	Barberry Control (%)	Barberry Cover (%)	Other Shrubs Cover (%)	Forb Cover (%)	Grass Cover (%)	Fern Cover (%)	Bareground/ Litter Cover (%)
Mechanical + cut stump	75 bc	18 -	3 -	6 -	0 -	5 a	68 b
Mechanical + direct flame	73 c	18 -	7 -	3 -	1 -	4 a	67 b
Foliar – escort	92 ab	8 -	2 -	0 -	1 -	0 b	89 a
Foliar – Roundup PowerMax	98 a	2 -	1 -	0 -	0 -	0 b	98 a
Statistics[3]							
LSD P=0.05	17.7	14.84	5.08	10.54	1.45	1.15	20.55
Standard Deviation	8.86	7.43	2.54	5.27	0.73	0.58	10.28
CV	10.47	64.6	80.34	225.99	217.94	24.74	12.8
Treatment Prob(F)	0.0327	0.0806	0.1123	0.549	0.5187	0.0001	0.0227

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

420, 371 DAT – July 1st, 2022								
Treatment	Barberry Density (#/m²)	Barberry Cover (%)	Native Forb Cover (%)	Nonnative Forb Cover (%)	Native Woody Cover (%)	Nonnative Woody Cover (%)	Fern Cover (%)	Bareground/ Litter Cover (%)
Mechanical + cut stump	1.2 -	35.4 ab	48.1 a	39.2 -	61.2 -	10.4 ab	15.4 -	12.3
Mechanical + direct flame	1.6 -	45.2 a	47.8 a	36.1 -	44.3 -	18.7 a	21.6 -	28.97
Foliar – escort	0.4 -	12.7 bc	17.1 b	58.6 -	35 -	0 b	0 -	26.13
Foliar – Roundup PowerMax	0.2 -	4.4 c	27 b	61.5 -	34.9 -	3.6 b	6.5 -	25.37
Statistics								
LSD P=0.05	1.125	23.654	24.053	24.706	67.014	10.833	18.197	42.72
Standard Deviation	0.563	11.839	12.039	12.366	33.543	5.422	9.108	21.386
CV	66.95	48.47	34.4	25.31	76.46	66.39	83.56	92.21
Treatment Prob(F)	0.0560	0.0172	0.0456	0.0974	0.7531	0.0223	0.0995	0.7834

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[3] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

420, 371 DAT – July 1st, 2022				
Treatment	*Native Forb Richness	*Native Woody Richness	*Total Native Richness	*Total Species Richness
Mechanical + cut stump	10.7 a	6.7 -	17.3 a	20 a
Mechanical + direct flame	10.3 a	4.3 -	14.7 ab	17.7 ab
Foliar – escort	4 b	3.7 -	7.7 c	10.7 c
Foliar – Roundup PowerMax	6.3 b	4.7 -	11 bc	13 bc
Statistics[4]				
LSD P=0.05	3.73	3.69	6.18	6.66
Standard Deviation	1.86	1.85	3.09	3.33
CV	23.79	38.24	24.4	21.74
Treatment Prob(F)	0.0122	0.3157	0.0354	0.0471

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

854, 805 DAT – September 8th, 2023								
Treatment	Barberry Density (#/m²)	Barberry Cover (%)	Native Forb Cover (%)	Nonnative Forb Cover (%)	Native Woody Cover (%)	Nonnative Woody Cover (%)	Fern Cover (%)	Bareground/ Litter Cover (%)
Mechanical + cut stump	1.3 a	37.7 ab	18.1 -	2.9 -	13 -	0.7 -	3.6 -	37.7 bc
Mechanical + direct flame	1.8 a	48.6 a	20.3 -	5.1 -	29 -	5.8 -	2.9 -	17.4 c
Foliar – escort	0.3 b	0.7 c	2.9 -	1.4 -	8.7 -	10.1 -	0 -	76.8 a
Foliar – Roundup PowerMax	0.1 b	2.2 bc	18.8 -	0 -	16.7 -	4.3	0 -	63.8 ab
Statistics								
LSD P=0.05	0.5646	35.578	20.246	7.488	29.244	17.714	7.06	27.493
Standard Deviation	0.2826	17.808	10.134	3.748	14.637	8.866	3.53	13.761
CV	32.81	79.85	67.45	159.48	86.95	168.88	132.44	28.13
Treatment Prob(F)	0.0009	0.0347	0.2257	0.4547	0.4308	0.6508	0.3430	0.0072

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[4] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

* Data shows number of plant species found for each category per plot..

854, 805 DAT – September 8th, 2023				
Treatment	*Native Forb Richness	*Native Woody Richness	*Total Native Richness	*Total Species Richness
Mechanical + cut stump	6 -	2 -	8 -	9.7 -
Mechanical + direct flame	4.7 -	4.3 -	9 -	11 -
Foliar – escort	1.7 -	2 -	3.7 -	4.7 -
Foliar – Roundup PowerMax	4 -	2.3 -	6.3 -	8.3 -
Statistics[5]				
LSD P=0.05	4.37	2.47	4.38	4.53
Standard Deviation	2.19	1.24	2.19	2.27
CV	53.53	46.35	32.48	26.93
Treatment Prob(F)	0.2065	0.1591	0.0947	0.0599

[5] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.
* Data shows number of plant species found for each category per plot.

Onalaska

14 Days Before Treatment – April 29th, 2021							
Treatment	Barberry Cover (%)	Forb Cover (%)	Other Shrub Cover (%)	Grass Cover (%)	Fern Cover (%)	Bareground/Litter Cover (%)	Canopy Cover (%)
Mechanical + cut stump	53 -	1 -	5 -	1 -	1 -	38 -	48 -
Mechanical + direct flame	55 -	2 -	5 -	1 -	1 -	36 -	42 -
Foliar – escort	48 -	1 -	4 -	1 -	1 -	44 -	55 -
Foliar – Roundup PowerMax	47 -	1 -	7 -	1 -	1 -	43 -	33 -
Statistics[6]							
LSD P=0.05	16.98	2.38	5.37	.	.	18.98	22.28
Standard Deviation	8.5	1.19	2.69	0	0	9.5	11.15
CV	16.72	79.35	51.19	0	0	23.51	25.01
Treatment Prob(F)	0.6092	0.5826	0.7509	1	1	0.6594	0.2053

14 Days Before Treatment – April 29th, 2021				
Treatment	Barberry < 2.5 ft Density (#/m²)	Barberry 2.5-6 ft Density (#/m²)	Barberry > 6 ft Density (#/m²)	Total Barberry Density (#/m²)
Mechanical + cut stump	0.33 -	0.11 -	0.01 -	0.45 -
Mechanical + direct flame	0.28 -	0.18 -	0.00 -	0.46 -
Foliar – escort	0.33 -	0.05 -	0.01 -	0.39 -
Foliar – Roundup PowerMax	0.36 -	0.07 -	0.01 -	0.44 -
Statistics				
LSD P=0.05	0.14525	0.1352	0.03114	0.07499
Standard Deviation	0.0727	0.06767	0.01559	0.03753
CV	22.35	67	230.94	8.67
Treatment Prob(F)	0.6085	0.1867	0.8587	0.1882

[6] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

175, 133 DAT – November 4th, 2021							
Treatment	**Barberry Control (%)**	**Barberry Cover (%)**	**Forb Cover (%)**	**Other Shrub Cover (%)**	**Grass Cover (%)**	**Fern Cover (%)**	**Bareground/ Litter Cover (%)**
Mechanical + cut stump	78 ab	12 -	1 -	4 -	0 -	2 -	80 -
Mechanical + direct flame	60 b	23 -	1 -	4 -	0 -	4 -	69 -
Foliar – escort	97 a	2 -	0 -	8 -	0 -	1 -	89 -
Foliar – Roundup PowerMax	99 a	1 -	0 -	4 -	0 -	0.3 -	94 -
Statistics[7]							
LSD P=0.05	23.53	17	1	7.99	.	3.07	21.46
Standard Deviation	11.78	8.51	0.5	4	0	1.54	10.74
CV	14.12	88	120	77.42	0	87.81	12.94
Treatment Prob(F)	0.0207	0.0574	0.117	0.5135	1	0.1139	0.1029

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

428, 387 DAT – July 16th, 2022								
Treatment	**Barberry Density (#/m²)**	**Barberry Cover (%)**	**Native Forb Cover (%)**	**Nonnative Forb Cover (%)**	**Native Woody Cover (%)**	**Nonnative Woody Cover (%)**	**Fern Cover (%)**	**Bareground/ Litter Cover (%)**
Mechanical + cut stump	0.9 a	18 -	57 -	12.5 -	41.7 -	6.9 -	14.6 -	18.1 -
Mechanical + direct flame	1.1 a	18 -	72.2 -	5.6 -	43.7 -	11.8 -	34.1 -	6.9
Foliar – escort	0.03 b	8 -	53.2 -	4.9 -	49 -	11.8 -	14.7 -	18.1
Foliar – Roundup PowerMax	0 b	2 -	49.3 -	9.7 -	24.3 -	6.9 -	4.9 -	31.3
Statistics								
LSD P=0.05	0.568	14.84	24.971	22.525	17.796	12.484	23.187	22.226
Standard Deviation	0.284	7.43	12.499	11.275	8.908	6.249	11.606	11.625
CV	57.5	64.6	21.58	137.91	22.45	66.65	68.0	62.58
Treatment Prob(F)	0.0066	0.0806	0.2254	0.8191	0.0607	0.6323	0.0975	0.1897

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[7] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

428, 387 DAT – July 16th, 2022				
Treatment	*Native Forb Richness	*Native Woody Richness	*Total Native Richness	*Total Species Richness
Mechanical + cut stump	11 -	6 -	17 -	20.7 -
Mechanical + direct flame	13 -	5.7 -	18.7 -	22.3 -
Foliar – escort	12 -	7 -	19 -	21.3 -
Foliar – Roundup PowerMax	11 -	6 -	17 -	19.7 -
Statistics[8]				
LSD P=0.05	3.60	3.05	5.38	5.33
Standard Deviation	1.80	1.53	2.69	2.67
CV	15.34	24.77	15.03	12.7
Treatment Prob(F)	0.5170	0.7400	0.7134	0.6773

851, 810 DAT – September 12th, 2023								
Treatment	Barberry Density (#/m²)	Barberry Cover (%)	Native Forb Cover (%)	Nonnative Forb Cover (%)	Native Woody Cover (%)	Nonnative Woody Cover (%)	Fern Cover (%)	Bareground/ Litter Cover (%)
Mechanical + cut stump	1.4 b	25 b	10 -	8.7 -	4.3 -	6 -	7.3 a	35 b
Mechanical + direct flame	2.5 a	46 a	6.7 -	3.3 -	6.7 -	5.3 -	7.7 a	22.7 c
Foliar – escort	0.1 c	3 b	8.3 -	8.3 -	5 -	8.3 -	3.7 ab	62.3 a
Foliar – Roundup PowerMax	0.1 c	4 b	12 -	2.7 -	3.7 -	4 -	1.3 b	74 a
Statistics								
LSD P=0.05	0.888	21.84	13.50	8.00	5.93	5.95	4.66	12.09
Standard Deviation	0.445	8.41	6.76	4.00	2.97	2.98	2.33	15.176
CV	422.88	48.27	73.03	69.63	60.35	50.31	46.67	45.07
Treatment Prob(F)	0.0013	0.0218	0.7960	0.2300	0.6580	0.4148	0.0434	0.0573

Note: Means followed by same letter or symbol do not significantly differ (P=.05, LSD).

[8] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.

851, 810 DAT – September 12th, 2023				
Treatment	*Native Forb Richness	*Native Woody Richness	*Total Native Richness	*Total Species Richness
Mechanical + cut stump	7.7 -	6 -	13.7 -	16.3 -
Mechanical + direct flame	8 -	5.3 -	13.3 -	16 -
Foliar – escort	7.7 -	6.3 -	14 -	17.3 -
Foliar – Roundup PowerMax	7 -	4 -	11 -	12.7 -
Statistics[9]				
LSD P=0.05	4.91	4.91	7.64	6.91
Standard Deviation	2.46	2.46	3.83	3.46
CV	32.38	45.33	29.43	22.2
Treatment Prob(F)	0.9643	0.6781	0.7716	0.4444

* Data shows number of plant species found for each category per plot.

[9] All statistical analyses were conducted in ARM software and assumptions of ANOVA were not evaluated.