

**Broadleaf Rangeland Herbicide Effects on Established and Seedling Native Forbs, Shrubs, and Grasses**

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**Section 1: Abstract**

Herbicides are commonly used to control invasive and common weeds on native rangeland and natural areas, but not enough is known about their potential to cause injury to native shrubs, forbs, and grasses. An experiment was conducted where 16 different herbicide treatments were evaluated for their potential to cause injury to five native grasses or grass-like plants, eight native shrubs, and 15 native forbs. Injury was ranked on a scale of 0-10 where 0-2 was considered as no injury, 3-6 as acceptable injury from which plants would recover, and 7-10 as unacceptable from which most plants would not recover. Variation in plant response within and among treatments was very large and often statistical differences were masked by the variance. In general, Paramount (quinclorac), Plateau (imazapic), and Overdrive (dicamba + diflufenzopyr) caused the least injury to native vegetation. None of the grasses were injured by any herbicide treatment, but injury from auxin-like herbicides to sand lily was unacceptable. Western ragweed, one-sided penstemon, clammy groundcherry, low milkweed, and winged buckwheat displayed minimal injury (none to acceptable) from all herbicide treatments. American plum was highly susceptible to all treatments and only Paramount and Transline (clopyralid) caused no injury. Yucca was tolerant of all treatments. Louisiana sage injury from Transline, 2,4-D ester, and Cimarron Max (metsulfuron + dicamba) was unacceptable. Wild rose was injured unacceptably by all treatments except Overdrive, Transline, and 2,4-D amine. Plateau was the only treatment not to injure fringed sage, although it most likely also will recover from Overdrive- and

Paramount-induced injury. Cimarron Max was the only treatment from which gayfeather most likely will not recover. All auxin-like herbicides caused unacceptable injury to robust spurge and it was killed by Curtail (clopyralid + 2,4-D), 2,4-D amine, 2,4-D ester, and Escort (metsulfuron). Blue flax was injured unacceptably from the pyridine herbicides and most likely will recover from Overdrive, Paramount, and 2,4-D amine. Unacceptable injury to wavyleaf thistle was caused by all herbicides. Yellow sundrop injury ranged from none to unacceptable and it most likely will not recover from Curtail, 2,4-D amine, and 2,4-D ester. The sulfonyleurea herbicides and all pyridines, except Transline and Milestone (aminopyralid), caused unacceptable injury to evening primrose. Little sunflower was very susceptible to any treatment that contained a pyridine or auxin-like herbicide except for Overdrive. Slimflower scurfpea was not injured by Paramount or Plateau, whereas, all pyridine, sulfonyleurea, and auxin-like herbicides except those containing dicamba caused unacceptable injury. Scorpionweed was injured unacceptably by the sulfonyleurea and pyridine herbicides except possibly Transline and Tordon (picloram). Injury to fineleaf was acceptable only from Overdrive, Paramount, and Plateau. Only Escort and Grazon P+D (picloram + 2,4-D) caused unacceptable injury to locoweed, which is not surprising because these two herbicides are commonly recommended to control this poisonous native forb when necessary to protect grazing livestock.

A second experiment was conducted to assess injury to seedling native shrubs, forbs, and grasses but droughty conditions dramatically influenced the outcome. Kochia dominated the study site and grasses began to establish only where kochia was controlled by herbicide treatment. No forbs or shrubs emerged and injury from herbicide treatment could not be assessed.

## **Section 2: Introduction and literature review**

Weeds infest established pastures and rangeland typically in response to disturbance, which is expressed in many different forms such as overgrazing, wildfires, flooding, and drought. Often increased levels of available nitrogen are associated with disturbance although, increased levels of soil nitrogen also are caused by atmospheric depositions associated with the burning of fossil fuels. Thus, weeds can be common occurrences even in pastures or on rangeland that are in good condition.

Herbicides that selectively control weedy forbs in the presence of desirable perennial grasses are commonly used to increase pasture or rangeland carrying capacity for wildlife and livestock and to decrease the spread of weeds. Most selective, broadleaf herbicides control weedy forbs without excessively injuring native perennial grasses. However, most established rangeland has many species of desirable forbs and shrubs present and while selectivity to perennial grasses is fairly-well understood, very little data are available to detail the selectivity of commonly used rangeland herbicides to these forbs and shrubs, especially native ones. Relative to achieving land management goals, land managers know it is in their best interest to control unwanted vegetation, especially noxious and invasive weeds. Without adequate knowledge of the risk to native forbs from herbicide application, the decision as to which herbicide to use becomes very difficult. This situation is even more difficult when reclaiming abandoned farmland or degraded pastures because seed mixes often include native forbs, shrubs, and grasses and sensitivity of the seedlings of these species is poorly understood. Often, land managers postpone the decision or choose to use physical methods such as mowing to keep the canopy open or hand pulling to control weeds, neither of which is as successful as using selective herbicides.

Invasive and common weeds infest pastures and rangeland and dramatically affect productivity. Over \$2 billion are lost each year in the U.S. because of weeds

invading pastures causing decreased carrying capacity and plant poisonings (Pimentel et al. 2000). Selective broadleaf herbicides often are used to control weedy forbs in rangeland and such herbicides usually do not injure perennial rangeland grasses, which is highly essential so they compete effectively with recovering weedy forbs or those that subsequently recruit from the soil seed reserve after initial treatment. Many experiments have shown the importance of effective competition from perennial grasses when managing weeds in rangeland using a successional weed management approach (Benz, et al 1999; Biesboer et al 1993; Sheley et al 1996). Perennial grasses often dominate western rangeland, but most healthy plant communities typically have an abundance of native forbs and shrubs and the latter usually are sown as part of the seed mixture. Porkony (2002) showed that native forbs compete directly with weedy forbs because they belong to the same plant functional group. Thus, it also is important not to injure established or seedling native forbs when controlling weedy forbs to create an effective successional weed management program where grass competition is augmented by native forbs.

Very little data are available to document the level of injury to native forbs when using selective broadleaf herbicides to control weedy forbs on rangeland whether the target area has been recently seeded to desirable species or is an established parcel of rangeland. Rice (1997) found that picloram did not injure all established native forbs in Montana when it was used to control spotted knapweed. But because very little is known about other herbicides relative to native forb and shrub injury, land managers often postpone the decision to use a herbicide thus, providing weeds with additional time to spread and dominate plant communities. Or land managers may choose to use physical methods such as mowing or hand pulling to manage weeds. Mowing is a disturbance and has been shown to stimulate weed recruitment and seldom is mowing commonly recommended as a control measure because its effects are inconsistent

(Beck and Sebastian 2000; Sebastian and Beck 1999). Hand pulling is an option on established rangeland, but it is very expensive compared to herbicide use and it also disturbs the soil dramatically thereby stimulating recruitment of more weeds (Sebastian and Beck 1999; Brown et al. 1999). Hand pulling is not a viable option on newly seeded sites because of the potential tremendous injury to seeded species by trampling, much less the subsequent weed recruitment that would occur because of the disturbance. Native forbs and shrubs are essential components of healthy native plant communities particularly relative to competing with weeds. Because herbicides are the most effective and least costly of the weed control methods, it is essential that we better understand the injury risk to established or seedling native forbs and shrubs from herbicides used to control invasive weeds on rangeland.

### **Section 3: Materials and methods**

We conducted two field experiments to describe the injury from commonly used rangeland herbicides. One was on established forbs and shrubs (***Established FS***) and the second on seedling forbs, shrubs, and grasses (***Seedling FSG***). Both experiments were designed as randomized complete blocks and herbicide treatments were replicated six times in each experiment. Non-herbicide-treated control plots were included in both experiments as references for no injury. Data were subjected to analysis of variance. Plot size for both experiments was 10 by 30 ft and each experiment was about 0.67 acres in size.

***Established FS:*** This experiment was established at a native rangeland site in 2006. The herbicides and rates used in this experiment included the pyridine herbicides aminopyralid at 0.11 lb ai/A (7 fl oz of Milestone/A), clopyralid at 0.38 lb ai/A (1 pt Transline/A), picloram at 0.25 lb ai/A (1 pt Tordon 22K/A), and triclopyr at 0.75 lb ai/A (2 pt Garlon 3A/A); the auxin-like herbicides dicamba at 1.0 lb ai/A (1 qt Vanquish/A), 2,4-D

amine at 1.5 lb ai/A (1.5 qt 2,4-D amine/A), and 2,4-D ester at 1.5 lb ai/A (1.5 qt 2,4-D LV4/A); quinclorac at 0.28 lb ai/A (6 oz of Paramount/A); the sulfonylurea herbicides chlorsulfuron at 0.94 oz ai/A (1.25 oz Telar XP/A) and metsulfuron at 0.6 oz ai/A (1 oz Escort XP/A); the imidazolinone herbicide imazapic at 0.19 lb ai/A (12 fl oz Plateau/A); and the tank mixes clopyralid plus 2,4-D at 0.29 + 1.5 lb ai/A (3 qt Curtail/A); clopyralid plus triclopyr at 0.28 + 0.84 lb ai/A (3 pt Redeem/A); picloram plus 2,4-D at 0.27 + 1.0 lb ai/A (2 qt Grazon P+D/A); dicamba plus diflufenzopyr at 0.25 lb ai of dicamba/A (equivalent to 8 oz Overdrive/A); metsulfuron plus dicamba plus 2,4-D at 0.6 oz + 0.5 lb + 1.44 lb ai/A (Rate III of Cimarron Max); and a non-treated control. We applied one rate of each herbicide or tank mix. This approach allowed us to evaluate potential injury from more commonly used rangeland herbicides than would a rate response approach. Herbicides were applied once with a CO<sub>2</sub> backpack sprayer using water as a carrier at 21 gallons per acre. Herbicide application coincided approximately with the optimal timing to control diffuse knapweed in spring and occurred on May 15, 2006. Native plant species present and their growth stages at application can be found in Table 1.

Visual estimates of percent injury to native forbs, shrubs and desirable grasses were collected 2, 4, 8, and 16 weeks after treatments were applied. We used a rating scale of 0 to 10 to evaluate injury where 0 equaled no injury and a rating of 10 was for dead plants. Generally, injury ratings from 0-2 were assigned when plants displayed no response to treatment or were slightly stunted or chlorotic and these ratings would be classified as no injury; injury ratings from 3-6 were assigned where up to half the leaves had died yet the remaining were green and alive, or plants were necrotic but showed substantial recovery, or if plants did not flower or set seed depending on the proportion for each situation and these ratings were classified as acceptable because injured plants recovered; ratings from 7-10 were assigned when injured plants had about 20% or less green tissue apparent with a 10 assigned to those plants that had died. These latter

ratings would be classified as unacceptable injury because plants would not recover by the end of the growing season. Stand counts of native forbs and shrubs were to have been counted in September, 2006, but all plants had dried up and it was impossible to determine live plants from those that had died from herbicide treatments so, an inventory will be taken in April, 2007 and the data provided as a supplement to this report.

**Seedling FSG:** The second experiment was established on a reclamation site where Boulder County Parks and Open Space personnel seeded a mixture of native forbs, shrubs, and perennial grasses in fall, 2005. Canada thistle and kochia were the target weed species and the same herbicide treatments were used in this experiment. We had originally outlined two herbicide application timings to evaluate but very dry conditions over the winter of 2005-06 along with intense kochia competition precluded seeded species emergence. So, we adjusted and just applied one set of herbicide treatments to target Canada thistle and kochia. All treatments were applied on May 18, 2006 when kochia was 0.5 to 3 inches tall. Kochia density ranged from 10 to 40 plants/ft<sup>2</sup>. Visual estimates of percent control of kochia and injury to seedling grasses were collected 2, 4, 8, and 16 weeks after treatments are applied. Biomass of seeded grasses and kochia was harvested in October 2006 by cutting aboveground vegetation at the soil level from inside four randomly placed 0.25 m<sup>2</sup> quadrats. Plants were separated into kochia and all seeded grasses and dried at 60 C to a constant weight then weighed.

#### **Section 4: Results**

##### *Established forbs, shrubs, and grasses*

Western wheatgrass, sideoats grama, and purple threeawn were not injured by any herbicide treatment (Tables 2 and 3). Little bluestem showed no injury when data were collected in June and showed only slight injury in September, which was considered acceptable. Sand lily was evaluated only in June because it had dried up by mid-summer even in the non-treated plots. In June, Paramount, Plateau, Tordon, Telar,

and Cimarron Max injured sand lily quite dramatically and the injury from these herbicides was unacceptable (Table 2).

Injury to Louisiana sage in June ranged from 1 to 5 with 2,4-D ester causing the latter (Table 4). Injury continued to increase from many treatments but most notably from Transline, 2,4-D ester, and Cimarron Max where injury by September was unacceptable. American plum was unacceptably injured from most herbicide treatments at both evaluation dates except from Paramount and Transline where injury was minimal and considered acceptable (Table 4). Injury to fringed sage in June was very low to acceptable for all treatments but injury continued to develop over the growing season and injury from Vanquish, Curtail, 2,4-D ester, Grazon P+D, Redeem, and Cimarron Max was unacceptable in September, however, injury ratings from these treatments statistically were not different from those herbicides that would have caused acceptable injury based upon our groupings. Stand counts in April, 2007 may cause these treatments to separate.

Wild rose was badly injured (8-9) at the June evaluation from Vanquish, Garlon 3A, Grazon P+D, Redeem, Tordon, and Cimarron Max and injury from these treatments remained similar in September (Table 5). Injury from Paramount, Milestone, Telar, and Escort continued to increase and by September, they were similar to those treatments mentioned immediately above. Yucca was not injured much by herbicide treatments when the June evaluation was made and while many treatments displayed a slight increase in injury by September, all but 2,4-D ester were rated as 3 or less and thus no injury or acceptable. Injury to broom snakeweed ranged from 0-6 in June and by September, injury from Vanquish, Curtail, Garlon 3A, Grazon P+D, Redeem, Escort, and Cimarron Max was unacceptable and ranged from 8-9 (Table 5). It is notable that Escort is commonly recommended to control broom snakeweed when such situations become

desirable to improve rangeland carrying capacity and it is not surprising that treatments containing metsulfuron (Escort and Cimarron Max) caused unacceptable injury.

Western ragweed was not injured by any herbicide except Redeem in June and Transline in September (Table 6). Both these herbicides contain clopyralid and apparently it has activity on *Ambrosia* species. It is worth noting that injury from Redeem decreased from 6 in June to 0 in September. Curtail, 2,4-D ester, Garlon 3A, and Cimarron Max caused moderate and acceptable injury to one-sided penstemon at the June evaluation and by September, this native forb had recovered from the injury incurred earlier in the year (Table 6). Injury to clammy groundcherry ranged from 0 to 3 in June and September except for an injury rating of 4 from Milestone in September, which still is acceptable (Table 6).

Very little injury to low milkweed was observed at the June evaluation, but Grazon P+D caused an injury rating of 8 by September and Tordon had killed low milkweed by the latter date (Table 7). Milestone also caused unacceptable injury by September to low milkweed. Injury to winged buckwheat was acceptable in June from all treatments but injury from all but Overdrive and Paramount increased between June and September (Table 7), however, all injury ratings in September ranged from 1-5 and would be considered acceptable because plants most likely will recover by next growing season.

Injury to Gayfeather in June ranged from 1 to 3 (Table 8). Injury continued to increase slightly from most treatments into September although all but injury from Cimarron Max were considered acceptable. Gayfeather had completely recovered by September from the slight injury that occurred from Telar at the June evaluation. Injury to robust spurge ranged from 1 to 8 at the June evaluation where the 2,4-D products caused rating of 7 and 8 (Table 8). However, injury continued to accrue throughout the remainder of the growing season and by September, 2,4-D amine, 2,4-D ester, Garlon

3A, and Escort had killed robust spurge and Telar and Cimarron Max caused injury ratings of 9. Transline injury was at the other extreme and injured robust spurge only minimally. Many treatments injured blue flax but all except Cimarron Max were acceptable in June (Table 8) but injury from Garlon 3A, Grazon P+D, Telar, Escort, and Cimarron Max ranged from 8 to 9 in September and was considered unacceptable. Yellow sundrop injury only was evaluated in June because plants in the non-treated control plots had dried up by mid-summer. Only Plateau did not injure yellow sundrop (a rating of 2) in June and all other treatments caused acceptable injury except Curtail, 2,4-D amine, and 2,4-D ester where injury was 7 or 8 (Table 8). It will be of value to determine whether yellow sundrop plants recovered from any of the treatments when stand counts are made in April 2007.

Injury to dwarf morningglory was minimal in June but injury increased from all treatments by September (Table 9). Injury from Vanquish, Curtail, 2,4-D ester, Garlon 3A, Grazon P+D, Redeem, Tordon, Escort, and Cimarron Max was 7 to 8 in September. Wavyleaf thistle was injured by the auxin herbicides in June and ratings ranged from 5 to 8 with 2,4-D ester causing the latter (Table 9). By September, however, injury was 9 to 10 from Vanquish, Transline, 2,4-D amine, 2,4-D ester, Garlon 3A, Tordon, Milestone, and Cimarron Max and it is highly unlikely that wavyleaf thistle will recover from any of these treatments. Injury to evening primrose was unacceptable in June from Vanquish, Curtail, 2,4-D amine and ester, Grazon P+D, Telar, Escort, and Cimarron Max (Table 9). Injury from Vanquish, Curtail, and 2,4-D amine had decreased to an acceptable level (5 to 6) by September but injury from Grazon P+D, Telar, Escort, and Cimarron Max increased to unacceptable levels and the latter three treatments had killed evening primrose by September. Injury from Garlon 3A had increased to 8 by September and also was considered unacceptable. Vanquish, Curtail, 2,4-D amine, 2,4-D ester, Grazon P+D, Escort, and Cimarron Max caused fineleaf injury ratings of 7 to 8 in June and all

treatments except Overdrive, Paramount, and Plateau caused unacceptable injury by September (Table 9). Curtail, 2,4-D amine and ester, Grazon P+D, and Cimarron Max had killed fineleaf by the end of the growing season.

Little sunflower was injured unacceptably by most of the auxin herbicides at the June evaluation with Overdrive, Transline, Tordon, and Milestone being notable exceptions (Table 10). By September, Vanquish, Curtail, 2,4-D amine and ester, Garlon 3A, Grazon P+D, Redeem, and Cimarron Max all injured little sunflower from 9 to 10. It is interesting that Overdrive, a dicamba product, did not injure little sunflower at either evaluation date. Scorpionweed injury was minimal to acceptable from all herbicides in June but by September, Vanquish, Curtail, 2,4-D amine and ester, Garlon 3A, Grazon P+D, Redeem, Tordon, Telar, Escort, and Cimarron Max caused 8 to 10 injury ratings (Table 10). Only Curtail, both formulations of 2,4-D, and Cimarron Max caused unacceptable injury (8 to 9) as of the June evaluation to slimflower scurfpea (Table 10). However, all treatments except Overdrive, Vanquish, Paramount, and Plateau caused unacceptable injury levels to slimflower scurfpea by September. Injury to locoweed was minimal to acceptable (1 to 4) in June and it had recovered from injury to acceptable levels or less by September except for Grazon P+D (7 injury rating) and Escort (9 injury rating). Locoweed is very susceptible to locoweed and this herbicide is commonly recommended to control it when necessary.

#### *Seedling grasses and shrubs*

Kochia was not controlled by Milestone, Transline, or Tordon, which is not unusual because these pyridine herbicides have little to no activity on this annual weed (Table 11). Kochia control ranged from 0 to 75% from herbicides 1 month after treatments (MAT) were applied and was controlled 100% in the handpulled check plot. Control improved from many treatments over the summer but the most notable control occurred where Vista was sprayed alone or added as a tank-mix partner. The only

exception to this was where Vanquish controlled 86% of kochia at 3 MAT. Vanquish plus Vista tended to control more kochia than other treatments except for the handpulled check plot. When grass biomass was harvested in October, only those herbicide treatments that controlled more than 70% of kochia had noticeable yields but only the Vanquish plus Vista treatment was superior compared to others. It is very clear from this experiment, that kochia and other annual weeds must be controlled to give seeded species the opportunity to establish. No seeded grasses were harvested from the non-treated control plots nor where kochia control was less than 5% in herbicide treated plots. Also, we did not observe emergence of any seeded species outside of the study area where kochia dominated and was the only species present.

## **Section 5: Discussion**

### *Established forb injury*

Grasses evaluated in this experiment were not injured by any of the herbicides tested, which is not surprising given the time of year of application and that most of the herbicides primarily have activity on dicotyledonous species. Sand lily, in contrast, was very sensitive to several herbicides, particularly the ALS inhibiting herbicides. If injury to sand lily cannot be tolerated then land managers should avoid using the ALS inhibiting herbicides in the vicinity of this native forb.

Louisiana sage was only moderately sensitive to the herbicides evaluated and in most cases, injury was acceptable. Possible exceptions include Transline, 2,4-D ester and Cimarron Max. The latter is a combination of metsulfuron (Escort) and dicamba (Vanquish) and while we had these herbicides represented alone in our experiment, it is not possible to determine which had the greater

effect on Louisiana sage and indeed, a synergistic relationship might have occurred. We have evaluated injury to Louisiana sage from Transline in other experiments and have not observed this much injury. The dry weather over the winter and early spring may have exacerbated injury from Transline and that can be determined if we repeat the experiment and environmental conditions change from 2006.

American plum was highly sensitive to most herbicides with the notable exceptions being Paramount and Transline. These two herbicides excellent choices to use on field bindweed and the knapweeds, respectively, and would be safe to use in the vicinity of American plum if they are the target weed species.

Fringed sage initially was not injured unacceptably by any herbicides that we evaluated but by the end of the growing season, injury was at an unacceptable level from Vanquish, Curtail, 2,4-D ester, Grazon P+D, Redeem, and Cimarron Max. However, response variation to herbicide application was large enough that many of the treatments were statistically similar. Generally, the auxin herbicides pose the greatest injury threat to fringed sage although we currently are evaluating Escort to control fringed sage in another experiment, but at higher rates than were used in this experiment. Most likely, fringed sage will recover from the injury incurred by most treatments by next spring but it will be revealing to determine whether the injury from 2,4-D ester and Cimarron Max dissipates.

Wild rose was injured by most of the herbicide treatments to an unacceptable level by the end of the growing season. Overdrive, Plateau,

Transline, and 2,4-D amine and ester were the only herbicides that did not injure wild rose unacceptably but other similar herbicides such as Vanquish, the remaining pyridine herbicides (Garlon 3A, Grazon P+D, Redeem, and Tordon), and the sulfonyleurea herbicides (Telar, Escort, and Cimarron Max) injured wild rose unacceptably. This is not surprising and land managers should avoid using any of these herbicides in the immediate vicinity of wild rose to avoid excessive injury.

Yucca injury was acceptable from all herbicides that were tested. We have evaluated many herbicides over the past 21 years, including some that were in this experiment, to control yucca and all have failed to do so. It is not at all surprising to see that one could control invasive weeds in the presence of yucca with any of these herbicides. Broom snakeweed, however, was badly injured by many treatments. Here too, we have tested Escort, Tordon, and Grazon P+D and all will control broom snakeweed and land managers should avoid using any of these herbicides when controlling invasive weeds in the presence of broom snakeweed if injury or attrition cannot be tolerated.

Overdrive, Paramount, and Plateau could be used to control susceptible invasive weeds in the presence of broom snakeweed. It is interesting to see that Vanquish caused unacceptable injury to broom snakeweed but Overdrive did not injure it at all. The two are the same active ingredient (dicamba) but Vanquish was applied at a much higher rate.

Western ragweed, one-sided penstemon, and clammy groundcherry were not injured unacceptably by any herbicide and most treatments did not injure

these species. Land managers should feel confident to control susceptible invasive weeds with any of the herbicides tested in the vicinity of these native forbs. Low milkweed too was not injured by most herbicides except Grazon P+D and Tordon. Picloram is commonly recommended to control several *Ambrosia* species and is the key active ingredient in both these herbicides. Land managers should avoid using either of them to control susceptible invasive weeds in the presence of low milkweed if severe injury or attrition cannot be tolerated. Winged buckwheat also was not injured unacceptably by any of the herbicides tested and land managers should feel confident that it will recover from the slight injury that may occur when treating susceptible invasive weeds in the presence of winged buckwheat. Gayfeather also was not injured unacceptably by any of the herbicides except Cimarron Max although injury from this treatment was not statistically greater than most other treatments. Most likely, gayfeather will recover even from the injury from Cimarron Max and we will determine this come spring when stand counts are taken.

Robust spurge was very sensitive to herbicides containing 2,4-D and was killed by Curtail, 2,4-D amine, and 2,4-D ester by the end of the growing season. Variation in injury response was very substantial, which was revealed by very little statistical separation of the means; i.e., treatments that caused injury levels of 4 and 5 were not different from those that killed robust spurge. Repetition of this experiment may help to better determine whether any of these herbicides can be used in the vicinity of robust spurge and not cause unacceptable injury.

Initially, blue flax was only injured unacceptably by Cimarron Max but by the end of the growing season, only Overdrive and 2,4-D amine treatments did not injure this native forb excessively. Land managers should avoid using any of these herbicides to control susceptible invasive weeds when blue flax is present unless significant injury can be tolerated. It was difficult to assess yellow sundrop because it dried up in mid-summer, which made assessing injury impossible. Treated plants simply were not different in appearance compared to non-treated yellow sundrop. A conservative approach at this moment would be to avoid using any herbicides in the vicinity of yellow sundrop except Paramount, Plateau, Telar, or Escort – even though statistical separation of means still was an issue - because these did not injure this forb excessively.

Dwarf morninglory was injured unacceptably by most herbicide treatments that we evaluated by the end of the growing season. Only Overdrive, Plateau, and possibly Transline did not cause injury levels that were unacceptable. As with many other of the forbs evaluated, response variation did not allow means to separate and treatments that caused unacceptable injury were not different from those that caused acceptable injury. Repetition of this experiment most likely will help to produce a more accurate picture of what land managers may anticipate. Not surprisingly, many herbicide treatments injured wavyleaf thistle unacceptably and most treatments killed this native thistle. Telar apparently did not cause unacceptable injury but again low populations of wavyleaf thistle created substantial variation and even though injury from Telar was only a 5, it was not statistically different than a 10. Land managers that use any of the herbicides

evaluated in this experiment to control susceptible invasive weeds should anticipate that wavyleaf thistle present in the treated area will be injured significantly if not killed.

Evening primrose was sensitive to many of the herbicides tested but initial injury from Vanquish, Curtail, and both 2,4-D formulations lessened as the season progressed. However, injury from these herbicides still would be considered unacceptable. Only Overdrive and Paramount did not injure evening primrose but again statistical separation was an issue. Similarly, only Overdrive, Paramount, and Plateau did not injure fineleaf beyond acceptable levels. Land managers should avoid using the other herbicides tested to control susceptible invasive weeds when fineleaf is present unless injury or attrition can be tolerated. Injury to little sunflower was similar to evening primrose and fineleaf in that only Overdrive, Paramount, and Plateau did not cause injury that was beyond acceptable levels.

Variation in injury response to herbicides by scorpionweed also masked treatment differences and ratings of 4 did not differ from 10. However, it is likely that scorpionweed will recover from an injury rating of 4 and will not recover from a 10 because by our own definition, such a rating equated to plant death. The stand counts we will take in spring will reveal these differences most likely. In contrast, slimflower scurfpea was not injured by Paramount or Plateau and these herbicides can be used in the vicinity to control susceptible invasive weeds such as field bindweed (Paramount), leafy spurge, or downy brome (Plateau). Injury produced by other herbicide treatments to slimflower scurfpea were

unacceptable but similar to what occurred with scorpionweed, injury caused by Overdrive and Vanquish most likely will dissipate by next spring but injury caused by the remaining herbicides may cause slimflower scurfpea to succumb over winter. No herbicide treatment injured locoweed excessively except Escort. The latter is not at all surprising. We have evaluated control of several *Oxytropis* species with Escort and it almost always kills these plants within one year of application. Escort should not be used to control invasive weeds when locoweed is present unless attrition can be tolerated. Escort has little to no residual activity and the soil seed reserve of locoweed – often up to 100 years – will allow this species to recover and reoccupy the site.

#### *Seedling forbs and shrubs*

The very dry weather over the winter months dramatically influenced not only the results of our experiment, but stand establishment of seeded species. It was very clear given the environmental conditions that existed in spring 2006 that unless annual weeds were controlled – in this case kochia – no seeded species would successfully establish. This was best revealed when seeded grass biomass (only seeded grasses emerged in 2006) data were taken in October and only treatments where kochia was controlled had any grasses present to harvest. Interestingly though, the treatments where kochia was controlled and grass was harvested did not differ statistically from no grass harvested where kochia was not controlled and likely was influenced by the severely dry winter of 2005-06. The differences among treated plots that controlled kochia may well have produced better stand establishment of seeded species had better soil moisture

been present than those plots where kochia was not controlled. At a minimum, this has been our research experience in the past.

## **Section 6: Conclusion**

It is very clear that the native shrubs and forbs in this experiment responded variably to the different herbicide treatments to which they were subjected. Generally, Paramount and Plateau were the least injurious to all shrubs, forbs, and grasses and auxin-like and pyridine herbicides displayed the broadest activity and tended to cause the most injury, but statistical variation was substantial. Exceptionally dry weather over the winter months before the experiment was initiated and hot, dry weather during the first two months after herbicides were applied most likely influenced experimental outcome. For example, many forbs simply dried up during June and July even in non-sprayed control plots, and it was impossible to distinguish injury from drought and that from the herbicide treatments. We will return in April 2007 to collect one final data set and we will compare it to baseline data to determine if any long-term effects are apparent.

It would be best to repeat this experiment to obtain an improved picture of injury potential from the various herbicide treatments as opposed to making final determinations based upon data collected during droughty conditions. Injury can be exacerbated or lessened during drought depending upon species and experiments conducted in different years will provide better insight with regard to predicting injury potential and give land managers greater confidence when using herbicides to control invasive and common weeds on rangeland and natural areas.

## **Section 7: Literature cited**

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