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The Response of Perennial Pepperweed (*Lepidium latifolium*) to Physical and Chemical Mowing and Herbicide Treatment of the Regrowth

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Summary: We measured the response of perennial pepperweed (*Lepidium latifolium*) canopy cover and stem numbers to 30 treatment combinations that included physical or chemical mowing, and application of a systemic herbicide to the regrowth of perennial pepperweed. Mowing treatment, regrowth herbicide treatment, and their interaction each influenced the response of perennial pepperweed. Telar (chlorsulfuron), with or without any type of mowing treatment, was the only herbicide that resulted in complete control of perennial pepperweed one-year post treatment. Mowing treatments generally did not increase the effectiveness of Roundup ProMax (glyphosate) or 2,4-D Ester that was applied to the regrowth. If chemical mowing is used as part of a treatment, initial treatment with a systemic herbicide provides better results than chemical mowing with a contact herbicide, but not better than a single treatment with a systemic herbicide.

INTRODUCTION

Perennial pepperweed (*Lepidium latifolium*) is also commonly known as tall whitetop and is a widespread invasive perennial weed throughout the Great Basin and other Western states (DiTomaso and Healy 2007). It commonly grows in grass-hay meadows, riparian and marsh areas, and other seasonally wet sites (Miller et al. 1986; Renz 2000; Leininger and Foin 2009). New perennial pepperweed plants can develop roots up to 3 feet deep in their first 90 days of growth (Renz and Blank 2004). Within a couple of years, mature plants have roots that can reach 10 feet deep, spread laterally tens of feet, and develop very high root–to-shoot ratios (Renz et al. 1997; Chen et al. 2002; DiTomaso and Healy 2003). These large and widespread root systems develop a substantial carbohydrate reserve, and large carbohydrate reserves allow perennial pepperweed to regrow rapidly when treatments fail to kill all of the buds on the root system (Young et al. 1997).

When perennial pepperweed plants approach the eight-leaf growth stage (six to eight weeks old), the roots develop buds and become perennial (Renz 2000). From the plant's

perspective these buds serve several purposes. First, as the roots expand laterally, the buds can initiate growth and establish new shoots above the soil surface, increasing the plant's leaf and root area. The expansion of both leaf and root area allows perennial pepperweed to extract additional resources (sunlight, water and nutrients) and increase its competitive ability with desired perennial plants. Second, when perennial pepperweed's roots are broken or severed, segments as short as 1 inch (and perhaps shorter) often have a viable bud. These buds begin growth and can produce a new plant. One large perennial pepperweed root, therefore, has the potential to produce hundreds of new stems or plants through vegetative reproduction.

After the roots of perennial pepperweed plants develop buds, chemical control of the population requires the use of systemic herbicides. Systemic herbicides are applied to the leaves (and/or soil), and the plant moves the chemical through its vascular system to the site of action. The site of action often is a small area composed of meristematic tissue, which are the plant's growing points. These microscopic growing points are the locations on a plant that produce new cells and a suite of biochemical reactions, two of the critical elements of plant growth. At the site of action, the herbicide interrupts a critical process the plant must complete to survive; thus, the growing point dies. If all of the plant's growing points (buds and other meristematic tissue) die before the next growing season, then the plant dies and weed control occurs.

Research in California (Renz and DiTomaso 2004 and 2006) found that physically mowing perennial pepperweed plants at the flowering-bud growth stage, and applying a systemic herbicide to the perennial pepperweed regrowth at the bud stage, is more effective than a single application of the herbicide to unmowed plants at the flowering-bud growth stage. This was particularly true for treatments with Roundup (glyphosate). The regrowth of physically mowed plants typically had larger leaves and a shorter and flatter (prostrate) growth form compared to unmowed plants. This resulted in greater exposure of the basal leaves to potential contact with an herbicide when the chemical was applied to the plant from above.

In the Great Basin, perennial pepperweed inhabits many grass-hay meadows that cannot be physically mowed. The micro-topography may be too rough, and/or the sites are seasonally flooded, with the soils staying very wet far into the growing season (July). Both conditions can prevent the use of large mowing equipment. However, perennial pepperweed stands can be "chemically mowed" via ground or aerial application, and the regrowth treated at the appropriate growth stage. This field study was designed to address two questions:

1) In a Great Basin grass-hay meadow system, does physical mowing at the bud-to-flowering growth stage, followed by treatment of the perennial pepperweed regrowth at the bud stage, with a systemic herbicide, improve perennial pepperweed control, compared to a single herbicide treatment at the bud-to-flowering growth stage?

2) Is chemical mowing followed by herbicide treatment of the regrowth as effective as physical mowing followed by an herbicide treatment of the regrowth?

METHODS

The study plot was located about 3 miles east of Elko, Nev., in the floodplain of the Humboldt River. Historically, the site was a meadow of predominately creeping wildrye (*Leymus triticoides:* NRCS 2003). All treatment plots were within 200 feet of the river, which is perennial and usually provides overland flow during the spring runoff. The proximity of the river allows the roots of the perennial pepperweed to access the water table throughout the potential growing season (April to October). The entire study area consisted of a long-established mature stand of perennial pepperweed, with a residual understory of creeping wildrye (Figure 1). The response of the perennial grasses to the various herbicide treatments applied will be reported in a subsequent publication.

Figure 1. The eastern portion of the study-area is to the right of the boundary that was mowed around the perimeter of the plots.

Thirty treatment combinations were applied, including untreated (control) plots (Tables 1 and 2). Treatment combinations were as follows:

- A single physical mowing followed by five herbicide treatments to the regrowth (including untreated plots).
- A single chemical mowing treatment with a contact herbicide, followed by five herbicide treatments to the regrowth (including untreated plots). This treatment parallels physical mowing in that only the above-ground portion of the plant is affected. It differs from physical mowing in that the affected part of the plant remains upright, while physically mowed plants lay the affected stems down on top of the soil or plant stubble.
- Separate application of two systemic herbicides, singularly and as a tank mix, the same day the other plots were physically or chemically mowed. The regrowth was treated with five herbicide treatments, including untreated plots (Table 1). For ease of discussion throughout this document, all plots that received an initial treatment with an herbicide will be called "chemically mowed," with the understanding that "mowing" with a systemic herbicide affects both the aboveground stems and some of the root system and its associated buds.

Table 1. Initial and follow up treatments to perennial pepperweed in 2009. All possible combinations of initial and regrowth treatments resulted in 30 total treatment combinations.

Initial treatments at the bud-to-flowering stage (July)	Regrowth herbicide treatment (September)
None (untreated)	None (untreated)
Rotary mower	2,4-D Ester
Reward (chemical mowing)	Telar
Roundup ProMax & 2,4-D Ester	Roundup ProMax
Roundup ProMax	Roundup ProMax& 2,4-D Ester
2,4-D Ester	

Table 2. Herbicide names, concentrations and rates applied.

Common name	Product name	Systemic or contact	Active ingredient (ai) concentration	Rate product and (ai) applied
2,4-D Ester		Systemic	3.8 lb A/GAL	2.1 qt/ac (2.0 lb A/ac)
Chlorsulfuron	Telar	Systemic	75% AW/W	1.0 oz/ac (0.75 oz /ac)
Diquat	Reward	Contact	2.0 lb A/GAL	2.0 qt/ac (1.0 lb A/ac)
Glyphosate	Roundup ProMax	Systemic	4.5 lb A/GAL	3.0 qt/ac (3.375 lb A/Ac)

Each treatment combination was applied four times for 120 total treatment plots. All treatments occurred in plots that measured 10 feet by 30 feet. Initial mowing and herbicide treatments occurred on July 21, 2009, when the perennial pepperweed was at the bud-to-flowering growth stage (Figure 1). Physical mowing was conducted with a rotary brush mower pulled behind an ATV. All herbicides were applied with a CO_2-pressurized backpack sprayer with a 10-foot boom. As previously mentioned, the “chemical mowing” treatments included a contact herbicide and two different systemic herbicides. The regrowth was treated at the bud-to-early-flowering growth stages on Sept. 28, 2009 (Figure 2).

Figure 2. A physically mowed treatment block with a chemically mowed treatment block located on each side. Perennial pepperweed regrowth in the physically mowed plots is at the bud-to-early-flowering growth stage.

We measured two perennial pepperweed response variables: a visual estimate of percent canopy cover and stem counts (stems per m^2). Means were determined for each treatment combination and analyzed with a two-way analysis of variance to assess the respective effects of the mowing and regrowth treatments, and their interactions. When an analysis of variance test indicated that the difference between two or more means had a 90 percent or greater probability of being due to a treatment, we used the Least Significant Difference (LSD) mean separation test to identify which specific treatments were different from one another. All statistical tests used the 10 percent probability level ($P \leq 0.10$). That is, there was a 90 percent or greater chance that the differences between the means were due to the treatments applied, and no more than a 10 percent chance that the differences were due to some factor other than the treatments applied.

RESULTS

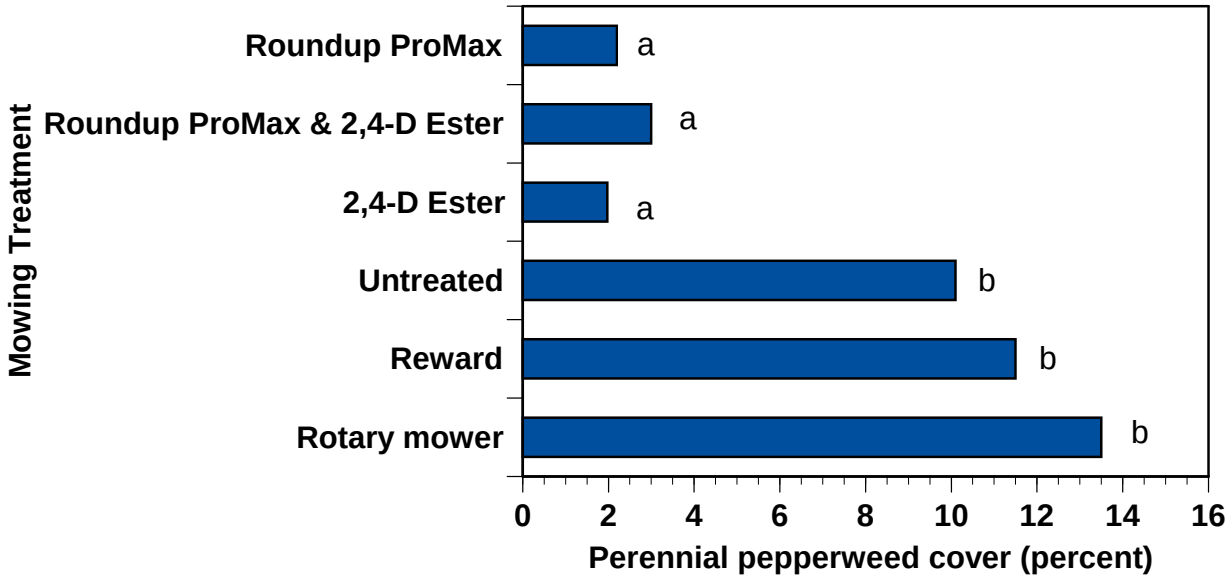
Perennial Pepperweed Cover

There was a greater than 99 percent probability that mowing treatment, regrowth herbicide treatment and their interaction each affected the amount of perennial pepperweed canopy cover one year after treatment (Table 3). Figure 3 shows the influence of each mowing treatment. Compared to untreated plots, perennial pepperweed had more cover on plots physically mowed with a rotary mower or chemically mowed with a contact herbicide (Reward). The probability that the increase in canopy cover on the rotary mowed plots was due to the mowing treatment was greater than 90 percent. Chemically mowed treatments that used systemic herbicides (Roundup ProMax and 2,4-D) had substantially

Table 3. Analysis of variance table for the response of perennial pepperweed cover to mowing treatments, herbicide treatments and their interaction.

Type of treatment	Degrees of freedom	Probability that the means are different due to a factor other than ~~than~~ the treatment applied
Mowing	5	0.00
Herbicide	4	0.00
Mowing*herbicide interaction	20	0.00

Figure 3. Effect of mowing on perennial pepperweed cover**.** Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.



less cover from perennial pepperweed than the untreated plots, the physically mowed plots, and the plots chemically mowed with a contact herbicide. The probability that the differences were due to the use of the systemic herbicides as the chemical mowing agent was 90 percent or greater.

Compared to the untreated plots, all treatments that included application of a systemic herbicide to the regrowth had substantially less cover of perennial pepperweed (Figure 4). There was a 90 percent or greater probability that the difference between each treatment and the untreated plots was due to the herbicide treatment. There were clear statistical differences between treatments with Telar and all of the other regrowth herbicide treatments (Figure 4). Telar treatments resulted in the complete absence of perennial pepperweed. The second most effective regrowth treatment was a tank mix of Roundup ProMax and 2,4-D Ester (3 percent cover), followed sequentially by treatments with 2-4,D Ester (4.5 percent cover) and Roundup ProMax (6.5 percent cover). The addition of 2,4-D Ester to Roundup ProMax resulted in a statistically significant decrease in perennial pepperweed canopy cover, but the absolute decline was only about 3.5 percent: from 7 percent to about 3.5 percent.

The interaction of mowing treatment and regrowth herbicide treatment resulted in a wide range of canopy cover from perennial pepperweed (Table 4). The untreated plots had a mean perennial pepperweed canopy cover of 34 percent. Chemical mowing with a contact herbicide and no regrowth herbicide treatment resulted in average absolute increase in perennial

Figure 4. The response of perennial pepperweed one year after an herbicide application to its regrowth. Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.

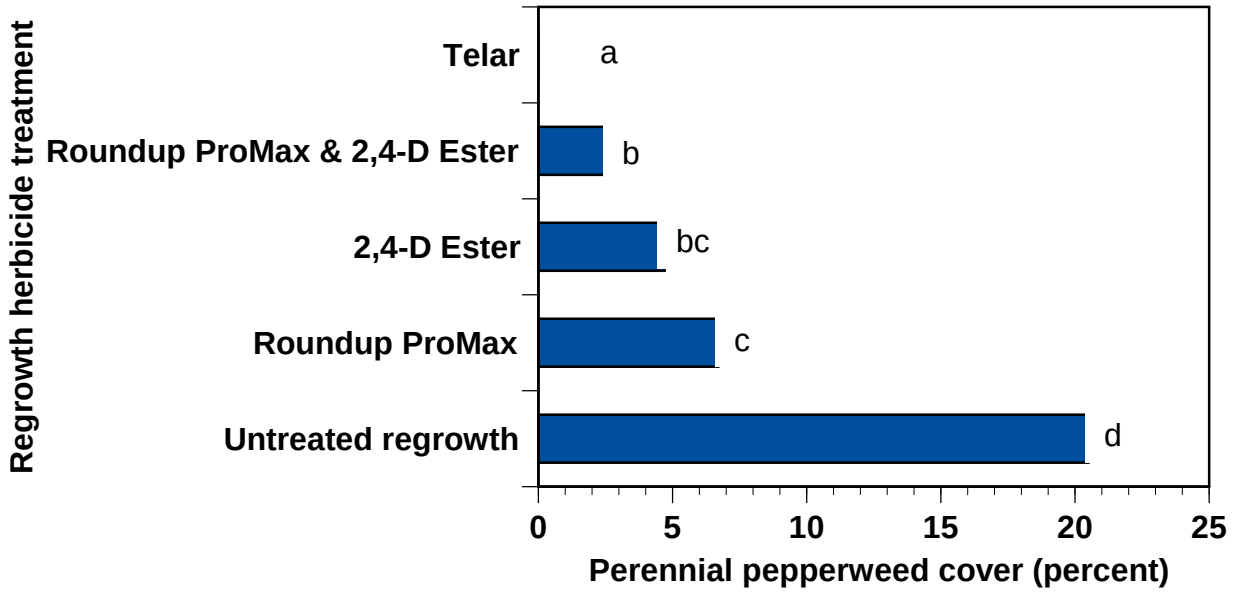


Table 4. Cover of perennial pepperweed in response to interactions of mowing and herbicide treatments to the regrowth. Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.

Mowing treatment	Regrowth herbicide treatment	Perennial pepperweed canopy cover	Mean separation
Rotary mower	None	42.5	A
Reward	None	38.8	AB
None	None	34.4	B
None	Roundup ProMax	12.5	C
Rotary mower	Roundup ProMax	10.6	CD
Rotary mower	2,4-D Ester	8.3	CDE
Roundup ProMax& 2,4-D Ester	2,4-D Ester	7.6	CDEF
Reward	Roundup ProMax & 2,4-D Ester	7.3	CDEF

Mowing treatment	Regrowth herbicide treatment	Perennial pepperweed canopy cover	Mean separation
Reward	Roundup ProMax	6.8	CDEFG
Rotary mower	Roundup ProMax & 2,4-D Ester	6.3	CDEFG
Reward	2,4-D Ester,	4.6	DEFG
Roundup ProMax	2,4-D Ester	3.8	EFG
2,4-D-Ester	Roundup ProMax	3.5	EFG
Roundup ProMax & 2,4-D Ester	Roundup ProMax	3.5	EFG
Roundup ProMax	Roundup ProMax	3.3	EFG
Roundup ProMax & 2,4-D Ester	None	3.0	EFG
2,4-D-Ester	Roundup ProMax & 2,4-D Ester	2.5	EFG
Roundup ProMax	None	2.4	EFG
None	2,4-D Ester	2.3	EFG
2,4-D Ester	None	2.3	EFG
2,4-D Ester	2,4-D Ester	1.6	EFG
Roundup ProMax	Roundup ProMax & 2,4-D Ester	1.5	EFG
None	Roundup ProMax & 2,4-D Ester	1.2	FG
Roundup ProMax & 2,4-D Ester	Roundup ProMax & 2,4-D Ester	1.0	FG
None	Telar	0.0	G
Rotary mower	Telar	0.0	G
Roundup ProMax	Telar	0.0	G
2-4,D-Ester	Telar	0.0	G
Reward	Telar	0.0	G
Roundup ProMax & 2,4-D Ester	Telar	0.0	G

pepperweed canopy cover of over 4 percent. Rotary mowing, without a regrowth herbicide treatment, resulted in an increase in perennial pepperweed canopy cover of 8.1 percent, to over 42 percent. The probability that rotary mowing was the factor that increased perennial pepperweed cover was greater than 90 percent.

Compared to the untreated plots, all other treatment combinations decreased perennial pepperweed canopy cover at least 21.9 percent (Table 4). There was a 90 percent or greater probability that the difference in mean perennial pepperweed canopy cover between each treatment interaction and the untreated plots was due to the specific interaction.

The effectiveness of Telar was not improved by any mowing treatment (Table 4). All treatment combinations had zero percent canopy cover of perennial pepperweed in July 2009, three months after growth started (during the middle of the first growing season after treatment). The other 21 treatment combinations had perennial pepperweed cover that ranged from 1 to 12.5 percent.

Treatment combinations that applied a chemical mowing treatment in July (with a systemic herbicide) and no regrowth treatment in September were the functional equivalent of a single herbicide application at the bud-to-flowering growth stage. Likewise, treatment combinations that did not have a mowing treatment in July, but applied an herbicide treatment in September, were the functional equivalent of a post-flowering/post-seed production treatment. Compared to the untreated plots, all single applications of a systemic herbicide (July or September) resulted in an absolute decline in perennial pepperweed canopy of at least 21.9 percent (Table 4). For Telar, the post-flowering application (in September) resulted in complete removal of perennial pepperweed the following July. There was a 90 percent or greater probability that the difference between the means for the untreated plots and the treatment plots, for each systemic herbicide, were due to the treatment and not another factor.

Roundup ProMax was the least effective herbicide when applied at the post-flowering growth stage. Perennial pepperweed canopy cover was 12.5 percent on plots that were not mowed and treated with Roundup ProxMax in September (post-flowering). Plots that received an application of Roundup ProMax in July, at the bud-to-flowering growth stage, and had no perennial pepperweed regrowth treatment in September, had a perennial pepperweed canopy cover of 2.4 percent. There was a 90 percent or greater probability that the difference in mean perennial pepperweed cover between the July and September applications of Roundup ProMax, on unmowed plots, was due to the difference in plant growth stage.

2,4-D Ester was equally effective whether applied as a sole treatment in

July or September, with 2.3 percent mean perennial pepperweed canopy cover for each treatment period. When it was applied post-flowering, a tank mix of 2,4-D with Roundup ProMax was more effective than an application of only Roundup ProMax. Plots that received the tank mix post-flowering had over 11 percent less canopy cover from perennial pepperweed than unmowed plots treated only with Roundup ProMax (Figure 4).

For Roundup ProMax, the two least effective treatment interactions included rotary mowing (10.6 percent perennial pepperweed cover) and chemical mowing with a contact herbicide (6.8 percent cover). As a regrowth treatment, Roundup ProMax was most effective after chemical mowing with the systemic herbicides 2,4-D Ester or Roundup ProxMax, singly or in combination with one another. These three treatment combinations resulted in mean perennial pepperweed canopy cover of 3.3 to 3.5 percent. The difference in perennial pepperweed cover between these three interactions (i.e., chemical mowing with systemic herbicides and Roundup ProMax applied to the regrowth), and physical mowing followed by treatment of the regrowth with Roundup ProMax, can be attributed to the specific treatments, with a 90 percent or greater probability.

Mowing treatments generally did not enhance the effectiveness of 2,4-D Ester for controlling perennial pepperweed (Table 4). The application of 2,4-D Ester without any mowing treatment resulted in an average canopy cover of 2.3 percent regardless of whether the chemical was applied at bud-to-flowering (July) or post-flowering (September) stage. Regardless of mowing treatment, almost all regrowth treatments with 2,4-D Ester had more canopy cover from perennial pepperweed, than did the 2,4-D treatment without mowing. The only exception was chemically mowing with 2,4-D Ester in July and applying 2,4-D Ester to the regrowth in September. This treatment combination had 1.6 percent mean canopy cover of perennial pepperweed. None of the 2,4-D Ester treatment combinations was statistically different from one another. There was a greater than ten percent probability that the difference in the means was due to factors other than the specific treatments.

When applied to unmowed perennial pepperweed in July, the tank mix of Roundup ProMax and 2,4-D Ester resulted in an average perennial pepperweed canopy cover of 3.0 percent (Table 4). Applying the tank mix as a stand-alone treatment post-flowering in September resulted in perennial pepperweed canopy cover of 1.2 percent. Physical mowing did not improve the effectiveness of a Roundup ProMax/2,4-D Ester tank mix, as that treatment combination had a mean perennial pepperweed canopy cover of 6.3 percent. Chemical mowing with a contact herbicide and applying the Roundup ProMax/2,4-D Ester tank mix to the regrowth was even less effective:

mean perennial pepperweed canopy cover was 7.3 percent. Chemical mowing treatments with 2,4-D Ester, or the tank mix Roundup ProMax and 2,4-D Ester, and treating the regrowth with the tank mix, slightly improved perennial pepperweed control, and reduced perennial pepperweed cover to 1.5 and 1.0 percent, respectively (Table 4). None of the Roundup ProMax/2,4-D Ester tank mix treatment combinations were statistically different from one another. The probability that the treatment means were different because of some factor other than the specific treatments was greater than 10 percent.

Chemical mowing treatments in July at the bud-to-flowering growth stage that were not followed with any treatment of the perennial pepperweed regrowth were the functional equivalent of a single herbicide treatment at one growth stage. These treatments occurred with the Roundup ProMax/2,4-D Ester tank mix and individual applications of both chemicals. All three treatments resulted in very similar amounts of perennial pepperweed cover, 2.3 percent to 3.0 percent (Table 4), and were not statistically different from one another at the 10 percent probability level. Also, the means of these three treatments were not statistically different from any of the mowing and regrowth treatment interactions, except the treatment combination that used a rotary mower followed by application of Roundup ProxMax to the regrowth.

Stem Counts

The data for perennial pepperweed stem counts was very similar to perennial pepperweed canopy cover. There was a greater than 99 percent probability that mowing treatment, regrowth herbicide treatment and their interaction affected the mean number of perennial pepperweed stems. Because the results closely parallel the response of perennial pepperweed cover, they are not presented in written detail. Data tables, figures and associated statistical results are presented in Appendix 1.

DISCUSSION

Research in California generally found that physically mowing perennial pepperweed at the bud to early flowering stage and applying systemic herbicides to the regrowth at the bud growth stage resulted in better control of perennial pepperweed, than applying only a single application of the same systemic herbicides (no mowing treatment) at the flower-bud growth stage (Renz and DiTomaso 1999 and 2006). Physical mowing improved herbicide efficacy because it changed the shape and form of the regrowth, compared to unmowed plants, which resulted in more herbicide being placed on the basal leaves (Renz and DiTomaso 2004, 2006). The basal leaves of perennial pepperweed tend to translocate more herbicide to growing points in the root systems than do the leaves and flowers located in the upper part of the canopy (Renz and DiTomaso 2004).

In this study, physically mowing perennial pepperweed at the bud-to-flowering stage did not improve the effectiveness of applications of Telar, Roundup ProMax, 2,4-D Ester or a tank mix of Roundup ProMax and 2,4-D Ester. Plots that received single applications of Roundup ProMax, 2,4-D Ester or a tank mix of the two herbicides (in July 2008) all had 3.3 to 8.6 percent less canopy cover from perennial pepperweed in July 2009, than did treatment combinations that used a rotary mower in July 2008 and applications of the previously mentioned herbicides to the perennial pepperweed regrowth in September 2008 (bud-to-early-flowering growth stage). This result is very different from the results reported by Renz and DiTomaso (2006), but similar to those of Wilson et al. (2008). Wilson et al. (2008) also focused their research exclusively in a Great Basin environment (Susanville, Calif.), and found that mowing and other physical treatments (burning, grazing and disking) prior to herbicide application had little influence on herbicide efficacy.

Telar treatments resulted in complete control of the perennial pepperweed one year after treatment, with or without any type of mowing treatment. Telar was the only herbicide to provide this level of control. In other research, Telar usually provided the best control of perennial pepperweed, often approaching and occasionally achieving 100 percent control the first growing season after treatment (Young et al. 1998; Renz and DiTomaso 2006; Wilson et al. 2008; Hutchinson and Viers 2011). Laws (1999) found that Escort (metsulfuron methyl), an herbicide with a chemical structure is close to Telar, also provides very high control of perennial pepperweed.

From a statistical perspective, our results suggest that chemical mowing with either a contact or systemic herbicide is as effective as physical mowing prior to application of 2,4-D and/or Roundup ProMax to the regrowth of perennial pepperweed (Table 4). This conclusion would be misleading. Physical mowing or chemical mowing with a contact herbicide (Reward) has a direct effect only on the plants leaves and stems, not the roots, and did not improve perennial pepperweed control regardless of the treatment applied to the regrowth. The use of a systemic herbicide as the chemical mowing agent, with no follow- up treatment of the regrowth, always had less perennial pepperweed cover than any non-Telar treatment combination that used rotary mowing or a contact herbicide as the mowing agent. Use of a systemic herbicide as the chemical mowing agent, will affect the plant's top growth and root system. This clearly has a different effect on perennial pepperweed cover one year after treatment, compared with a mowing treatment that affects only the top growth of the plant (see Figure 3). Also, single applications of 2,4-D and/or Roundup ProMax, without any treatment of the regrowth, always had less perennial pepperweed

cover than any mowing treatment that directly affected only the top growth. Chemically mowing a site with a systemic herbicide and treating the regrowth with a systemic herbicide never increased control more than 2 percent, and usually 1 percent or less. These patterns clearly demonstrate that chemical mowing with a systemic herbicide is not equivalent to chemical mowing with a contact herbicide or physical mowing. Mowing in general did not increase the effectiveness of any herbicide treatment of the regrowth.

To a large degree, this parallels the results found by Renz and DiTomaso (1999). They found that perennial pepperweed plots chemically mowed at the flowering stage with 2,4-D, and retreated at the bud growth stage with Telar, Roundup or Arsenal (imazapyr) had levels of perennial pepperweed control almost identical to treatments that were physically mowed and retreated with the previously mentioned herbicides. They also found that treating the perennial pepperweed regrowth with 2,4-D Ester was much less successful (58 percent control) than treating the regrowth with Telar, Roundup and Arsenal, but all four regrowth treatments had much better control than a single application of each herbicide at the flowering stage. This latter result is very different from ours in two ways. First, our chemical mowing treatment with 2,4-D followed by an application of 2,4-D to the regrowth at the bud-flowering stage achieved over 95 percent control (1.6 percent perennial pepperweed cover) and was not statistically different than any of the Telar treatments. Second, none of our mowing treatments improved the use of Telar.

CONCLUSIONS

- Telar (chlorsulfuron) is more effective for the control of perennial pepperweed than the other labeled herbicides used in this study.
- In the environmental setting studied, neither physical nor chemical mowing improved the effectiveness of Telar for the control of perennial pepperweed.
- Physical mowing and chemical mowing with a contact herbicide generally did not increase the effectiveness of Roundup ProMax (glyphosate) or 2,4-D Ester that was applied to perennial pepperweed regrowth, and appeared to reduce their effectiveness.
- If Telar is not used, a single application of 2,4-D Ester or Roundup ProMax at the bud-to-flowering growth stage, individually or as a tank mix, is as effective, or more effective, than the inclusion of a physical or chemical mowing treatment.
- For 2,4-D Ester and Roundup ProMax, a two-stage herbicide treatment (bud-to-early-flower growth stage and regrowth at bud-to early-flower) is part of a treatment program. The use of a systemic herbicide as the initial treatment probably will provide better results

than use of a contact herbicide. However, the single application of either systemic herbicide, singularly or as a tank mix, at the bud-to-flowering growth stage was as effective as a two-stage treatment. Only those actions that affect the top growth of a plant, whether accomplished physically or chemically, should be considered as mowing agents.

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Listing a commercial herbicide does not imply an endorsement by the authors, University of Nevada Cooperative Extension or its personnel. Product names were used only for ease of reading, not specific endorsement. Herbicides should be selected for use based upon the active ingredient and the specific bioenvironmental situation. Read and understand all herbicide labels and apply herbicides only according to the information in the label.

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Appendix 1.

Data tables and figures for perennial pepperweed stem counts

Table 5. Analysis of variance table for the number of perennial pepperweed stems in response to mowing treatments, herbicide treatments and their interaction.

Type of treatment	Degrees of freedom	Probability that the means are different due to a factor other than the treatment applied
Mowing	5	0.00
Herbicide	4	0.00
Mowing*herbicide	20	0.00

Figure 5. Effect of mowing treatment on stem counts of perennial pepperweed. Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.

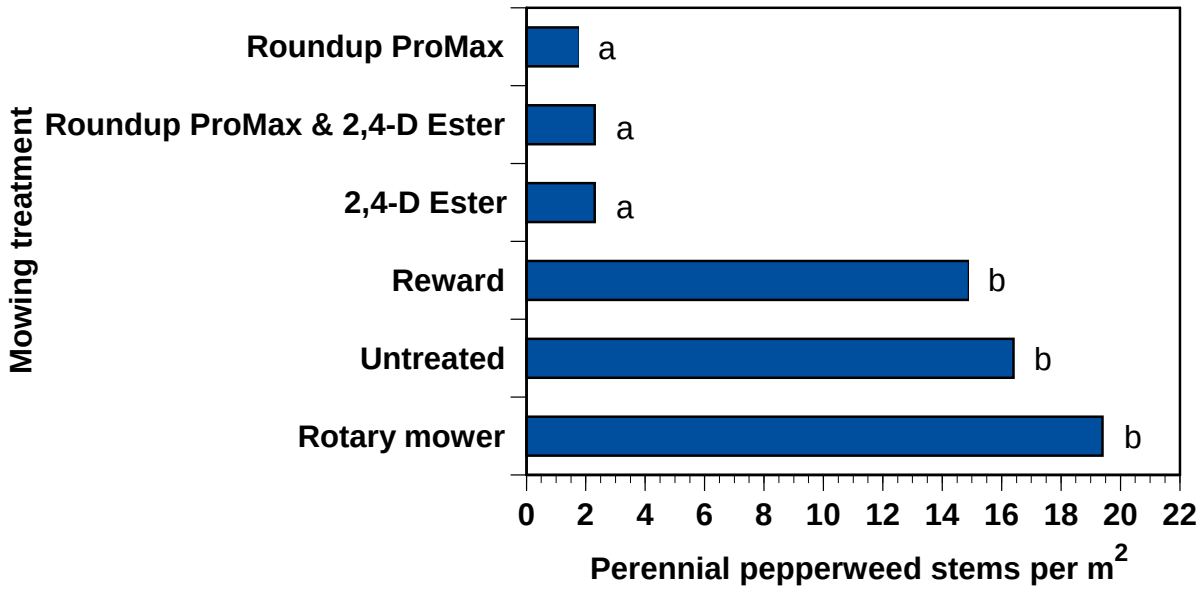

Figure 6. Effect of herbicide treatment to the regrowth of perennial pepperweed upon the number of perennial pepperweed stems. Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.

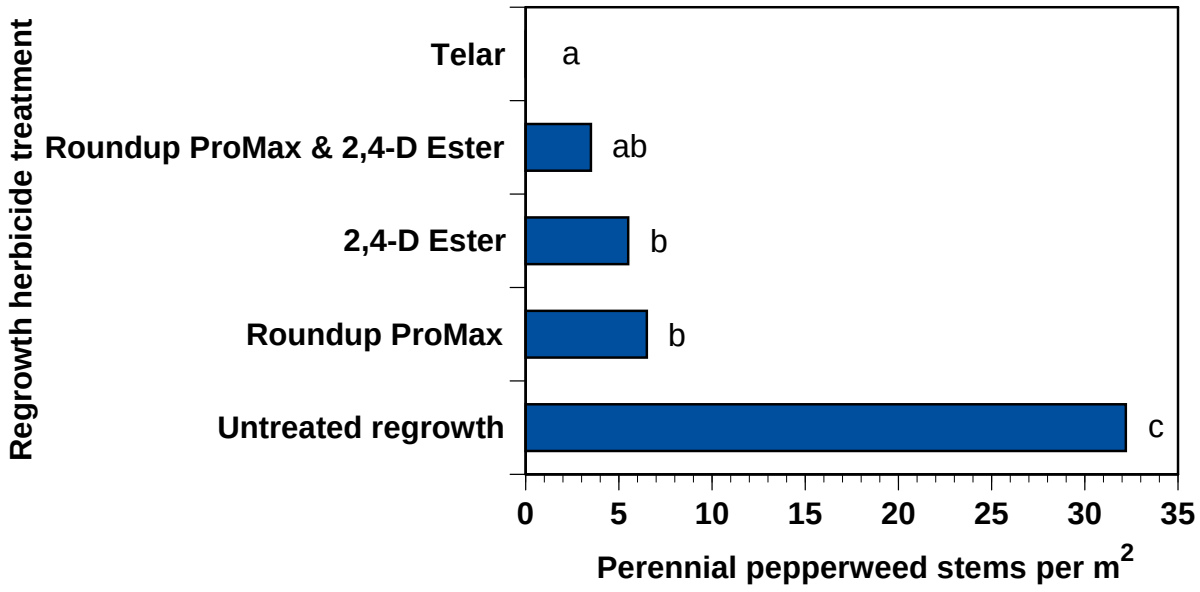

Table 6. Stem counts of perennial pepperweed in response to the interaction of mowing treatments and herbicide application to the perennial pepperweed regrowth. Means with different letters are different from one another at the 10 percent (P≤0.10) probability level.

Mowing treatment	Regrowth herbicide treatment	Perennial pepperweed stem count (#/m^2)	Mean separation
Rotary mower	None	69.2	A
None (control)	None	62.4	AB
Reward	None	53.4	B
None (control)	Roundup ProMax	13.9	C
Rotary mower	2,4-D Ester	12.1	CD
Rotary mower	Roundup ProMax	9.1	CDE
Reward	Roundup ProMax & 2,4-D Ester	8.6	CDE
Reward	Roundup ProMax	7.5	CDE
Roundup ProMax & 2,4-D Ester	2,4-D Ester	6.3	CDE

Mowing treatment	Regrowth herbicide treatment	Perennial pepperweed canopy cover	Mean separation
Rotary mower	Roundup ProMax & 2,4-D Ester	6.1	CDE
Reward	2,4-D Ester	5.1	CDE
None (control)	2,4-D Ester	4.5	CDE
2,4-D Ester	Roundup ProMax	4.3	CDE
Roundup ProMax	2,4-D Ester	3.3	CDE
2,4-D Ester	Roundup ProMax & 2,4-D Ester	3.2	DE
Roundup ProMax & 2,4-D Ester	None	2.8	DE
Roundup ProMax	None	2.5	DE
2,4-D Ester	None	2.4	DE
Roundup ProMax	Roundup ProMax	2.1	DE
Roundup ProMax® & 2,4-D Ester	Roundup ProMax	1.9	DE
2,4-D Ester	2,4-D Ester	1.8	DE
None (control)	Roundup ProMax & 2,4-D Ester	1.3	E
Roundup ProMax	Roundup ProMax & 2,4-D Ester	1.0	E
Roundup ProMax & 2,4-D Ester	Roundup ProMax & 2,4-D Ester	0.6	E
None (control)	Telar	0.0	E
Rotary mower	Telar	0.0	E
Roundup ProMax	Telar	0.0	E
2,4-D Ester	Telar	0.0	E
Reward	Telar	0.0	E
Roundup ProMax & 2,4-D Ester	Telar	0.0	E