INTRODUCTION

Noxious weeds are widespread across the western United States, including all counties in Nevada. To date, the Nevada Department of Agriculture has listed 47 plant species as noxious weeds. Noxious weeds are species that both harm agriculture and/or natural resources and are difficult to control or eradicate. In Nevada, noxious weeds are prohibited in commerce, and state law mandates that they be controlled. Landowners are responsible for controlling weeds on their property.

Paradise Valley is a large agricultural center in north-central Humboldt County, about 40 miles north of Winnemucca. The area winters over 10,000 beef cows and produces grass hay and/or alfalfa hay on about 40,000 acres. Most of the hay is fed in the valley but some is exported to other cattle producing areas. The valley’s meadows, riparian areas and brush fields provide habitat for many wildlife species, including mule deer, pheasant, wild turkey, ducks, geese, dove, shorebirds, small mammals and predators.

Public land administered by the Bureau of Land Management and the United States Forest Service surrounds much of Paradise Valley. These lands have many valuable resources that support wildlife, recreation, livestock production and other land uses. Widespread invasion of public lands by one or more noxious weeds will adversely affect their capability to produce a suite of resources for many land uses.

Noxious weeds were introduced into Paradise Valley over 60 years ago. The Paradise Valley Weed Control District (PVWCD) was formed to address hoary cress (Cardaria spp.) or short white top in the late 1940s. Since then, the intensity of weed control efforts in Paradise Valley has been highly variable, but has been on the upswing since 2002. In 2002, the PVWCD appointed a permanent coordinator, initiated regular interaction with University of Nevada Cooperative Extension and developed a comprehensive weed management plan. These developments occurred because hoary cress remains uncontrolled and numerous other noxious weeds have
become established. These include: Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), mayweed chamomile (*Anthema cotula*), musk thistle (*Carduus nutans*), medusahead (*Taeniatherum caput-medusae*), perennial pepperweed or tall white top (*Lepidium latifolium*), poison hemlock (*Conium maculatum*), Russian knapweed (*Centaurea repens*), saltcedar (*Tamarix spp.*), Scotch thistle (*Onopordum acanthium*) and water hemlock (*Cicuta douglasii*). Each of these species covers from tens of acres to thousands of acres in and/or near the PVWCD.

The PVWCD’s management plan acknowledges the need for an extensive treatment program to: 1) prevent the loss of additional acreage to noxious weeds; 2) prevent the establishment of new noxious weed species in the district; and 3) reduce the acreage adversely affected by noxious weeds. To achieve a successful weed-control program in Paradise Valley and other areas of Humboldt County, all residents must understand that methods exist to control most weeds. Control is defined as the reduction of a weed problem to a manageable level where economic impacts are small and new infestations can be prevented. Many landowners are reluctant to control noxious weeds because of the time and financial investment required. They lack knowledge about how well specific herbicides work and/or appropriate timing of specific weed control methods. Finally, some infestations remain uncontrolled because the window of opportunity for effective management of some species is short and other time critical tasks receive a higher priority.

Since 2003, the University of Nevada Cooperative Extension office in Humboldt County has cooperated with the PVWCD to establish a series of demonstration plots to increase local awareness and knowledge about weed control. The species targeted were hoary cress (2003), leafy spurge (2003 and 2004), Russian knapweed (2004) and perennial pepperweed (2005). Each demonstration plot (or group of plots) was developed to address one or more of the following issues: 1) a weed species for which the district had not previously emphasized control efforts; 2) a recently released herbicide without a history of local use; and/or 3) alternative timing for treatments. This publication addresses the treatment of perennial pepperweed with Plateau® (imazapic), Cimarron® Max (metsulfuron methyl, dicamba and 2,4-D), and a tank mix with the same active ingredients as Cimarron® Max, but applied at higher rates.

**The Target Species**

Perennial pepperweed is a deep rooted, long-lived forb (flowering plant) that spreads from creeping roots and seed. Root systems have about 85 percent of their biomass in the top two feet of soil, but can penetrate to a depth of
10 feet or more to reach the upper boundary of the water table. The roots have a very broad lateral spread, which often exceeds their depth. Perennial pepperweed roots have many viable buds that are often spaced an inch or less apart. When the roots are cut into small segments, each segment with a bud can produce an entirely new plant. New plants can emerge from small root segments buried several feet deep. Roots from new plants can reach almost three feet deep within 90 days.

Roots of mature perennial pepperweed store large amounts of soluble carbohydrates (i.e., energy). Energy reserves allow established plants to regrow after dormancy and/or complete leaf removal. Successful chemical control of established stands of perennial pepperweed is difficult because the large root systems have many buds and large energy reserves for regrowth, and the corresponding leaf area for herbicide uptake is comparatively small. The easiest and most effective strategy is to target young plants, small patches or new infestations before an extensive root system is formed.

New plants may also establish from germinating seed. Seed production can exceed 10,000 viable seeds annually per plant and six billion seeds per acre. Few seedlings have been observed by research scientists, but perennial pepperweed seed has high germination potential and exhibits little dormancy. This indicates a high potential for many new plants to establish when germination requirements are met. Seed incubated for 48 hours in water or after passing through an animal's digestive tract has germination levels that range from 40 to 60 percent. These incubation conditions are possible throughout Paradise Valley.

Perennial pepperweed occupies many landscape locations. These include riparian areas, irrigation ditches, ephemeral streams and ponds, cropland, irrigated pasture, roadsides, rights-of-way, barrow pits and many upland plant communities. Plants apparently establish either during unusually wet periods or where run-on moisture is abundant. Once established, perennial pepperweed plants persist well on dry sites because their deep roots tap shallow water tables.

Methods

Demonstration plots were located on private property in Paradise Valley about 40 miles north of Winnemucca, Nevada, along Shelton Lane. The area is a floodplain along Martin Creek, with associated diversion ditches and sloughs. The soil is the Delvada series, which has very deep, very poorly drained soil formed from mixed source alluvium. Clay content ranges from 40 to 50 percent and sand content is less than 15 percent. The soil is moderately to strongly alkaline (pH 7.9 to 9.0).

A seasonally high water table reaches the soil surface for one to three months when precipitation is average to
above average. The water table declines to about five feet deep, or more, during the summer and fall. The deep soil and relatively shallow water table allow perennial pepperweed’s deep roots to reach water the entire growing season and remain photosynthetically active. In both 2005 and 2006, the water table throughout Paradise Valley was at the soil surface for about three months each spring and early summer.

The treated area had a uniform high-density stand of perennial pepperweed (Figure 1). The most common understory species was creeping wildrye (*Leymus triticoides*), but its abundance was highly variable across all three treatment plots. Some areas had no perennial herbaceous species in the understory.

Three demonstration plots were established in 2005 and each was treated with a different herbicide mixture. Plateau® (imazapic) was applied to Plot 1 at 12 ounces of product per acre (3 ounces imazapic per acre). The Plateau® was mixed with a methylated seed oil surfactant at two pints per acre. Cimarron® Max and a nonionic surfactant (NIS: 13 ounces per acre) were applied to Plot 2. Cimarron® Max is a two part cocktail composed of three herbicides. The active ingredient in Part A is metsulfuron methyl (Escort®). Part B is composed of Dimethylamine salt of dicamba (dicamba) and Dimethylamine salt of 2,4-dichloro-phenoxyacetic acid (2,4-D). Cimarron® Max was applied at the labeled rate for perennial pepperweed: 1.0 ounce per acre of Part A and 4.0 pints per acre of Part B. For the active ingredients, the rate was 0.60 ounce per acre of metsulfuron methyl, 6.6 ounces per acre of dicamba, and 19.0 ounces per acre of 2,4-D. The third plot received a locally derived cocktail mix that the district typically used for perennial pepperweed. This mix has the same ingredients as Cimarron® Max, but applied them at higher rates. For the active ingredients, the applied rates were 1.2 ounces per acre of metsulfuron methyl (as Escort®), 7.7 ounces per acre of dicamba and 30 ounces per acre of 2,4-D amine. This treatment contained a non-ionic surfactant at 13 ounces per acre.

All treatments were applied on July 25, 2005. The day was warm, clear and had little wind. Application occurred from mid-morning to early afternoon. For the next 14 days, the weather was sunny and day-time high temperatures ranged about 90°F to 101°F. The first measurable rain did not occur until early September. The growth stage of perennial pepperweed at the time of herbicide application ranged from flowering to post-flowering. The herbicides were applied with a boom mounted to the back of a tractor (Figure 2), about 24 inches above the ground, and calibrated to apply a spray volume of 20 gallons per acre. Most of the standing perennial pepperweed stems from the previous growing season had been
grazed off or trampled down by cattle the previous fall and winter.

The treated area was photographed at the time of treatment to document the extent of the perennial pepperweed infestation. Repeat photography of the same locations occurred during early July and early August of 2006. A comparison of the before and after photos was used to demonstrate the results of each herbicide treatment.

Results

One year after application, all treatments had very high control of perennial pepperweed (Figures 3a-8b). Figures 3a and 4a show the high canopy cover of perennial pepperweed in the area treated with Plateau®. Figures 3b and 4b show the same locations almost one year later. Perennial pepperweed is almost completely absent. About five head of cattle periodically grazed the treated area for several weeks in May and early June; resulting in the short stature of the perennial grasses when the site was photographed in early July. There was no obvious visual evidence of grazing on the few remaining perennial pepperweed plants. Once the cattle were removed, grass growth was rapid and vigorous (Figure 3c).

Figures 5a and 6a show the perennial pepperweed stand in the area treated with Cimarron® Max. The large number of yellow/tan leaves indicate the late maturity of the plants. Figures 5b and 6b show almost complete control of perennial pepperweed. Figure 6b shows little if any herbicide effect on residual forage grasses.

Figures 7a and 8a show the perennial pepperweed stand in the areas treated with the tank mix of Escort®, dicamba, and 2,4-D. One year after treatment, perennial pepperweed was virtually absent from the treated area (Figures 7b and 8b). The adjacent untreated field has a dense stand of flowering perennial pepperweed (Figure 7b). Forage grasses responded well (Figures 7b and 8b) following reduced competition from perennial pepperweed and appeared unaffected by the higher application rate of the active ingredients compared to the rates in the Cimarron® Max treatment.

Figure 9 is an infrared composite aerial photo of the study area from July 17, 2006, almost one year after treatments were applied. The image was obtained with a high resolution (5 foot x 5 foot) hyperspectral sensor (178 color bands) mounted on a fixed-wing aircraft. The light blue shows areas with a large proportion of bare ground, which includes the treated areas and the adjacent road (Shelton Lane). The red is unharvested pasture grasses, the green is a recently harvested grass hay meadow and the pink is perennial pepperweed. This image further illustrates the short-term success of perennial pepperweed control across all three treatment areas.
Figure 1. The treatment area in Paradise Valley, Nevada. The tall plants with light-green leaves and small white flowers are perennial pepperweed.

Figure 2. The spray equipment used to apply the herbicides. The elevation of the boom was low enough to bend over the perennial pepperweed plants, ensuring that most of the lower leaves received some of the applied herbicide.
Figures 3a-3c. The area treated with Plateau® at the time of treatment in late July 2005* (3a) and one year later (2006) in early July (3b) and August (3c). Figure 3c shows the same general area as Figure 3b, but looking from south to north instead of east to west.
Figures 4a and 4b. The eastern portion of the area treated with Plateau® at the time of application (Figure 4a) and one year later (Figure 4b).
Figures 5a and 5b. The eastern portion of the area treated with Cimarron® Max at the time of herbicide application (Figure 5a) and one year later (Figure 5b).

Figures 6a and 6b. The western half of the area treated with Cimarron® Max at the time of herbicide application (Figure 6a) and one year after treatment (Figure 6b). The light color beyond the fence-line in Figure 6b is flowering perennial pepperweed.
Figures 7a and 7b. Part of the area treated with the tank mix of Escort®, dicamba and 2,4-D amine at the time of treatment (Figure 7a) and one year later (Figure 7b). The arrows identify the same fence post in both photos. Figure 7b also shows an extensive stand of perennial pepperweed in the adjacent field at the flowering growth stage.

Figures 8a and 8b. Another part of the area treated with the tank mix of Escort®, dicamba and 2,4-D amine at the time of treatment (Figure 8a) and one year later (Figure 8b). The arrows in both pictures identify the same corner post.
Figure 9. A color composite image from July 17, 2006 that shows all three treatment areas: a) is the Plateau® treatment; b) the Cimarron® Max treatment; and c) the area treated with the tank mix of Escort®, dicamba and 2,4-D amine. The light green dots identify sites where perennial pepperweed canopy cover was measured for a different study. The yellow square is an area known to contain no pepperweed. The yellow dots are GPS ground control point locations. The blue correlates with a high percentage of bare ground. In addition to the treated areas (a, b and c) it includes Shelton Lane, the access road to the property and a parking area behind the property’s house (white square near treatment plot c).
Results - Cost Comparison

The Cimarron® Max treatment had the lowest chemical cost (Table 1). It was $2.31 per acre cheaper than the Plateau® treatment. Both the Plateau® and Cimarron® Max treatments had substantially lower chemical costs than the locally derived tank mix, even at a very low cost for Escort®.

Discussion

When the plots were rephotographed in July and August 2006, perennial pepperweed had been growing for three to four months. The few perennial pepperweed plants observed in the treated areas were 8 to 12 inches tall, but not flowering. Perennial pepperweed plants in the adjacent fields were flowering (Figures 6b and 7b). Roots from perennial pepperweed can grow three feet deep within 90 days of growth initiation. Upward growing stems most likely have a similar capability. The presence of only a few perennial pepperweed plants 90 to 120 days into the growing season strongly suggests that all three treatments killed most of the buds on the roots. It is essential to kill root buds when attempting to control perennial plants that spread by producing new shoots from their roots and/or rhizomes.

The high rate of perennial pepperweed control from all three herbicide treatments was somewhat unexpected. Plateau® is recommended for use from full bloom until desiccation. Escort®, a traditional herbicide for control of perennial pepperweed, and the primary component of two other herbicide mixtures, is recommended for actively growing plants up to the early bud stage. All perennial pepperweed plants in this study were at peak flowering or later stages of growth. The herbicides containing Escort® were expected to provide somewhat less effective control than Plateau® because of non-optimal application timing. This, however, was not the case.

The reasons for the observed results are unknown and can only be speculated. First, the active ingredients in both Escort® and Plateau® affect plants by interrupting the same enzyme (ALS) reaction. Application of these herbicides, however, is recommended at very different stages of plant growth: vegetative through early bud stage for Escort® and flowering to post-flowering for Plateau®. Since both herbicides have the same mode of action but are recommended for application at different growth stages perennial pepperweed may have different rates of uptake or translocation for different chemical molecules. The unusually high water table in late July 2005 may have altered plant growth enough to facilitate a higher rate of uptake from the Escort® based herbicide mixes than would typically be expected. Second, the mix of Escort®, dicamba and 2,4-D may have an additive (synergistic) effect that results in their sum working
**Table 1. Cost comparison for each herbicide treatment. Application rates are for product per acre. The amount of active ingredient is discussed in the methods section.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Application Rate/ac</th>
<th>Unit Cost</th>
<th>Cost per oz</th>
<th>Cost per acre</th>
</tr>
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<tbody>
<tr>
<td><strong>Plateau®</strong></td>
<td>12 oz</td>
<td>$ 277.00/G</td>
<td>$2.164</td>
<td>$ 25.97</td>
</tr>
<tr>
<td>MSO surfactant</td>
<td>32 oz</td>
<td>$ 16.00/G</td>
<td>$0.125</td>
<td>$  4.00</td>
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<tr>
<td>Dye</td>
<td>6 oz</td>
<td>$ 35.00/G</td>
<td>$0.273</td>
<td>$  1.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$ 31.61</strong></td>
</tr>
<tr>
<td><strong>Cimarron® Max</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part A</td>
<td>1 oz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part B</td>
<td>64 oz (4 pt)</td>
<td>$ 52.50/G^a</td>
<td>$0.410</td>
<td><strong>$ 26.25^a</strong></td>
</tr>
<tr>
<td>NIS (R-11)</td>
<td>13 oz</td>
<td>$ 14.00/G</td>
<td>$0.109</td>
<td>$  1.42</td>
</tr>
<tr>
<td>Dye</td>
<td>6 oz</td>
<td>$ 35.00/G</td>
<td>$0.273</td>
<td>$  1.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$ 29.31</strong></td>
</tr>
<tr>
<td><strong>Escort®</strong></td>
<td>2 oz</td>
<td>$ 10.25/oz</td>
<td>$10.25</td>
<td><strong>$ 20.50</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>$ 19.00/oz</td>
<td>$19.00</td>
<td><strong>$ 38.00</strong></td>
</tr>
<tr>
<td>**Dicamba (Banvel®)</td>
<td>16 oz</td>
<td>$ 82.95/G</td>
<td>$0.648</td>
<td>$  10.37</td>
</tr>
<tr>
<td>2,4-D amine (Weedar® 64)</td>
<td>64 oz</td>
<td>$ 12.40/G</td>
<td>$0.969</td>
<td><strong>$  6.20</strong></td>
</tr>
<tr>
<td>NIS (R-11)</td>
<td>13 oz</td>
<td>$ 14.00/G</td>
<td>$0.109</td>
<td>$  1.42</td>
</tr>
<tr>
<td>Dye</td>
<td>6 oz</td>
<td>$ 35.00/G</td>
<td>$0.273</td>
<td>$  1.64</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>$40.13-57.63</strong></td>
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</table>

^a includes the cost of metsulfuron methyl from part A.
much better than their individual parts. Third, the location of the boom relative to plant canopies (Figure 2) may have influenced control. The boom was located from the middle to the upper third of the canopy. As it passed through the canopy of the perennial pepperweed, the plants were pulled over. This resulted in most, if not all, lower leaves receiving some chemical. Herbicide placement on the lower leaves may have increased uptake, increasing plant mortality. Additional research is required to find definitive answers to each of these questions.

The results suggest that the potential treatment period for unmowed perennial pepperweed is longer than traditionally practiced (i.e., pre-flowering) in Paradise Valley. Also, several herbicides or herbicide mixes can be used. This expands the window of opportunity to potential weed control programs, particularly in areas where wet soil inhibits the use of large, heavy equipment until after perennial pepperweed reaches the flowering growth stage. The timing of many weed control programs overlaps other agricultural management and production activities that often cannot be delayed. The longer the potential treatment period for any weed, the more likely producers (and other entities) will develop successful weed management programs.

None of the herbicide treatments were 100 percent effective. Residual perennial pepperweed plants were scattered throughout each plot, but were more common along each plot’s perimeter. Each plot’s perimeter coincided with the area where the tractor would turn after it passed across the plot. This suggests that the spray from the boom may have had inadequate coverage between adjacent turns. The appropriate fix for this problem is to spray the entire perimeter of a field with one or two laps before treating the large interior. This strategy would result in vehicle turns only occurring at the field’s corners. Any corners with inadequate herbicide coverage could easily be treated by backpack or ATV-mounted sprayers. Vehicle turns at the end of each pass across the field would have a better probability of overlapping the initial perimeter treatment, dramatically increasing the probability of complete coverage of the field.

Not all noxious weeds on the plots were controlled by the herbicide treatments. Following treatment, there was an obvious increase of hoary cress and Scotch thistle. Several factors account for this result. First, in 2005, hoary cress had completed its growth cycle by late July and was becoming quite desiccated. It was largely unseen at the time of treatment and thus unaffected by the herbicides applied. Second, soil moisture and available sunlight (at ground level) both increased after perennial pepperweed control, resulting in both a higher density and increased growth per
plant for hoary cress. Third, Scotch thistle germinates best in full sunlight, where bare ground is abundant and the soil is moist. Perennial pepperweed control in 2005, combined with ample spring rains and a high water table in 2006 promoted Scotch thistle germination and growth.

Initial control efforts may create an environment suitable for other weed species. The visual absence of a weed species at the time of herbicide application does not mean or guarantee the weed species is not present. Visual absence never guarantees physical absence, especially for species that germinate readily from seed. Weed species found in the surrounding area are likely to show up following treatment, particularly when the treatment enhances or creates microsites favorable for germination.

The abundant bare ground present after treatment (Figures 3b, 4b, 5b and 9) demonstrates that reseeding is necessary after weeds are controlled on sites with almost pure monocultures. Also, it underscores the need for proper vegetation management. For grass-hay pastures, only a dense stand of desirable well-managed perennial grasses can provide sufficient competition to potentially exclude most invasive noxious weeds. Healthy perennial grass stands only occur when harvest (grazing or cutting) is timed to meet the plant’s biological needs. Thinning of the desired perennial grasses increases the probability that perennial herbaceous weeds will establish. Once the first few weeds are established, it is only a matter of time until their population increases, particularly if management continues to weaken desired plants and increase bare ground.

At the Paradise Valley site, the root density and canopy cover of the desired perennial forage grasses must increase; otherwise, perennial pepperweed and/or other weeds will reoccupy the site in a few years. Seed will be transported from adjacent fields by wind, water and/or animals and seedlings will eventually establish. Both multi-day saturation in water and passage through the digestive system of cattle substantially increase the germination rate of perennial pepperweed seed. Additional spread from the creeping roots of current or newly established plants will rapidly fill the area between existing plants. Existing plants should be treated annually until full control is achieved and/or to prevent them from occupying more of the pasture.

The result of these demonstration plots illustrate Plateau®, Cimarron® Max, and a tank mix of Escort®, dicamba and 2,4-D amine are all effective control measures for perennial pepperweed. The tank mix has been used for perennial pepperweed control in Paradise Valley for many years. Although it contains the same chemical ingredients as the commercial product Cimarron® Max, the locally derived cocktail contains higher
rates of each of the three components. The extra chemical does not appear to affect herbicide performance one year after application but does add significantly to the cost.

**Conclusions**

- **Plateau®, Cimarron® Max and an herbicide mixture with the same components as Cimarron® Max** were all very effective (>90%) for initial control of perennial pepperweed at the flowering to post-flowering growth stages. Additional monitoring is necessary to determine mid- and long-term effectiveness.

- It may be feasible to broaden the period of treatment for perennial pepperweed from only during the pre-flowering growth stage to both pre- and post-flowering. This adds flexibility to potential weed control programs for many producers. The additional cost for waiting to use Plateau® at or after flowering is about $2.30 per acre.

- Follow-up treatments are necessary to control residual plants, and/or keep perennial pepperweed from spreading beyond their current occupancy.

- Removal of dense stands of perennial pepperweed results in a substantial amount of bare ground. This creates a microenvironment that benefits hoary cress, Scotch thistle and probably other weed species. Follow-up control efforts must address weeds that establish or increase after control of the initial target species.

- Sites with substantial bare ground after treatment should be quickly revegetated to prevent or slow the re-establishment of weed species.

- Post-treatment management of vegetation must be changed to enhance the cover and competitive ability of desired perennial plants.

- None of the herbicide mixes applied had an adverse effect on the residual population of desired forage grasses (primarily creeping wild-rye).

**Bibliography**


* (Lepidium latifolium). Weed Science 34:252-255.


The information given herein is supplied with the understanding that no discrimination is intended and no endorsement by Cooperative Extension is implied.