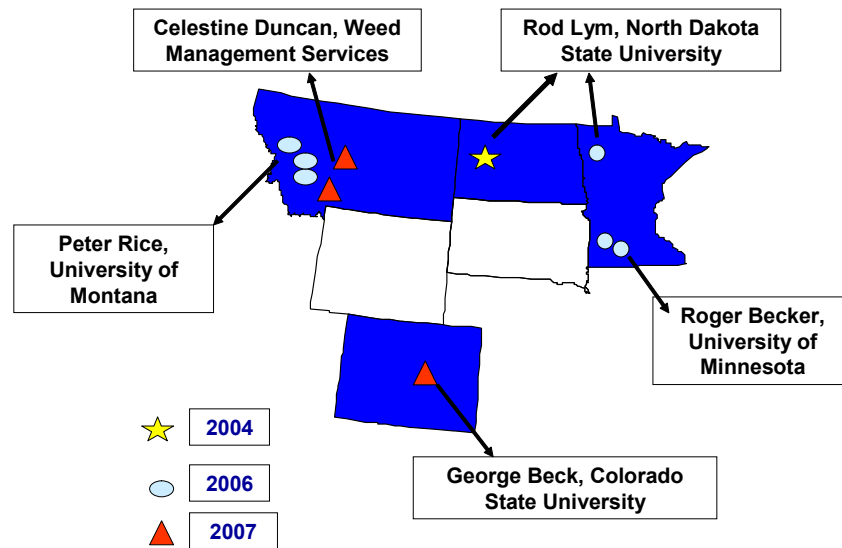


NATIVE FORB AND SHRUB TOLERANCE TO MILESTONE® VM HERBICIDE

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Milestone® VM herbicide (aminopyralid) is a broadleaf herbicide that has reduced risk to the environment compared with other commercially available herbicides, making it a desirable alternative for invasive weed control on rangeland and wildland sites. Effect of Milestone VM on desirable native forbs and shrubs is a consideration for land managers when making decisions about controlling invasive plants. Experiments were established at ten locations in four states to determine long-term response of native forbs and shrubs to Milestone VM applied in early summer or fall, and to develop a tolerance/susceptibility ranking for native plants. Studies were established within diverse native plant communities in western Montana, Boulder, Colorado, Theodore Roosevelt National Park (TRNP), North Dakota, and Glacial Ridge Preserve and restored prairies in Minnesota.

Experiments Established at 10 Locations



Field experiments were designed as randomized complete block with two to five replications and initiated from 2004 to 2007. Herbicide treatments were Milestone® VM at 5 or 7 fluid ounces/A. Broadcast ground applications were made with either a CO₂ backpack sprayer, or pickup boom sprayer. At one Montana location a broadcast application was made with a helicopter. Treatments were made in September or October at six locations, June at two locations, and June and September comparisons at two Minnesota sites. Data collection across sites varied from either canopy cover or plant counts along a permanent transect, or plant density within each plot.

Table 1: Research Locations and Methods:

Name	Location	Researcher	Site Type	Treatments	Methods
Theodore Roosevelt National Park	Western ND	Rod Lym and Luke Samuel, North Dakota State University	Canada thistle/arid grassland	Milestone [®] VM at 7 f oz/A applied in October 2004	Pre and Post: 30 plots - 3 frames/plot - <u>90 frames</u> per treatment
Two Rivers - MN Dept of Natural Resources(DNR)	Southwest MN	Roger Becker, University of Minnesota	Canada thistle prairie restoration	Milestone [®] VM at 5 fluid oz/A applied June and September comparisons -2006	Post only: <u>20 frames</u> per treatment for counts by species and presence per plot
Hedquist - MN DNR	SW MN 2006	Roger Becker, University of Minnesota	Canada thistle prairie restoration		
Glacier Ridge Nature Conservancy	Northern MN Fall 2006	Rod Lym and Travis Almquist, North Dakota SU	Canada thistle prairie restoration	Milestone [®] VM at 7 f oz/A applied in October 2006	Pre and Post: <u>90 frames</u> per treatment % cover by species
Larry Creek Bitterroot National Forest	Western MT	Peter Rice, University of Montana	Open canopy, commercially thinned Ponderosa pine with spotted knapweed	Milestone [®] VM at 5 fluid oz/A applied in October 2006	Pre and Post: 5 reps - 4 transects with 9 frames - <u>180 frames</u> per treatment (720 per location). Canopy cover and frequency of occurrence
Grant Cr. Elk Refuge National Wildlife Federation	Western MT	Peter Rice	Rough fescue grassland with spotted knapweed		
Pattee Canyon Lolo National Forest	Western MT	Peter Rice	Open canopy, Ponderosa pine habitat with spotted knapweed		
Boulder Open Space	Boulder, CO	George Beck, Colorado State University	Diffuse knapweed upland rangeland	Milestone [®] VM at 5 fluid oz/A applied in June 2007	Pre and post data - density of each species per plot.
Native rangeland with good forb diversity	Helena, MT	Celestine Duncan, Weed Management Services	Native Rangeland weed free	Milestone [®] VM at 5 fluid oz/A applied in June 2007	Pre and post canopy cover by species
Montana USFS Aerial Operational Study	Western MT	Celestine Duncan and Andy Kulla, US Forest Service	Spotted knapweed open canopy forest	Milestone [®] VM at 5 fluid oz/A applied by helicopter in October 2007	Pre and post canopy cover by species

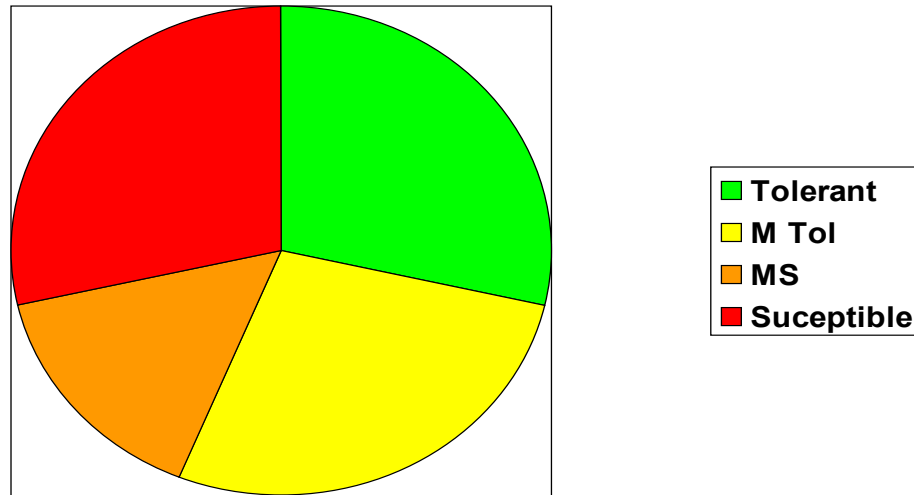
First year post-application vegetation sampling was conducted in June and July the summer after treatment at all locations. Second year sampling was completed at eight study sites. There were a total of 118 native forbs across sites, with 20 species occurring at more than one location. Individual rankings of tolerance to Milestone[®] VM herbicide were established for 98 native forb species and 19 shrubs. Evaluations were based on individual species reduction in canopy cover or density compared to non-treated controls or baseline data.

Table 2: Four categories were developed for ranking tolerance of forbs and shrubs to Milestone VM herbicide:

Code	Category	Symptoms	Injury Level
T	Tolerant	Minimal symptoms <15% injury - may have slight cupping of leaves	<15%
MT	Moderately tolerant	Symptoms include cupping/yellowing and can inhibit flowering, with recovery the first growing season after application	15 to 50% stand reduction
MS	Moderately susceptible	Injury could be significant the first year and may reduce stand	51 to 75% stand reduction
S	Susceptible	Severe injury the season of application and stand reduction the year after treatment with possible death of established plants. Some plants may regenerate from seed bank	>75% stand reduction

Figure 2: Results of 68 forb species with both 1 and 2 YAT data showing increase in species tolerance by the second year following treatment.

All Forb Species Combined- 1 YAT

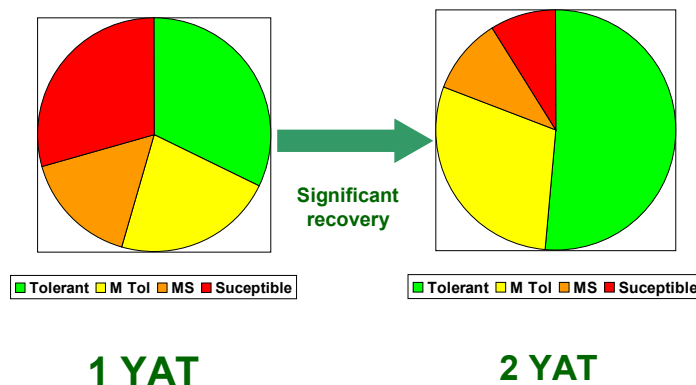


Of the 98 forb species categorized, 28, 17, 25, and 28 were ranked susceptible, moderately susceptible, moderately tolerant, and tolerant, respectively.

Data were collected on 68 species approximately 2 years after treatment. Many forbs recovered by the second year following Milestone[®] VM application with only 14 of 68 native forbs ranked either moderately susceptible or susceptible. Forbs classified as tolerant and moderately tolerant increased from 51% in the first year after treatment to 77% in the second year after treatment showing excellent recovery of the forb community. Sunflower, yarrow, and lobelia were very susceptible to Milestone VM while lupine, golden Alexander and wild bergamot were very tolerant.

Figure 2: Results of 68 forb species with both 1 and 2 YAT data showing increase in species tolerance by the second year following treatment.

Results of 68 Forbs Evaluated 2 YAT



There were 29 plant families represented, with the greatest number of species (35%) in the Asteraceae family.

Table 3: Tolerance of forb species to Milestone® VM herbicide. Forbs are listed alphabetically by common name within plant family. Rankings include: T=tolerant; MT moderately tolerant; MS moderately susceptible; S= susceptible; and NA = data not available (see Table 2 for category description)

Common Name	Family	Genus	Species	1 YAT	2 YAT	Location
Golden Alexanders	Apiaceae	<i>Zizia</i>	<i>aurea</i>	T	T	Glacier Ridge Fall
Heart-leaved alexanders	Apiaceae	<i>Zizia</i>	<i>aptera</i>	T	NA	MN: Summer/Fall
Nine-leaf lomatium	Apiaceae	<i>Lomatium</i>	<i>triternatum</i>	MT	T	MTRice-Fall
Wyeth's biscuitroot	Apiaceae	<i>Lomatium</i>	<i>ambiguum</i>	T	T	MTRice-Fall
Spreading dogbane	Apocynaceae	<i>Apocynum</i>	<i>androsaemifolium</i>	T	T	Glacier Ridge Fall
Common milkweed	Asclepiadaceae	<i>Asclepias</i>	<i>syriaca</i>	T	T	Glacier Ridge Fall
Arrowleaf balsamroot	Asteraceae	<i>Balsamorhiza</i>	<i>sagittata</i>	MS	MT	MTRice-Fall
Black-eyed Susan	Asteraceae	<i>Rudbeckia</i>	<i>hirta</i>	S	NA	MN: Summer/Fall
Blanket flower	Asteraceae	<i>Gaillardia</i>	<i>aristata</i>	MT	T	MTR-Fall, Glacier Ridge
Canada goldenrod	Asteraceae	<i>Solidago</i>	<i>canadensis</i>	MS	MS	Glacier Ridge Fall
cudweed sage	Asteraceae	<i>Artemesia</i>	<i>ludoviciana</i>	T	T	MTDuncan-summer
Cup plant	Asteraceae	<i>Silphium</i>	<i>perfoliatum</i>	MT	NA	MN: Summer/Fall
Daisy fleabane	Asteraceae	<i>Erigeron</i>	<i>strigosus</i>	MT	NA	MN: Summer/Fall
Gay feather	Asteraceae	<i>Liatris</i>	<i>punctata</i>	T	T	CO-summer
Giant goldenrod	Asteraceae	<i>Solidago</i>	<i>gigantea</i>	MT	NA	MN: Summer/Fall
Giant sunflower	Asteraceae	<i>Helianthus</i>	<i>giganteus</i>	S	MS	Glacier Ridge Fall
Gumweed	Asteraceae	<i>Grindelia</i>	<i>squarrosa</i>	MS	MT	MTRice-Fall
Hairy golden aster	Asteraceae	<i>Chrysopsis</i>	<i>villosa</i>	MT	T	MTR-Fall, MTD summer
Heath aster	Asteraceae	<i>Aster</i>	<i>ericoides</i>	MT	NA	MN: Summer/Fall
Hound's tongue hawkweed	Asteraceae	<i>Hieracium</i>	<i>cynoglossoides</i>	MT	MT	MTRice-Fall
Little sunflower	Asteraceae	<i>Helianthus</i>	<i>pumilus</i>	MT	MT	CO-summer
Maximilian sunflower	Asteraceae	<i>Helianthus</i>	<i>maximiliani</i>	S	S	Glacier Ridge Fall
Missouri goldenrod	Asteraceae	<i>Solidago</i>	<i>missouriensis</i>	MT	T	MTRice-Fall
Nuttall's pussy-toes	Asteraceae	<i>Antennaria</i>	<i>parviflora</i>	MS	MT	MTR-fall, MTD-summer
Orange arnica	Asteraceae	<i>Arnica</i>	<i>fulgens</i>	S	S	MTRice-Fall
Panicled aster	Asteraceae	<i>Aster</i>	<i>lanceolatum</i>	MT	NA	MN: Summer/Fall
Prairie blazingstar	Asteraceae	<i>Liatris</i>	<i>aspera</i>	MT	NA	MN: Summer/Fall
Prairie goldenrod	Asteraceae	<i>Solidago</i>	<i>missouriensis</i>	MS	MT	Glacier Ridge Fall
Prairie sunflower	Asteraceae	<i>Helianthus</i>	<i>pauciflorus</i>	MS	NA	Glacier Ridge Fall, MN
Rosy pussy-toes	Asteraceae	<i>Antennaria</i>	<i>microphylla</i>	MT	T	MTRice-Fall
Shaggy fleabane	Asteraceae	<i>Erigeron</i>	<i>pumulis</i>	MT	T	MTRice-Fall
Smooth Blue aster	Asteraceae	<i>Aster</i>	<i>laeve</i>	MT	NA	MN: Summer/Fall
Stiff goldenrod	Asteraceae	<i>Solidago</i>	<i>rigida</i>	MT	NA	MN: Summer/Fall
Stiff sunflower	Asteraceae	<i>Helianthus</i>	<i>pauciflorus</i>	MS	MT	Glacier Ridge Fall
Sweet clover	Asteraceae	<i>Melilotus</i>	<i>officinalis</i>	S	T	Glacier Ridge Fall
Sweet smooth oxeye	Asteraceae	<i>Heliopsis</i>	<i>helianthoides</i>	MT	NA	MN: Summer/Fall
Tall sunflower	Asteraceae	<i>Helianthus</i>	<i>giganteus</i>	S	NA	MN: Summer/Fall
White panicle aster	Asteraceae	<i>Aster</i>	<i>simplex</i>	S	MT	Glacier Ridge Fall
White prairie aster	Asteraceae	<i>Aster</i>	<i>ericoides</i>	MT	MT	Glacier Ridge Fall
Yarrow	Asteraceae	<i>Achillea</i>	<i>millefolium</i>	S	S	MTRice-Fall
Yellow prairie coneflower	Asteraceae	<i>Ratibida</i>	<i>pinnata</i>	S	NA	MN: Summer/Fall
Wayside gromwell	Boraginaceae	<i>Lithospermum</i>	<i>ruderales</i>	MT	MT	MTRice-Fall
Alyssum	Brassicaceae	<i>Alyssum</i>	<i>alyssoides</i>	T	T	MTDuncan-summer
Nuttall's rockress	Brassicaceae	<i>Arabis</i>	<i>nuttallii</i>	T	T	MTRice-Fall
Palespike lobelia	Campanulaceae	<i>Lobelia</i>	<i>spicata</i>	S	S	Glacier Ridge Fall
Field chickweed	Caryophyllaceae	<i>Cerastium</i>	<i>arvense</i>	MS	MT	MTRice-Fall
Jagged chickweed	Caryophyllaceae	<i>Holosteum</i>	<i>umbellatum</i>	S	T	MTRice-Fall
threadleaf sandwort	Caryophyllaceae	<i>Arenaria</i>	<i>capillaris</i>	S	MT	MTDuncan-summer
Prairie spiderwort	Commelinaceae	<i>Tradescantia</i>	<i>occidentalis</i>	MS	NA	MN: Summer/Fall

Table 3: Tolerance of forb species to Milestone® VM herbicide (continued)

Common Name	Family	Genus	Species	1 YAT	2 YAT	Location
Dwarf morning glory	Convolvulaceae	<i>Ipomoea</i>	<i>tricolor</i>	MT	T	CO-summer
Equisetum	Equisetaceae	<i>Equisetum</i>	<i>arvense</i>	T	NA	MN: Summer/Fall
Flowering spurge	Euphorbaceae	<i>Euphorbia</i>	<i>corollata</i>	T	NA	MN: Summer/Fall
Robust spurge	Euphorbia	<i>Tithymalus</i>	<i>brachyceras</i>	T	T	CO-summer
Lupine	Fabaceae	<i>Lupinus</i>	<i>sericeus</i>	T	T	MTR-fall, MTD-summer
Purple prairie clover	Fabaceae	<i>Dalea</i>	<i>purpurea</i>	S	MS	Glacier Ridge Fall
Round-headed bush clover	Fabaceae	<i>Lespedeza</i>	<i>capitata</i>	MS	NA	MN: Summer/Fall
Showy tickfoil	Fabaceae	<i>Desmodium</i>	<i>canadense</i>	MS	NA	MN: Summer/Fall
Silky prairie clover	Fabaceae	<i>Petalostemum</i>	<i>villosum</i>	MS	NA	MN: Summer/Fall
Slimflower scurfpea	Fabaceae	<i>Psoralea</i>	<i>lanceolata</i>	S	MT	CO-summer
Trailing wild bean	Fabaceae	<i>Strophostyles</i>	<i>helvola</i>	T	NA	MN: Summer/Fall
Weedy milkvetch	Fabaceae	<i>Astragalus</i>	<i>miser</i>	S	MS	MTRice-Fall
White prairie clover	Fabaceae	<i>Dalea</i>	<i>candida</i>	S	S	Glacier Ridge Fall
White wild indigo	Fabaceae	<i>Baptisia</i>	<i>alba</i>	MT	NA	MN: Summer/Fall
American water horehound	Lamiaceae	<i>Lycopus</i>	<i>americanus</i>	T	T	Glacier Ridge Fall
Hedgenettle	Lamiaceae	<i>Stachys</i>	<i>palustris</i>	T	T	Glacier Ridge Fall
Horsemint	Lamiaceae	<i>Monarda</i>	<i>fistula</i>	T	T	MTRice-Fall
Wild bergamot	Lamiaceae	<i>Monarda</i>	<i>fistulosa</i>	T	T	Glacier Ridge Fall
Wild mint	Lamiaceae	<i>Mentha</i>	<i>arvensis</i>	T	T	Glacier Ridge Fall
Death camas	Lilaceae	<i>Zigadenus</i>	<i>venenosus</i>	T	T	MTRice-Fall
Yellow bell	Lilaceae	<i>Fritillaria</i>	<i>pubida</i>	T	T	MTRice-Fall
Prairie onion	Liliaceae	<i>Allium</i>	<i>stellatum</i>	T	NA	MN: Summer/Fall
Sand lily	Lillaceae	<i>Leucocrinum</i>	<i>montanum</i>	MS	MT	CO-summer
Blue flax	Linaceae	<i>Linum</i>	<i>lewisii</i>	S	MS	CO-summer
Common primrose	Onagraceae	<i>Oenothera</i>	<i>biennis</i>	S	NA	MN: Summer/Fall
Evening Primrose	Onagraceae	<i>Oenothera</i>	<i>howardii</i>	MS	MT	CO-summer
Scarlet beeblossum	Onagraceae	<i>Gaura</i>	<i>coccinea</i>	S	MT	CO-summer
Tall annual willow-herb	Onagraceae	<i>Epilobium</i>	<i>paniculatum</i>	S	MS	MTRice-Fall
Common yellow woodsorel	Oxalidaceae	<i>Oxalis</i>	<i>stricta</i>	T	T	Glacier Ridge Fall
Narrow-leaf collomia	Polemoniaceae	<i>Collomia</i>	<i>linearis</i>	S	MS	MTRice-Fall
Pink microsteris	Polemoniaceae	<i>Microsteris</i>	<i>gracilis</i>	T	T	MTRice-Fall
Douglas's knotweed	Polygonaceae	<i>Polygonum</i>	<i>douglasii</i>	T	T	MTRice-Fall
Pale dock	Polygonaceae	<i>Rumex</i>	<i>altissimus</i>	S	NA	MN: Summer/Fall
Water smartweed	Polygonaceae	<i>Polygonum</i>	<i>amphibium</i>	MS	T	Glacier Ridge Fall
Winged buckwheat	Polygonaceae	<i>Pterogonum</i>	<i>alatum</i>	S	S	CO-summer
Western androsace	Primulaceae	<i>Androsace</i>	<i>occidentalis</i>	MS	T	MTRice-Fall
Purple meadow-rue	Ranunculaceae	<i>Thalictrum</i>	<i>dasycarpum</i>	MT	MT	Glacier Ridge Fall
Prairie cinquefoil	Rosaceae	<i>Potentilla</i>	<i>arguta</i>	S	NA	MN: Summer/Fall
Prairie smoke	Rosaceae	<i>Geum</i>	<i>triflorum</i>	MT	T	MTRice-Fall
Soft cinquefoil	Rosaceae	<i>Potentilla</i>	<i>gracilis</i>	S	MT	MTRice-Fall
Virginia strawberry	Rosaceae	<i>Fragaria</i>	<i>virginiana</i>	T	T	MTRice-Fall
wild rose	Rosaceae	<i>Rosa sp.</i>		S	NA	MTDuncan-summer
Small-flowered fringe cup	Saxifragaceae	<i>Lithophragma</i>	<i>parviflora</i>	S	MS	MTRice-Fall
Blue-eyed Mary	Scrophulariaceae	<i>Collinsia</i>	<i>parviflora</i>	T	T	MTRice-Fall
One-sided penstemon	Scrophulariaceae	<i>Penstemon</i>	<i>secundiflorus</i>	MT	MT	CO-summer
Clammy groundcherry	Solanaceae	<i>Physalis</i>	<i>heterophylla</i>	S	NA	MN: Summer/Fall
Stinging nettle	Urticaceae	<i>Urtica</i>	<i>dioica</i>	MT	NA	MN: Summer/Fall
Blue vervain	Verbenaceae	<i>Verbena</i>	<i>hastata</i>	T	NA	MN: Summer/Fall
Hoary vervain	Verbenaceae	<i>Verbena</i>	<i>stricta</i>	T	NA	MN: Summer/Fall
Nuttalls violet	Violaceae	<i>Viola</i>	<i>nuttallii</i>	MS	T	CO-summer

Shrubs were more tolerant than forbs to Milestone VM. There were 19 shrub species, and 74% were ranked either MT or T. Shrubs in the Rosaceae Family were generally the most susceptible to Milestone.

Table 4: Tolerance of shrub species to Milestone® VM herbicide. Rankings include: T=tolerant; MT moderately tolerant; MS moderately susceptible; and S= susceptible (see Table 2 for category description)

Common Name	Family	Genus	Species	1 YAT	Location
Yucca	Agavaceae	<i>Yucca</i>	<i>glauca</i>	T	CO-Summer
Dogbane	Apocynaceae	<i>Apocynum</i>	<i>andro</i>	MT	USFS MT
Big Sagebrush	Asteraceae	<i>Artemisia</i>	<i>tridentata</i>	T	Wyoming Summer
Fringe sage	Asteraceae	<i>Artemisia</i>	<i>frigida</i>	MS	CO-Summer
Louisiana sage	Asteraceae	<i>Artemisia</i>	<i>ludoviciana</i>	MS	CO-Summer
Silver sagebrush	Asteraceae	<i>Artemisia</i>	<i>cana</i>	T	USFS ND Fall
White sagebrush	Asteraceae	<i>Artemisia</i>	<i>ludoviciana</i>	T	USFS ND Fall
Oregon Grape	Berberidaceae	<i>Berberis</i>	<i>repens</i>	T	USFS MT
Elderberry	Caprifoliaceae	<i>Sambucus</i>	<i>racemosa</i>	T	USFS MT
Western snowberry	Caprifoliaceae	<i>Symphoricarpos</i>	<i>occidentalis</i>	T	USFS ND Fall, USFS MT
Buffaloberry	Elaeagnaceae	<i>Shepherdia</i>	<i>canadensis</i>	MT	USFS MT
Silver Buffaloberry	Elaeagnaceae	<i>Shepherdia</i>	<i>argentea</i>	T	USFS ND Fall
Kinnikinnick	Ericaceae	<i>Arctostaphalos</i>	<i>uvaursi</i>	T	USFS MT
Buckbrush	Rhamnaceae	<i>Ceanothus</i>	<i>velutinus</i>	T	USFS MT
Chokecherry	Rosaceae	<i>Prunus</i>	<i>virginiana</i>	MT	USFS ND Fall, USFS MT
Nine-bark	Rosaceae	<i>Physorcarpus</i>	<i>mon</i>	S	USFS MT
Serviceberry	Rosaceae	<i>Amelancheir</i>	<i>alnifolia</i>	S	USFS MT
Wood's rose	Rosaceae	<i>Rosa</i>	<i>woodsii</i>	S	CO-Summer, USFS MT
Golden current	Saxifragaceae	<i>Ribes</i>	<i>aureum</i>	T	USFS ND Fall

Conclusions:

- Most native forb species and shrubs were moderately tolerant to tolerant, or recovered following treatment with Milestone VM herbicide.
- Historical data¹ suggests that by the third or fourth year post-application, there would be little difference in non-target forb tolerance with only a few very sensitive forbs being adversely impacted in the long term.
- Land managers can use these data as a guideline to evaluate risk to native plant communities when using Milestone VM for invasive species management.
- Milestone® VM herbicide (aminopyralid) can be used to manage invasive plants in mixed plant communities and facilitate recovery of desirable forbs and shrubs.

¹Rice, P. M., J. C. Toney, D. J. Bedunah, and C. E. Carlson. 1997. Plant community diversity and growth form responses to herbicide applications for control of *Centaurea maculosa*. *J. Appl. Ecol.* 34:1397-1412