Invasive Pestiferous Weeds of the Northern Plains Grasslands

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Pestiferous weeds are aggressive vexatious competitors that have the potential to swiftly invade and colonize any declining grassland community of the Northern Plains by supplanting desirable vegetation and severely exploiting any previously degraded grassland ecosystem. Most pestiferous weed invasions start from seed and an opening in an impaired grassland ecosystem. Pestiferous weed invasion into Northern Plains grassland ecosystems has usually been considered to be by forceful, aggressive, invader plants that become established by dislodging the desirable native grass plants. Except, the invasion of these problematical unwanted weeds cannot occur without the previous creation of open spaces in grassland communities from antagonistic management practices. The presence of pestiferous weeds in grassland communities are the visual symptoms of degraded grassland ecosystems; invading pestiferous weeds are not the cause of degradation of the grasslands. Reduction of the weedy species by prescribed control treatments can temporarily decrease the quantity of weeds, but weed reduction cannot restore the problems of deteriorated ecosystems. Degraded grassland ecosystems continue to remain susceptible to reinfestation of pestiferous weeds. Restoration of the degraded grassland ecosystems requires that the old style management practices be changed to biologically effective grazing management strategies (Manske 2018a).

Once pestiferous weeds have invaded and become established they are extremely difficult to control. This report is intended to provide useful information to help Northern Plains grassland managers with the reduction of invading pestiferous weeds. The first section describes the mechanisms and processes that functionalize grassland ecosystems and describes the biologically effective management strategies that activate the grassland ecosystem mechanisms and processes at potential biological levels that effectively prevent invasion of pestiferous weeds. The second section provides botanical description of each of twenty potential pestiferous weeds. The third section describes the available control management practices that can be used on Northern Plains grasslands. The fourth section explains the effectiveness or ineffectiveness of the specific control practices for each of the pestiferous weeds.

Pestiferous Weed Invasion Prevention

Mechanisms and Processes of Grassland Ecosystems

Traditional grazing practices are designed for the use of grassland forage based on observations of changes in the aboveground vegetation. However, grassland ecosystems are much more complex than the traditional concept. Maintenance of the total grassland ecosystem structure and functionality necessitates the implementing of biologically effective grazing management strategies that meet all of the biological and physiological requirements of grass plants and soil microorganisms, and the nutrient requirements of grazing livestock.

Fortunately, the long needed basic science of the critical grass physiological growth mechanisms and the essential grassland ecosystem biogeochemical processes performed by soil microbes were described in detail during a concentrated effort in the late 1970's through the 1990's. These important research findings were not reported on the 6 o'clock news nor in the popular farm magazines and the general public has remained unaware of the existence of this paradigm changing breakthrough science. Knowledge of the grass growth mechanisms and ecosystem biogeochemical processes permits development of management strategies that consider all the above - and belowground components while meeting the biological requirements of the grass plants and soil microbes and enhancing the functionality of the ecosystem resulting in grassland productivity at biological potential levels. Biologically effective management strategies that are designed to activate the grass physiological growth mechanisms and promote the ecosystem biogeochemical processes is also sound livestock grazing management and beneficial wildlife habitat management.

Grasslands are complex ecosystems; exceedingly more complex than the most complicated machines ever built by humans. Grassland ecosystems are comprised of biotic and abiotic components. The indispensable biotic components are grass vegetation, rhizosphere organisms, and domesticated graminivores which have biological and physiological requirements (Manske 2018b, c, d). The abiotic components include radiant energy from sunlight, the major essential elements of carbon, hydrogen, nitrogen, and oxygen, and the minor essential elements of macro - and micro - nutrients required by living organisms, and the environmental conditions. Grass plants, rhizosphere organisms, and grazing graminivores have developed complex symbiotic relationships. Grazing graminivores depend on grass plants for nutritious forage. Grass plants depend on rhizosphere organisms for mineralization of essential elements from the soil organic matter. Rhizosphere organisms, which are achlorophyllous, depend on grass plants for short chain carbon energy that is exudated through the roots of lead tillers at vegetative growth stages following partial defoliation by grazing graminivores. Grass plants produce double the leaf biomass than is needed for photosynthesis in order to attract the vital partial defoliation by grazing graminivores on which they depend.

The indispensable grass vegetation provides nutritious forage to large grazing graminivores and habitat to wildlife. Grass plants use the major and minor essential elements in the inorganic form to synthesize vital organic components of carbohydrates, proteins, and nucleotides for growth. Grass plants have four primary internal plant growth mechanisms that help grass tillers withstand and recover from partial defoliation by grazing graminivores. The primary mechanisms are: compensatory physiological mechanisms (McNaughton 1979, 1983; Briske 1991); vegetative reproduction by tillering (Mueller and Richards 1986, Richards et al. 1988, Murphy and Briske 1992, Briske and Richards 1994, 1995); nutrient resource uptake (Crider 1955, Li and Wilson 1998, Kochy and Wilson 2000, Peltzer and Kochy 2001); and water use efficiency (Wight and Black 1972, 1979).

Compensatory physiological mechanisms give grass plants the capability to replace lost leaf and shoot biomass following partial grazing defoliation by increasing meristematic tissue activity, increasing photosynthetic capacity, and increasing allocation of carbon and nitrogen. Fully activated mechanisms can produce replacement foliage at 140% of the herbage weight that was removed during grazing (Manske 2000a, b, 2010a, b, 2014a, b). The growth rates of replacement leaves and shoots increase after partial defoliation by grazing. The enhanced activity of meristematic tissue produces larger leaves with greater mass (Langer 1972, Briske and Richards 1995). Developing leaf primordia not fully expanded at time of defoliation have increased growth rates and tend to grow larger than leaves on undefoliated tillers (Langer 1972). Partial defoliated tillers increase photosynthetic rates of remaining mature leaves and rejuvenated portions of older leaves not completely senescent (Atkinson 1986, Briske and Richards 1995). Changes in cytokinin levels and other signals produced as a result of the increase in the root-shoot ratio rejuvenate the photosynthetic apparatus, inhibit or reduce the rate of senescence, and increase the life span and leaf mass of remaining mature leaves (Briske and Richards 1995). Activation of the compensatory physiological mechanisms after partial defoliation of grass tillers by grazing require alternative sources of abundant carbon and nitrogen (Coyne et al. 1995). Carbon fixed during current photosynthesis in remaining mature leaf and shoot tissue and rejuvenated portions of older leaves is preferentially allocated to areas of active meristematic tissue (Ryle and Powell 1975, Richards and Caldwell 1985, Briske and Richards 1995, Coyne et al. 1995). The quantity of leaf area required to fix adequate quantities of carbon is 67% to 75% of the predefoliated leaf area (Manske 1999, 2011b, 2014c). Very little, if any, of the carbon and nitrogen stored in the root system is remobilized to support compensatory growth (Briske and Richards 1995). The mobilizable nitrogen pools in the shoot tissue are reduced following partial defoliation. This loss in nitrogen from the shoot increases preferential use of the quantities of mineral nitrogen available in the media around the roots (Millard et al. 1990, Ourry et al. 1990). This available soil mineral nitrogen has been converted from soil organic nitrogen by active rhizosphere organisms, absorbed though the roots, and moved to areas of active meristematic tissue.

Vegetative secondary tillers are shoots that develop on lead tillers from growth of axillary buds by the process of tillering (Dahl 1995). Meristematic activity in axillary buds and the subsequent development of vegetative tillers is regulated by auxin, a growth-inhibiting hormone produced in the apical meristem and young developing leaves (Briske and Richards 1995). Tiller growth from axillary buds is inhibited indirectly by auxin interference with the metabolic function of cytokinin, a growth hormone (Briske and Richrds 1995). Partial defoliation of young leaf material at vegetative growth stages temporarily reduces the production of the blockage hormone, auxin (Briske and Richards 1994). The abrupt reduction of plant auxin in the lead tiller allows for cytokinin synthesis or utilization in multiple axillary buds, stimulating the development of vegetative secondary tillers (Murphy and Briske 1992, Briske and Richards 1994).

If no defoliation occurs before the flower (anthesis) stage, the lead tiller continues to hormonally inhibit secondary tiller development from axillary buds. Production of the inhibitory hormone, auxin, declines gradationally as the lead tiller reaches the flower stage. The natural reduction of auxin in the lead tiller usually permits only one secondary tiller to develop. This developing secondary tiller produces auxin that hormonally suppresses development of additional axillary buds (Briske and Richards 1995). Vegetative tiller growth is the dominant form of reproduction in semiarid and mesic grasslands (Belsky 1992, Chapman and Peat 1992, Briske and Richards 1995, Chapman 1996, Manske 1999) not sexual reproduction and the development of seedlings. Recruitment of new grass plants developed from seedlings is negligible in healthy grassland ecosystems. The frequency of true seedlings is extremely low in functioning grasslands, and establishment of seedlings occurs only during years with favorable moisture and temperature conditions (Wilson and Briske 1979, Briske and Richards 1995), in areas of reduced competition from vegetative tillers, and when resources are readily available to the growing seedling.

Grass plant dominance within a grassland community is related to the plants competitiveness at nutrient and water resource uptake. Crider (1955) found that grass tillers with 50% or more of the aboveground leaf material removed reduce root growth, root respiration, and root nutrient absorption resulting in reduced functionality of these grass plants. Reduction of active root biomass caused diminishment of grass plant health and vigor (Whitman 1974) that resulted in a loss of resource uptake efficiency and a suppression of the competitiveness of grass plants to take up mineral nitrogen, essential elements, and soil water (Li and Wilson 1998, Kochy 1999, Kochy and Wilson 2000, Peltzer and Kochy 2001). The loss of active root length contributed to the reduction of rhizosphere biomass and the decline of ecosystem biogeochemical processes (Coleman et al. 1983, Klein et al. 1988). The nutrient resource uptake competitiveness of healthy grasses is able to suppress the expansion of shrubs and prevent successful establishment of grass, forb, and shrub seedlings into grasslands (Peltzer and Kochy 2001). The grass growth form has competitive advantages of nutrient uptake over the shrub growth form (Kochy and Wilson 2000). Grass aboveground biomass is primarily productive photosynthetic leaves resulting in a high resource uptake efficiency. Grasses are good competitors for belowground nutrient resources and superior competitors for mineral nitrogen because of a high root: shoot ratio and no woody stems to maintain. Shrubs have a great reduction in resource uptake efficiency because a large portion of the photosynthates produced in the leaves must be used to build and maintain their unproductive woody stems. However, the taller woody stems make shrubs superior competitors for aboveground sunlight resources (Kochy and Wilson 2000). Competition for belowground nutrient resources from healthy grasses reduce the growth rates of shrub rhizomes and cause high mortality rates of young suckers (Li and Wilson 1998).

Shrubs can compete for some of the belowground resources only after the grass plants have been degraded by ineffective management. Following the reduction in grass plant resource uptake competitiveness, the belowground resources no longer consumed by the smaller, less vigorous degraded grasses, are taken up by the shrub plants resulting in proportional increases of biomass production (Kochy and Wilson 2000). With greater nutrient resources, shrub rhizome suckers are able to establish a faster growth rate and a higher survival rate (Li and Wilson 1998). The resulting greater shrub stem density increases the competition for the aboveground resources of light causing strong suppression of the grasses (Kochy and Wilson 2000). Traditionally, the observation of increasing woody shrubs and trees into grasslands would have been explained as a result of fire suppression (Humphrey 1962, Stroddart, Smith, and Box 1975, Wright and Bailey 1982). The invasion of the cool season exotic grasses, Kentucky bluegrass, and smooth bromegrass, into much of the northern mixed grass prairie was presumed to be caused by the absence of fire (Kirsch and Kruse 1972). Seedlings of trees, shrubs, weedy forbs, and introduced grasses cannot become established in healthy functioning grassland ecosystems with grasses that have retained full resource uptake competitiveness (Peltzer and Kochy 2001, Manske 2019).

Grasslands of the Northern Plains managed with traditional practices are notorious for their inhibitory deficiency in available soil mineral nitrogen (Goetz et al. 1978) which has been determined to cause the observed low herbage production. Deficiencies in mineral nitrogen limit herbage production more often than water deficiencies in temperate grasslands (Tilman 1990). Total herbage biomass production on grassland ecosystems has been shown to increase with increases in the quantity of available soil mineral nitrogen (Rogler and Lorenz 1957; Whitman 1957, 1963, 1976; Smika et al. 1965; Goetz 1969, 1975; Power and Alessi 1971; Lorenz and Rogler 1972; Taylor 1976; Wight and Black 1979). Greater quantities of available soil mineral nitrogen has been shown to also cause the soil water use efficiency to improve in grassland plants (Smika et al. 1965, Wight and Black 1972, Whitman 1976, 1978). Using a proxy method, Wight and Black (1972) found that precipitation (water) use efficiency of grass plants improved when soil mineral nitrogen was available at threshold quantities of 100 lbs/ac (112 kg/ha) and greater. The inhibitory deficiencies of mineral nitrogen on grasslands that had less than 100 lbs/ac of available soil mineral nitrogen caused the weight of herbage production per inch of precipitation received to be reduced an average of 49.6% below the weight of herbage produced per inch of precipitation on the grassland ecosystem that had greater than 100 lbs/ac of mineral nitrogen and did not have mineral nitrogen deficiencies (Wight and Black 1979). The efficiency of water use in grass plants function at low levels when mineral nitrogen is deficient, and function at high levels when mineral nitrogen is available at threshold quantities of 100 lbs/ac or greater (Manske 2009d). The level of water use efficiency determines the level of herbage biomass productivity on grasslands. Manske (2010a, b) found that the threshold quantity of 100 lbs/ac of available mineral nitrogen was also critical for functionality for two internal grass plant growth mechanisms of the vegetative reproduction by tillering and the compensatory physiological mechanisms. Both of these mechanisms function at high potential levels on grasslands that have 100 lbs/ac or greater available soil mineral nitrogen and do not function or function at extremely low levels on grasslands that have mineral nitrogen deficiencies (Manske 2009c, 2010a, b, c, 2011c).

The indispensable rhizosphere microorganisms are responsible for the performance of the ecosystem biogeochemical processes that determine grassland ecosystem productivity and functionality. Biogeochemical processes transform stored essential elements from organic forms or ionic forms into plant usable mineral forms. Biogeochemcial processes capture replacement quantities of lost or removed major essential elements of carbon, hydrogen, nitrogen, and oxygen with assistance from active live plants and transform the replacement essential elements into storage as soil organic matter for later use. Biogeochemical processes decompose complex unusable organic material into compounds and then into reusable major and minor essential elements (McNaughton 1979, 1983; Coleman et al. 1983; Ingham et al. 1985; Mueller and Richards 1986; Richards et al. 1988; Briske 1991; Murphy and Briske 1992; Briske and Richards 1994, 1995).

The quantity of ecosystem biogeochemical processes conducted is dependent on the quantity of rhizosphere microorganism biomass (Coleman et al. 1983). The greater the microbial biomass, the greater the grassland ecosystem productivity. The greater the productivity, the greater the annual increase in soil organic matter. Increases in the organic matter content of a soil improves the stability of soil aggregates, improves the physical and chemical properties, improves soil air and water infiltration and water holding capacity, improves soil fertility, and increases cation exchange capacity (Schimel, Coleman, and Horton 1985, Six et al. 1998, 2004). Rhizosphere organism biomass and activity are limited by access to simple carbon chain energy (Curl and Truelove 1986) because the microflora trophic levels lack chlorophyll and have low carbon (energy) content.

Partial defoliation by large indispensable grazing graminivores that removes 25% to 33% of the aboveground leaf and shoot weight from grass lead tillers in vegetative phenological growth between the three and a half new leaf stage and the flower stage (Manske 1999) causes large quantities of exudates containing simple carbon compounds to be released through the plant roots into the rhizosphere (Hamilton and Frank 2001). With the increase in availability of energy from simple carbon compounds in the rhizosphere, microorganism activity (Elliot 1978, Anderson et al. 1981, Whipps 1990) and biomass (Gorder, Manske, and Stroh 2004) greatly increase. The elevated biomass and activity of the microfauna trophic levels results in heavy consumption of the low carbon, high nitrogen content microflora trophic levels resulting in ingestion of greater quantities of nitrogen than the microfauna organisms need for a balanced diet based on energy (carbon); the excess nitrogen is excreted as ammonium (NH_4). As a result of the increase in availability of energy from the exudated simple carbon chains, the biomass and activity of rhizosphere organisms greatly increased, transforming greater quantities of organic nitrogen into mineral nitrogen (Coleman et al. 1983, Klein et al. 1988, Burrows and Pfleger 2002, Rillig et al. 2002, Bird et al. 2002, Driver et al. 2005).

The increased available mineral nitrogen is absorbed into grass plant roots and through complex processes, the plant combines the mineral nitrogen with carbon, hydrogen, and oxygen to synthesize different kinds of amino acids which are combined into large organic compounds to produce various types of proteins, nucleotides, and chlorophyll, resulting in greatly increased herbage biomass production at or near potential biological levels (Manske 1999, 2003). As a result of the great increase in ecosystem net primary productivity, much greater quantities of organic nitrogen are returned annually back to the grassland ecosystem pool of soil organic matter which will raise the ecosystem functionality.

Production of herbage biomass on grassland ecosystems at potential biological levels requires mineral nitrogen to be available at the threshold amount of 100 lbs/ac or greater. The biogeochemical processes of the nitrogen cycle in grassland ecosystems that convert organic nitrogen into mineral nitrogen are a function of the complex symbiotic interactions among rhizosphere organisms, grass plants, and large grazing graminivores. Soil organic matter in grassland ecosystems generally contains about three to eight tons of organic nitrogen per acre. Organic nitrogen is a form of nitrogen not directly usable by grass plants. Organic nitrogen must be transformed into inorganic (mineral) nitrogen in order to be usable by plants. In grassland ecosystems, the transformation of plant usable mineral nitrogen from soil organic nitrogen requires active rhizosphere organisms comprised of several trophic levels of microbes existing in the narrow zone of soil around active roots of perennial grass plants (Harley and Smith 1983, Campbell and Greaves 1990, Caesar-TonThat et al. 2001b).

The nitrogen cycle within grassland soils functions with two major biogeochemical processes. Immobilization is the process of assimilation of mineral nitrogen into organic forms of living organisms. Mineralization is the process of converting organic nitrogen into mineral (inorganic) nitrogen. Mineralization is a complex biogeochemical process conducted by saprotrophic and heterotrophic soil microorganisms that convert immobilized organic nitrogen from soil organic matter detritus into mineral (inorganic) nitrogen (Power 1972). Ammonium salts are the first inorganic nitrogen compounds produced by microbial digestion. Complex proteins and other organic nitrogen compounds are simplified by enzymatic digestion that hydrolyze the peptide bonds and liberate and degrade the amino acids by deamination to produce ammonia (NH_3) and carbon dioxide, or other low molecular weight carbon compounds (Power 1972, Brady 1974). Most of the ammonia released is readily hydrolyzed into stable ammonium (NH_4). The ammonium ions are fairly immoble and some can be oxidized during nitrification producing nitrite (NO_2) and then nitrate (NO_3) (Brady 1974, Legg 1975, Coyne et al. 1975). The quantity of available nitrate in soil increases when the soil moisture content is abundant (Brady 1974). Mineral nitrogen (NH_4 and NO_3) have several optional biological and chemical pathways and are not available for very long. The quantity of available mineral nitrogen varies with changes in soil microorganism biomass and plant phenological growth and development during the growing season (Whitman 1975) and is the net difference between the total quantity of organic nitrogen mineralized by soil microorganisms and the quantity of mineral nitrogen immobilized into organic forms by plants and soil microbes (Brady 1974, Legg 1975). Maintaining available mineral nitrogen at the threshold quantity of 100 lbs/ac or greater requires a very large biomass of soil microorganisms.

Perpetuation of life on earth requires that the abiotic major and minor essential elements be reused over and over. Recycling of the essential elements is also performed by rhizosphere microorganisms. The essential elements are required for life to exist by ensuring growth and development of organisms and the maintenance of all life functions. Animals require twenty one elements and plants require seventeen elements. Sixteen of the same essential elements are required by both animals and plants. The four major essential elements: carbon (C), hydrogen (H), nitrogen (N), and oxygen (O) are required in very large amounts by animals and plants. A portion of the major essential elements is lost annually from grassland ecosystems by natural processes and a portion is removed from grassland ecosystems as weight biomass produced by insects and wildlife and as animal growth from essential elements transferred from grass plants to grazing livestock. When greater quantities of major essential elements are lost and removed than the quantities accumulated, the ecosystem degrades (declines). When greater quantities of major essential elements are accumulated than the quantities removed, the ecosystem aggrades (improves). Biologically effective management strategies can replenish the quantity of lost or removed major essential elements by capturing input essential elements from the surrounding environment through ecosystem biogeochemical processes performed by the indispensable rhizosphere microorganisms.

Animals and plants require large amounts of the same five macronutrients: potassium (K), calcium (Ca), phosphorus (P), magnesium (Mg), and sulfur (S). Animals require one additional macronutrient: sodium (Na) and require chlorine (Cl) as a macronutrient. Warm season plants and cacti use some sodium (Na). Animals and plants require very small amounts of the same seven micronutrients or trace elements: iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and nickel (Ni). Animals require four additional micronutrients: iodine (I), cobalt (Co), selenium (Se), and chromium (Cr). Plants require one additional micronutrient: boron (B), and require chlorine (Cl) as a micronutrient. A few plants and rhizobia use some cobalt (Co).

The ecosystem source for all of the minor essential elements required by animals and plants is weathered parent material. The elemental content of the parent material greatly influences the quantity of macro - and micronutrients in the soil. The minor essential elements are stored in the soil organic matter as unavailable organic forms or as ions adsorbed by colloidal complexes and are biologically and chemically immobilized, respectively. While in these stable forms, the minor essential elements are not subjected to potential losses through volatilization or leaching movement (Legg 1975, Gibson 2009). The immobilized minor essential elements are made available through the ecosystem biogeochemical cycles performed by rhizosphere microorganisms (McGill and Cole 1981, Cheng and Johnson 1998, Manske 2012b, 2014c). The quantity of available minor essential elements is determined by the recycling rates of soil organic matter decomposition and mineralization that are directly regulated by the biomass of active rhizosphere microorganisms. Without the stimulation from the partial defoliation of grass lead tillers by the indispensable grazing graminivores none of the ecosystem biogeochemical processes and the internal grass plant mechanisms are activated and do not function.

Prescribed burning and mowing grass hay cannot activate the grass plant growth mechanisms or the ecosystem biogeochemical processes because these practices remove too much of the leaf area preventing adequate quantities of carbon energy to be fixed through leaf photosynthesis. Stored carbohydrates are not mobilized for complementary replacement growth following defoliation events (Richards and Caldwell 1985, Briske and Richards 1995).

Repeated prescribed burning can modify the composition of the aboveground vegetation in degraded grasslands which have been invaded by shrubs. The composition of introduced cool season grasses may change, and early succession and weedy forbs, and shrub aerial stems decrease temporarily after four repeated prescribed burns (Manske 2007a, 2011a). However, the fundamental problems of weak nutrient resource uptake, reduced water use efficiency, nonfunctional compensatory physiological mechanisms, impaired vegetative reproduction by tillering, and diminished ecosystem biogeochemcial processes will remain in the degraded grassland ecosystem following repeated burning events.

None of the biological, physiological, or asexual mechanisms within grass plants and none of the rhizosphere microbes or biogeochemcial processes they perform are activated by fire (Manske 2007a, 2011a). Almost all of the essential elements in the aboveground herbage are volatilized when a grassland is burned, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992). When the losses of essential elements are greater than the quantity of captured essential elements, the result is degradation of the grassland (McGill and Cole 1981). Fire does not improve grassland ecosystems biologically, or ecological and fire cannot replace the partial defoliation achieved by grazing graminivores in managing healthy and productive grassland ecosystems (Manske 2018a).

Proper Scientific Management of Grassland Ecosystems

Functionality of grassland ecosystems at full biological potential requires recycling adequate quantities of essential elements through the biogeochemical processes performed by the belowground soil microbes in order to replace removed aboveground leaf and stem biomass of grass plants through the primary physiological growth mechanisms, all of which must be activated annually by partial defoliation by grazing graminivores during vegetative growth stages of grass lead tillers.

Grasslands of the Northern Plains managed by traditional practices are low in available mineral nitrogen. This low nitrogen availability has long been known to be responsible for the reduced herbage productivity and below genetic potential calf weight gains per acre. However, intact grasslands have adequate nitrogen, usually at 5 to 6 tons of organic nitrogen per acre, which is not available to plants. Organic nitrogen must be mineralized by soil microorganisms in order for it to be available for plant use in the inorganic form. Unfortunately, traditional and gimmick grazing management practices do not elevate the soil microorganism biomass high enough to support mineralization of organic nitrogen at a level that can yield a supply at the threshold quantity of 100 lbs/ac or greater (Wight and Black 1972, 1979), which will permit the four primary grass plant growth mechanisms and all of the ecosystem biogeochemical processes to function at potential biological levels.

Intact grassland ecosystems that are low in available mineral nitrogen cannot be improved with some quick fix agronomic practice. The application of nitrogen fertilizer to grassland ecosystems does not solve the complex problems related to the cause of low soil mineral nitrogen (Manske 2014). It was found that nitrogen fertilization of native grasslands caused a synchronization of grass tiller growth stage development, resulting in a small increase in herbage biomass which later produced a high rate of leaf senescence and an early season decrease in forage nutritional quality compared to nonfertilized grasslands (Manske 2014). It also caused a short term shift in plant species composition, with an increase in mid cool season grass (e.g. western wheatgrass) and a decrease in short warm season grasses (e.g. blue grama) (Manske 2009a, 2014). Initially, these changes were considered by most observers to be beneficial (Manske 2009d). However, close examination of the data showed that the costs of the additional herbage weight were excessive (Manske 2009b), and that the long term disruptions of ecosystem biogeochemical processes were detrimental to desirable plant composition (Manske 2010). The reduction of short warm season grasses caused a decrease in total live plant basal cover, thus exposing greater amounts of soil to higher levels of solar radiation and erosion (Goetz et al. 1978). These large areas of open space became ideal invasion sites for undesirable plants, resulting in a long term plant species compositional shift towards a replacement community of domesticated and introduced mid cool season grasses (e.g. Kentucky bluegrass, Smooth bromegrass), and in the removal of nearly all the native plant species (Manske 2009c, 2010, 2018a).

Implementation of the strategy to interseed alfalfa into intact semiarid native grassland does not solve the complex problems related to the cause of low soil mineral nitrogen (Manske 2005). The introduction of alfalfa increased demand on the existing low levels of soil mineral nitrogen because almost all of the alfalfa plants' nitrogen requirements had to be taken from the soil. The interseeded alfalfa plants had extremely low levels of nodulation of rhizobium bacteria on the roots and, consequently, almost no nitrogen fixation. The inoculated rhizobium had been consumed by the resident soil microbes before the alfalfa seedlings had grown sufficient root material to permit infection (Manske 2004). The low amounts of mineral nitrogen available in the soil resulted in slower rates of growth and higher rates of mortality for the interseeded alfalfa plants than those for alfalfa plants solid seeded into cropland (Manske 2005). In addition, the high water use of the interseeded alfalfa plants depleted soil water levels within a 5 foot radius from each crown to an average of 35% below ambient soil water levels, causing drought stress conditions in the adjacent grass plants and, subsequently, further reducing grass herbage production (Manske 2004, 2005). Agronomic strategies implemented on grassland ecosystems slowly stifled grass internal growth mechanisms and ecosystem biogeochemical processes to ineffectiveness (Manske 2018a).

Grassland ecosystems should be managed with sound ecological principles. The ecological method to increase the quantity of available mineral nitrogen to 100 lbs/ac or greater in grassland ecosystems is to increase the biomass of the rhizosphere microorganisms. The rhizosphere is the narrow zone of soil bonded by extracellular adhesive polysaccharides around active roots of perennial grassland plants. The primary biologically active rhizosphere microbes are the endomycorrhizal fungi, ectomycorrhizal fungi, low carbon: high nitrogen bacteria, and normal carbon: nitrogen protozoa. The rhizosphere microbes do not possess chlorophyll nor do they have direct access to sunlight, as a consequence, these microbes are deficient of energy and require an outside source of simple carbon energy. Contrary to common assumptions, there isn't enough short chain carbon energy in recently dead grass material and there isn't enough energy from natural plant leakage to support a large active biomass of soil microbes. The only readily accessible source of large quantities of short chain carbon energy is the surplus fixed carbon energy photosynthesized by grass lead tillers at vegetative phenological growth stages. Grass plants fix a great deal more carbon energy than they use, furthermore, grass plants do not store the surplus fixed energy until during the winter hardening period, which starts in mid August and lasts to hard frost. Surplus carbon energy not programed for use, is broken down during night respiration. However, grass lead tillers at vegetative growth stages, between the three and a half new leaf stage and the flower (anthesis) stage, can be manipulated to exudate most of the surplus carbon energy into the rhizosphere through the roots following partial removal of 25% to 33% of the aboveground leaf biomass by grazing graminivores. This technique supplies sufficient quantities of short chain carbon energy into the rhizosphere initiating the production of large increases in microbe biomass and activity when 60% to 80% of the grass lead tiller population are partially defoliated by grazing graminivores over a period of 7 to 17 days on each pasture during the 45 day stimulation period from 1 June to 15 July.

Initiation of a twice-over strategy on native grassland that had previously been managed by nongrazing or traditional seasonlong practices will have a rhizosphere microbe biomass that is low to very low and it will require about three growing seasons to increase the microbe biomass large enough to mineralize 100 lbs/ac of mineral nitrogen. The response from the rhizosphere microbes is not instantaneous and rhizosphere weight changes respond differently to different management treatments (Manske 2018b).

Management of grassland ecosystems without large grazing graminivores is not sustainable. Fifty years of research have been devoted to the development of a biologically effective grazing management strategy that can improve and maintain grassland ecosystems at their potential biological levels.

The biologically effective twice-over rotation strategy was designed to coordinate partial defoliation events with grass phenological growth stages, to meet the nutrient requirements of the grazing graminivores, the biological requirements of the grass plants and the rhizosphere microorganisms, to enhance the ecosystem biogeochemical processes, and to activate the internal grass plant growth mechanisms in order for grassland ecosystems to function at the greatest achievable levels.

The twice-over rotation grazing management strategy uses three to six native grassland pastures. Each pasture is grazed for two periods per growing season. The number of grazing periods is determined by the number of sets of tillers: one set of lead tillers and one set of vegetative secondary tillers per growing season. The first grazing period is 45 days long, ideally, from 1 June to 15 July, with each pasture grazed for 7 to 17 days (never less or more). The number of days of the first grazing period on each pasture is the same percentage of 45 days as the percentage of the total season's grazeable forage contributed by each pasture to the complete system. The forage is measured as animal unit months (AUM's). The average grazing season month is 30.5 days long (Manske 2012a). The number of days grazed are not counted by calendar dates but by the number of 24-hr periods grazed from the date and time the livestock are turned out to pasture. The second grazing period is 90 days long, ideally from 15 July to 14 October, each pasture is grazed for twice the number of days as in the first period. The length of the total grazing period is best at 135 days; 45 days during the first period plus 90 days during the second period.

There is some flexibility in the grazing period dates. The starting date has a variance of plus or minus 3 days with a range of start dates from 29 May to 4 June. This gives an extreme early option to start on 29 May with the first period to 12 July and with the second period to 11 October. The extreme late alternative option can start on 4 June with the first period to 18 July and with the second period to 17 October. There is also the option to add a total of 2 days to the total length of the grazing period. These 2 days can be used when a scheduled rotation date occurs on an inconvenient date by adding one day to each of two rotation dates. The limit of additional days is two per year resulting in a total length of 137 days. If inconvenient rotation dates occur during 3 or more times, an equal number of days greater than two must be subtracted from the grazing season, so total number of days grazed per year does not exceed 137 days. If the start date is later than 4 June, the scheduled rotation dates must remain as if the start date were on 4 June, in order to maintain the coordinated match of the partial defoliation events with the grass phenological growth stages. The total number of days grazed will be 135 days minus the number of days from 4 June to the actual start date. However, it is best to start on 1 June each year.

During the first period, partial defoliation that removes 25% to 33% of the leaf biomass from grass lead tillers between the 3.5 new leaf stage and the flower stage increases the rhizosphere microbe biomass and activity, enhances the ecosystem biogeochemical processes, and activates the internal grass plant growth mechanisms. Manipulation of these processes and mechanisms does not occur at any other time during a growing season. During the second grazing period, the lead tillers are maturing and declining in nutritional quality and defoliation by grazing is only moderately beneficial to grass development. Adequate forage nutritional quality during the second period depends on the activation of sufficient quantities of vegetative secondary tillers from axillary buds during the first period. Livestock are removed from intact grassland pastures in mid October, towards the end of the perennial grass growing season, in order to allow the carryover tillers to store the carbohydrates and nutrients which will maintain plant mechanisms over the winter. Most of the upright vegetative tillers on grassland ecosystems during the autumn will be carryover tillers which will resume growth as lead tillers during the next growing season. Almost all grass tillers live for two growing seasons, the first season as vegetative secondary tillers and the second season as lead tillers. Grazing carryover tillers after mid October causes the termination of a large proportion of the population, resulting in greatly reduced herbage biomass production in subsequent growing seasons. The pasture grazed first in the rotation sequence is the last pasture grazed during the previous year. The last pasture grazed has the greatest live herbage weight on 1 June of the following season (Manske 2018a).

Stocking rates are based on peak herbage biomass on seasonlong grazing practices. The starting stocking rate on the “new” twice-over grazing practice is usually 80% to 100% of the seasonlong stocking rate (Manske 2012b). It usually requires three grazing seasons with the twice-over strategy stocked at 100% to increase the rhizosphere microbe biomass to be great enough to mineralize 100 lbs/ac of mineral nitrogen (nitrate NO_3 and ammonium NH_4). After the increased rhizosphere microbe biomass can mineralize 100 lbs/ac of mineral nitrogen, the stocking rate can be increased at 10% per year until the system is stocked at 140% of the seasonlong stocking rate. This has been the maximum biological potential reached on North American grasslands from the twice-over rotation strategy.

Once a rotation date scheduled has been determined, do not change that schedule greater than one day for any worldly reason. If you do not like your neighbors bull, build a fence that the bull cannot jump. If you have water sources that sometimes go dry, put in a water tank system on a pipeline. Fix the problems that develop with solutions that do not change the rotation schedule.

Implementation of the biologically effective twice-over rotation strategy will activate functionality of the four primary grass physiological growth mechanisms at much higher rates during the summer grazing period of 1 June to 14 October with the availability of 100 lbs/ac mineral nitrogen than the lower grass growth rates on traditional seasonlong practices with inadequate quantities of mineral nitrogen. On the twice-over rotation strategy, the greater than 100 lbs/ac mineral nitrogen result in higher functioning rates of the grass growth mechanisms causing cool season grass lead tiller biomass to be 25.5% greater during the July peak and causing a secondary vegetative tiller biomass to be 50.7% greater during the second peak in September, and causing warm season grass lead tiller biomass to be 29.9% greater during the peak in September and October, which causes total native grass herbage biomass to be 31.2% greater than those on the seasonlong treatment during the growing season. The increased grass biomass and improved nutrient content result in greater stocking rates, with calf weight gain per acre to be 23.0% greater, and cow weight gain per acre to be 46.9% greater than the productivity on traditional seasonlong grazing practices (Manske 2018c).

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Botanical Descriptions of the Pestiferous Weeds

The list of pestiferous weeds (table 1) consists of 13 forbs, 1 from the spurge family, 10 from the aster family, and 2 from the figwort family, 1 tree from the cypress family, 5 grasses from the poa family, and 1 lycopod from the spikemoss family. Eighteen of these pestiferous weeds were introduced into North America and became naturalized with no natural enemies. The one tree is native to eastern North America but not native to the Northern Plains and is effective at invading declining grasslands. And one is 350 million years old and not an effective invader but an effective survivor. None of these twenty pestiferous weeds have redeeming characteristics, they are all bad and good at it.

Leafy spurge

Leafy spurge, *Euphorbia esula* L., is a member of the spurge family, Euphorbiaceae. Leafy spurge in North America is a complex of variable genotypes as a result of multiple introductions from different parts of Europe and Asia. Leafy spurge is an introduced invasive noxious weed that is a long lived perennial forb. Annual aerial growth produces several clustered upright stems appearing during early to late April and growing to 16 to 32 inches (40-80 cm) tall from a stout subterranean woody crown (caudex). Stems are erect, simple, glabrous, pale blue-green, having a woody texture when mature. All parts of the plant emit milky, toxic sap (latex) when injured. Stem (cauline) leaves are alternate, linear to lanceolate, 1 to 4 inches (3-10 cm) long, 3-10 mm wide, widest above the middle, rounded at apex, smooth margins with one nerve and lateral veins. The tough, coarse, woody, vertical roots can descend to 15 to 18 feet (4.6-5.5 m) deep. Large horizontal roots occur in the top 2 feet (60 cm) of soil extend outward about 3.5 feet (1 m). Numerous fine white roots occupy a large volume of the top 2 feet (60 cm) of soil. The crown, vertical roots, and horizontal roots produce large quantities of pink buds that give rise to new stems. The large roots are also capable of accumulating large quantities of total nonstructural carbohydrates after the flowering period. The inflorescence at the top of the stem is a flat topped umbel with a cluster of showy, yellowish-green bracts that has later branching forming farther down the stem from leaf axils. The small true flowers (cyathia) develop between two heart shaped bracts and are greatly reduced, lacking both sepals and petals, with a central female flower surrounded by five groups of male flowers that develop around mid June when sticky pollen is produced. The nectar attracts numerous types of insects that cross pollinate the flowers. The oblong, gray to brown, smooth seeds 2-3 mm long, are borne in a three celled capsule, with each cell containing one seed, that mature about 30 days after pollination. At maturity the capsules are dehiscent, throwing the seeds up to 15 feet (5 m) from the stem. Each stem can produce about 140 seeds. Seeds may remain viable in the soil for five to eight years. Peak seed germination occurs during late May to early June. Seedlings do not flower during the first year. The seedling mortality is usually high with as much as 80% to 90%. Stand persistence and expansion depends primarily on vegetative reproduction from the crown buds and root buds.

Russian knapweed

Russian knapweed, *Rhaponticum repens* (L.) Hidalgo, is a member of the aster (sunflower) family, Asteraceae, syn.: Centaurea repens L., Acroptilon repens (L.) DC., and it is a long-lived, persistent, noxious perennial weed that can form dense monocultural colonies from vigorous spreading rhizomes. Annual aerial shoot growth emerges from perennial rhizomes during early spring after soil temperatures remain above freezing forming rosettes of pinnately lobed leaves 2-4 inches (5-10 cm) long and 0.3-1 inch (1-2.5 cm) wide. Floral stems originate from the rosettes and bolt in late May to mid June and are erect, thin, stiff, 18-36 inches (45-90 cm) tall with numerous corymbose spreading leafy branches. Young stems are canescent (covered with soft gray hairs). The rosettes wither and the hairs wear off as the stems mature. The alternate lower stem leaves are oblanceolate to oblong, irregularly pinnately lobed, 1-6 inches (3-15 cm) long and 0.3-1 inch (1-2.5 cm) wide. The sessile upper stem leaves are linear to narrowly lanceolate, toothed and become progressively smaller. The numerous flower heads are terminal on the leafy branches, urn-shaped, solitary, 15-17 mm high composed of 15 to 36 pink to lavender tubular disk florets occurring during June to September and turning straw colored at maturity. The florets are insect pollinated. The involucral bract phyllaries are greenish, rounded ovoid appearance with transparent tips. Achene 3-3.5 mm long, whitish to ivory, slightly ridged, attachment scar sub-basal and lateral at base of fruit. Pappus bristles are short and stiff. Each flower head produces 5 to 8 seeds, there is high ovule abortion rate, and about 100 to 300 seeds per plant. The flowers have no active mechanism of seed dispersal. The pappus are too small to facilitate wind dispersal. Seeds are viable for only two to three years. The numerous long lived perennial roots are dark brown to black. The taproot system has a large swollen root crown at the top and can descend to 20 feet (6 m) deep. The numerous rapidly expending lateral creeping rhizomes have small alternately arranged scale leaves with buds in their axils at about one inch intervals on the rhizomes. These buds can develop into adventitious leafy shoots enabling the stand to spread rapidly and form dense colonies. The extensive root system helps exclude other plants from the colony through strong competition for soil water and nutrients, and through the exudation of the phytotoxic, allelopathic chemicals, including polyacetylenes and cnicin. The leaves contain repin, acroptilin, and hyrcanin which are sesquiterpene lactones that contribute to the allelopathic activity of the roots to form dense monocultural colonies. The extensive root system is also capable of storing large amounts of soluble carbohydrates as energy reserves for winter survival and spring growth. Russian knapweed is avoided by grazing cattle and sheep because of its bitter taste, and is poisonous to horses causing a neurological disorder.

Spotted knapweed

Spotted knapweed, *Centaurea stoebe* L. spp. *micranthos* (Gugler) Hayek, is a member of the aster (sunflower) family, Asteraceae, syn.: *Centaurea maculosa* Lam., and it is an introduced short lived perennial, that is a rapidly spreading invasive, noxious weedy forb that can form dense monocultural colonies. Each spotted knapweed plant can produce numerous seeds that mature during late summer or early autumn, with some of the seeds spread close to the parent plant, and some seeds are dispersed long distances by animals, vehicles, farm machinery, running water, or as contamination in crop seeds or livestock hay. These seeds can become established in almost any type of disturbed open plant community. Seeds can germinate at any time the temperatures are above freezing and there is sufficient soil water or they can remain viable in the soil for 5 to 8 years. Most seeds germinate in early spring and out compete late developing native species. The seeds produce a low growing basal rosette on a short stalk with deeply lobed leaves up to 8 inches (20 cm) long, 2 inches (5 cm) wide, covered with fine short hairs. The rosettes must reach a threshold size before they can produce flower stems. Some rosettes live for three or more years before they are large enough to bolt. Most rosettes bolt at 2 years old. Each rosette also produces a stout root crown with a single large deep taproot that is perennial and can live for about 9 years. The diameter increases with age by producing annual rings that can be used to age the plant. Taproots greater than 7 years old usually have a high incidence of root rot. The root crown can produce a few extended lateral roots just below the soil surface that can form individual rosettes adjacent to the parent plant. The root crowns can form multiple rosettes, up to about 6 per year, when soil moisture conditions are favorable. One to six flower stems develop from a rosette during May through June and grow from 1 foot to 4 feet (30 to 122 cm) tall. Stem leaves are alternate and deeply lobed but smaller than the rosette basal leaves and decrease in size and progressively less lobed higher on the stem. The upper half of the stem produces numerous panicled long first degree axillary leafy branches, usually with one to a few shorter second degree axillary branches, and sometimes with one very short third degree axillary branch. Each branch has one terminal flower head at the tip with different ages, determined by the degree of branching, resulting in an extended flowering period from July to September. Flower heads are urn-shaped, ⅜ inch (10 mm) wide with 20 to 30 vibrant pink to lavender disc flowers that can produce one seed each. The involucral bract (phyllaries) are stiff with a black tip and black comb like fringes, that give this plant its common name. Spotted knapweeds are obligate xenogamous and must be cross pollinated by insects from flowers on separate plants. Seeds (achene) are ⅛ inch (3 mm) long, oval, brown to black, with pale longitudinal lines, and with persistent pappus of short uneven white bristles. Most seeds are shed at maturity. Each plant is capable of producing between 350 to 20,000 seeds per year. Plant population density fluctuates greatly from year to year depending on the quantity of spring and early summer precipitation.

The spotted knapweed that makes up almost the entire population in North America is *Centaurea stoebe* L. spp. *micranthes* and is tetraploid containing four sets of chromosomes, 4n=36. In Europe, there are two other genetic forms of spotted knapweed; *Centaurea stoebe* L. spp. s*toebe* and *Centaurea stoebe* L. spp. s*erbica* that are diploid containing two sets of chromosomes, 2n=18, which make up a very low proportion of the spotted knapweed population in North America. Diffuse knapweed is also diploid, 2n=18. Hybrids between diploid diffuse knapweed and diploid spotted knapweed have been identified in Europe and in North America. However, the diploid hybrids in North America did not occur here; they most likely crossed in Europe and were later introduced into North America as hybrids.

The tetraploid form is far more aggressively invasive than the diploid forms of spotted knapweed and has several traits that enhance its extreme competitive abilities. 1) It has high fecundity; it produces great quantities of multiple flowering stems, that produce high quantities of viable seeds that can remain viable in the soil a long time, the seeds can germinate throughout the growing season when favorable conditions exist, and it can produce a high amount of new plants. 2) It is adapted to a wide variety of different soil and vegetation types; it can live at a wide range of altitudes, it can withstand drier environments, and it can survive with dense competing vegetation. 3) It is highly competitive, it has a stout taproot that uptakes soil water and nutrients faster than neighboring grass root systems and it can form dense monocultural colonies. 4) It has low palatability; it has a bitter taste, and it has an absence of control by grazing animals. 5) It is believed to be allelopathic; it is capable of exuding biochemicals into the soil that have antimicrobial and plant growth inhibiting properties.

Diffuse knapweed

Diffuse knapweed, *Centaurea diffusa* Lam., is a member of the aster (sunflower) family, Asteraceae, and it is an introduced short lived perennial, that is a rapidly spreading invasive, noxious, weedy, forb that can form dense monocultural colonies. Each diffuse knapweed plant can produce numerous seeds that mature usually during late August with the seeds spread as a tumbleweed. The seeds can become established in most types of disturbed area except in dense shade or on poorly drained soils. Seeds can germinate during the fall or early spring. However, if the temperatures are below freezing and soils are dry, the seeds can remain viable for several years. The seeds produce a low growing basal rosette on a short stalk, the leaves are deeply divided into lobes on both sides of the midrib and are up to 8 inches (20 cm) long, 2 inches (5 cm) wide, covered with fine short hairs. A deep taproot forms below the rosette. The plants can live for several years as a rosette. A single flower stem, rarely 2 stems, bolt from a rosette in early May. Flower stems are erect, 1 to 3 feet (30-91 cm) tall. Stem leaves are alternate and sessile, lower leaves are larger and lobed, upper leaves are smaller and entire. Numerous long spreading axillary branches give the plant a ball-shape. Shorter second and third degree axillary branches form a little later. Each branch forms a flower bud that develops into a terminal flower head that is urn-shaped 3/16 to ¼ inch (5-6 mm) in diameter with 10 to 15 white disc flowers, occasionally rose to lavender. The flowers on the first, second, and third degree axillary branch are different ages, extending the flower period from July to September. Each flower can produce one seed. The involucral bracts (phyllaries) are pale yellowish green with a marginal fringe of buff to brown spines that have one large spreading spine ⅛ inch (3 mm) long at the tip that gets stiff at maturity. Diffuse knapweed is cross pollinated by insects. Seeds (achene) are about ⅛ inch (3 mm) long, buff to dark brown with pappus generally absent. After the flower stalks mature, they become senescent at the end of the growing season and dryout. At the base of the stem, just above the root crown, an abscission zone forms, within which cell layers break down and the entire old flower stem can become separated from the root crown forming a ball shaped tumbleweed. The urn shaped flower heads do not open widely but form a small opening from which the seeds fall out gradually along the long traveled wind driven route.

Vegetative sprouts can form on the root crown. However, most diffuse knapweed plants die after producing one flower stem. While the plant is living, it has several traits that enhance its competitive abilities. 1) It produces a high number of seeds each year and rapidly invades disturbed areas. 2) It has the ability to exist and maintain greater life processes during drought conditions than the native species. 3) It has superior resource competition, by starting growth earlier than the native species, it can uptake greater soil water and nutrients. 4) In North America, it is absent of natural enemies and it is absent of control by grazing animals. 5) Whether or not it has allelopathic chemicals, it greatly reduces the quantity of native species and is successful at establishment of monocultures.

Yellow starthistle

Yellow starthistle, *Centaurea solstitialis* L., is a member of the aster (sunflower) family, Asteraceae, and it is an introduced long lived winter annual, that is a rapidly spreading invasive, weedy forb that can form dense colonies that depletes soil moisture. Each seedhead can produce two types of seeds (achenes). The central flowers produce glossy, gray or tan to mottled cream seeds with short stiff, unequal, white pappus that are usually dispersed within 2 feet (60 cm) of the parent plant soon after flowers senesce and drop their petals with most of these seeds germinating during the fall if adequate soil moisture available. The periphery flowers produce dull dark brown, often specked with tan seeds that have no pappus, are retained in the seedhead extending into the winter, and remain dormant in the soil for two to three years. The seedlings that germinate during the fall have cold tolerance hardiness and produce a basal rosette with deeply lobed leaves eight inches (20 cm) long and 2 inches (5 cm) wide that has a vigorous deep, to 6 feet (183 cm) depth, taproot that has short secondary branches. These seedlings have high mortality rate because of competition for light and soil moisture. Yellow starthistle need large disturbed areas with well drained silt loam to loam soils with high levels of magnesium. Plants do not tolerate shade, are intolerant of flooding, are insensitive to photoperiod, and mature plants are not frost tolerant. The over wintering rosettes resume activity very early using more water at a greater soil depth than the later growing desirable native vegetation inhibiting their growth and development.

The rosettes bolt during late May to early June. The stems are stiff, gray to blue-green, about 3 feet (90 cm) tall, with spreading branches from the base forming a rounded bushy plant. Stem leaves are alternate, linear or narrowly oblong to oblanceolate, lower leaves are deeply pinnate-lobed, with leaf bases extending down the stems (decurrent) forming 3 mm wide wings that are photosynthetic. Stems and leaves densely covered with fine white cottony hair (tomentose) that hide thick stiff hairs and glands. Buds form at the ends of branches (terminal), develop into urn-shaped flower heads (capitula) about 12-16 mm across with 50-100 yellow disc florets that are insect pollinator-dependent for outcross breeding and are mostly self-incompatible. They flower during early to mid July to September. The involucre bracts (phyllaries) are palmately spined, with one long central spine 10-25 mm long, stout, yellowish to straw colored with 2 or more pairs of shorter lateral spines.

Flowerheads produce dimorphic achenes (cypselae) with about 55% to 90% with pappus and the rest without pappus. Plants senesce during late summer or fall, shedding the long central spines and the papposed seeds, but retaining the plumeless seeds well into the winter. The stems dry to silver-gray skeletons with cottony-white seedheads, slowly degrading and remain erect for a year. Yellow starthistle is an annual semelparous species that reproduce once in a lifetime, however, if the stems are cut off before full flower, new stems can sprout from the root crown or any leaf axils below the cut line. Living plants have several traits that enhance its competitive abilities. 1) It has massive seed production with high levels of genetic variation. 2) It has extended reproductive periods with nonspecialized pollinators, but is facultatively xenogamous and must be pollinated from flowers of separate plants (self-incompatible). 3) It is highly competitive at capturing resources, it starts growth earlier than the native species, it has early rapid growth of a deep taproot using greater quantities of water than its neighbors, and it can tolerate drought conditions. 4) In North America, it is absent of natural enemies and it produces long stout spines that can cause mechanical injury and discourage grazing except by goats. 5) Its rapid colonization of large disturbed areas eliminates other plant species from growing and it successfully establishes monocultures.

Canada thistle

Canada thistle, *Cirsium arvense* (L) Scop., is a member of the aster (sunflower) family, Asteraceae, syn.: *Carduus arvensis* (L.) Robson, and it is an introduced, long-lived perennial, aggressive, invasive, noxious, weedy forb, that is variable with many forms, polymorphic, and develops dense colonies. Annual aerial growth has a single erect hollow stem arising from a crown (caudex) root bud, or winter rosette. Requires 14 to 16 hour photoperiod, mid April to mid August, for shoot elongation and flower production. Stem grows to 3 feet (90 cm) tall and has numerous branches that form on the upper portion. Stem (cauline) leaves are alternate, shallowly or pinnately lobed, bases sessile clasping to decurrent, extending down along stem for 10-20 mm, wary, oblong to oblanceolate, to 7 inches (18 cm) long and 2 inches (5 cm) wide, progressively reduced upward, margins bearing short fine spines to strong spines, 5 mm long. Leaves green, upper surface glabrous or lightly arachrose-floccose (cobwebby to long tangled hairs), lower surface densely white tomentose (short, matted, soft, wooly hairs). Extensive underground root system, slender taproot at 3 to 10 feet (9-30 dm) deep with most roots in top 2 feet (6 dm). Numerous lateral root stock spreading horizontally from taproot out to 12 to 15 feet (36-46 dm) with root buds arising every 2 to 6 inches (5-15 cm) along lateral rootstock. Root buds develop shoots forming rosettes during fall when soil temperature still warm, air temperature cool, and photoperiod shorter to 13 hours. Carbohydrate reserves stored in roots reaching 26% wet weight. Flowerhead is urn-shaped capitula form at the ends of branches (terminal), ½ inch (1-1.5 cm) wide, involucral bracts (phyllaries) not spined, ovate, 2-6 mm long gradually pointed. Flowers occur during June to September are imperfectly dioecious with male and female flowers occurring on separate plants, with pink to purple or light lavender disk florets. Flowers must be cross pollinated by insects, with the separate plants close enough to each other so insects can visit each. One shoot can produce 32 to 69 flowerheads in a compound corymbiform inflorescence. Seeds are achenes, oblong 2.5-5 mm long, 1-1.5 mm wide, tan to light brown or brown, smooth, tapered with pappus of white to tan feathery bristles loosely attached at seed tip that enables wind dispersal with good aerodynamic efficiency to travel long distances, however, most seeds remain in the head until winter and germinate nearby in spring, seeds remain viable in the soil for less than 5 years. Seeds are most successful in open sunny, moist, disturbed areas, they are intolerant of shade, and sensitive to competition with water stress. Possibly Canada thistle has allelopathic effects and produce phytotoxins that inhibit growth of other plants.

Bull thistle

Bull thistle, *Cirsium vulgare* (Savi) Ten., is a member of the aster (sunflower) family, Asteraceae, syn.: *Cirsium lanceolatum* (L.) Hill, and it is an introduced, biennial or short lived perennial, invasive, troublesome, weedy forb. Seedlings form a single rosette up to 3.3 feet (1 m) in diameter, rosette leaves deeply pinnatifid, clefted halfway to midrib with 4 to 8 pairs of lobes each tipped with stout, needle-like spines, leaves lanceolate, hairy above and very pubescent below giving a cottony appearance. Taproot short fleshy to 28 inches (70 cm) deep with several small lateral roots. Stems are erect to 3 to 4 feet (0.9 to 1.2 m) tall, hairy and spiny along entire length, with many spreading branches. Stem (cauline) leaves are alternate, deeply lobed each extended with yellow spine and terminal long spine from midrib, leaf base extending down the stems (decurrent) forming long photosynthetic wing, upper surface with coarse tangled hairs and lower surface with short wooly hairs. Flower head 1.5 to 2 inches (3.8 to 5 cm) in diameter, 1 to 2 inches (2.5 to 5 cm) tall, solitary at terminal ends of branches. Florets bisexual from pink to deep purple in color, fragrant with abundant nectar to attract insect pollinators. Receptacles with rows of bracts tipped with yellow spines. Achenes are ⅛ inch (3 mm) long (1.5 mm) wide and are yellow, streaked with black and have white feathered pappus 1.9 cm long for wind dispersal, that have a short-lived viability of about 3 years. Bull thistle plants produce phenolic acids that have allelopathic effects against nearby plants.

Musk thistle

Musk thistle, *Carduus nutans L.*, is a member of the aster (sunflower) family, Asteraceae, is a polymorphic complex that is an introduced, biennial, invasive, noxious, weedy forb that can form dense stands. Seedling germinate during fall or spring and form a rosette, with basal leaves up to 20 inches (51 cm) long, 6 inches (15 cm) wide. Leaves are dark green, hairless, waxy and have characteristic white margins, with coarse lobes and spines along margins at lobe tips. A large, fleshy, corky, taproot that is hollow near the crown develops with the rosette. Root crown and upper root tissue contains buds. Most remain in rosette during first year. Flower shoot bolts during second year, grows to 2 to 6 feet (61 cm to 1.8 m) tall, stout and highly branched. Stem (cauline) leaves are alternate, and spiniferously lobed, with leaf base extending down the stems (decurrent) forming long photosynthetic wings that are spiny. Shoots are covered with spines. Flower heads up to 3 inches (7.5 cm) in diameter, solitary at terminal ends of branches which can bend or nod about 90 degrees to the shoot. Florets are bright purple. Achene are 0.3 to 0.5 cm long with hair-like pappus.

Plumeless thistle

Plumeless thistle, *Carduus acanthoides* L., is a member of the aster (sunflower) family, Asteraceae, and it is an introduced winter annual or biennial, invasive, troublesome, weedy forb, and under moist conditions can form dense colonies. Autumn seedlings form rosettes during early spring, basal leaves are 8 inches (20 cm) long, 2 inches (5 cm) wide, with silver white or purplish margins, pinnately (opposite) deep lobes with multiple sharp yellow spines, upper surface sparse hairs and lower surface dense long hairs. Root system with one stout, fleshy taproot that is hollow near crown. Plants bolt in spring or early summer, stems erect and highly branched, 3 to 4 feet (0.9 to 1.2 m) tall. Stem (cauline) leaves alternate, sessile, clasping, decurrent forming long spinous wings, deeply lobed with marginal pointed spines 1 to 4 mm long. Flower heads up to 1 inch (2.5 cm) in diameter, solitary at branch ends. Florets bisexual, from pink to purple in color. Receptacle bracts with sharp spines. Achenes small 1.5 mm long, yellow to brown, slightly curved with distinct light collar near top, pappus of small white bristles.

Scotch thistle

Scotch thistle, *Onopordum acanthium* L., is a member of the aster (sunflower) family, Asteraceae, and it is an introduced biennial, invasive, aggressive, weedy forb that can produce impenetrable thorny barriers. Seeds can germinate during fall or spring, seedling forms a rosette that can grow to 3 feet (0.9 m) in diameter, basal leaves can be up to 2 feet (61 cm) long, 1 foot (30 cm) wide. Root system is one large, fleshy taproot. Plant bolts in early summer, stems are robust, having numerous branches covered in woolly hair and have spiny wings extending entire length, can grow up to 7 or 8 feet (2.1 to 2.4 m) tall and 4 feet (1.2 m) wide. Stem (cauline) leaves are alternate, sessile, decurrent forming long wings, blades 2 to 12 inches (0.5 to 3 dm) long, 2 to 8 inches (0.5 to 2 dm) wide, with triangular lobes that have 5-15 mm long sharp yellow spines and upper and lower surfaces covered with thick mat of woolly hairs. Flower heads large up to 2 inches (5 cm) in diameter, solitary at branch ends. Florets bisexual, pink or purple. Receptacle has rows of long, needlelike bracts tipped with orange spines. Achenes over 5 mm long, gray with dark mottling, with pappus of long brown bristles that have short stiff barbs.

Absinth wormwood

Absinth wormwood, *Artemisia absinthium* L., is a member of the aster (sunflower) family, Asteraceae, and is an introduced noxious perennial weedy subshrub, that is fragrant with a strong sage odor. Annual aerial growth has 20 or more erect or ascending stems 0.9 to 1.5 m (3 to 5 feet) tall arising from a subterranean woody crown (caudex) that can have few short rhizomes. Root system is well developed with deep taproot about 5 cm (2 inches) in diameter and numerous shallow lateral branches extending radially to 1.8 m (6 feet). Stem (cauline) leaves about 5 to 8 cm (2 to 3 inches) long, deeply pinnately divided 2 or 3 times into lobed leaflets with long, soft, silky hairs and on long petioles. Upper leaves reduced on short petioles. Inflorescence an open, widely spreading panicle appearing from each upper leaf node, with numerous flower heads 3 mm (0.125 inches) in diameter with yellow florets during late July to mid August. Fruit is a small cypsela without pappus, less than 2 mm long, flat cylindrical, light gray-brown, scattered by wind, water, and animals, viable for 3 to 4 years.

Dalmation toadflax

Dalmation toadflax, *Linaria dalmatica* (L.) Mill., is a member of the figwort family, Scrophulariaceae, syn.: Linaria genistifolia L. and is an introduced, invasive, noxious, short-lived (3 to 5 years) perennial forb. Annual aerial growth is clumps of up to 25 stiff, vertical, leafy stems 0.8 to 1.5 m (2 to 5 ft) tall with thick fibrous to woody base and the upper portion frequently branched. Stem (cauline) leaves alternate 2 to 5 cm (1-2 in) long, lower leaves heart shaped and clasping the stem, upper leaves smaller and ovate to lanceolate shaped, bluish-green. Inflorescence is a raceme arising from axils of upper stem leaves with numerous pedicelled flowers that are bright yellow, two lipped, snapdragon like blossom with an orange throat and a long spur. Flowers are self-incompatible and must be cross pollinated with pollen from another plant by bumblebees or large bees. Fruit is an upright egg shaped seed capsules 0.4 to 1.0 cm (0.2 to 0.4 in) long, 0.4 to 0.9 cm (0.2 to 0.3 in) wide that contains 60 to 300 seeds. Seeds are sharply triangular, slightly winged about 0.1 cm (0.4 in) long, dispersed by the wind. Extensive root system has a deep taproot that extends down 1.3 to 3 m (4 to 10 ft) in depth and with lateral roots that extend 3.6 m (12 ft) from caudex. Numerous vegetative buds on lateral roots in upper 5 to 30 cm (2 to 12 in) of soil.

Yellow toadflax

Yellow toadflax, *Linaria vulgaris* (L). Mill., is a member of the figwort family, Scrophulariaceae, and is an introduced, aggressive, noxious, short-lived (at least 4 years) perennial forb. Annual aerial growth is clumps of up to 20 stems per crown usually 30-90 cm (12 to 36 in) tall, sparsely branched with reddish woody base and slender, succulent, green upper portion. Stem (cauline) leaves are alternate 2.5 to 5 cm (1 to 2 in) long, linear, pointed tip and narrow base tapering to petiole, pale green with silvery tinge. Inflorescence is a congested raceme arising from bases of upper stem leaves with numerous (6 to 30) pedicelled flowers, pale yellow, two-lipped, snapdragon like blossoms 2 to 4 cm (0.8 to 1.6 in) long with bright orange bearded throat and a long spur. Flowers are self-incompatible and must be cross pollinated with pollen from another plant mostly by bumblebees. Fruit is an upright, oval, two-celled seed capsule yielding up to 47 seeds. Seeds are small, lightweight, winged discs. Capsules dry and crack open releasing the seeds that usually fall within 1.5 m (5 ft) of parent plant. Extensive root system has a taproot that extends 1 m (3.3 ft) deep and with lateral roots that extend several meters long. Roots with vegetative buds are 2 to 5 cm (0.8 to 2 in) below soil surface.

Eastern redcedar

Eastern redcedar, *Juniperus virginiana* L., is a member of the cypress family, Cupressaceae, and is native to the eastern portion of the United States and Canada, long lived perennial (greater than 450 years), evergreen, gymnosperm, medium sized dioecious tree to 30 m (100 ft) tall with narrowly conical form with branches that grow up and out at a sharp angle or with a broadly conical form with branches that spread widely. Bark is thin, 0.75 to 1.6 cm (0.3 to 0.64 in) thick, reddish-brown to grayish, fibrous and shedding. Branches are usually reddish-brown. Leaves are opposite, simple, green or blue-green, closely pressed or flat overlapping the leaf above, on mature branches scale-like 0.2 to 0.3 cm (1/16 to ⅛ in) long or on new twigs needlelike, pointed and awl-shaped 0.6 to 1.2 cm (¼ to ½ in) long. Root system is generally fibrous and shallow. Young plants have deep taproots that penetrate 7.6 m (25 ft) that are replaced later by an extensive shallow lateral system that extends 6 m (20 ft) out from the trunk as trees mature. Male and female cones are on separate trees (dioecious). The staminate (male) cones are yellowish-brown, papery, solitary at the tips of branchlets, ovoid to ellipsoid, and 0.2 to 0.4 cm (1/16 to ⅛ in) long. The ovulate (female) cones are solitary at the tips of branchlets, dark blue or bluish-purple, waxy, and berry like, 0.4 to 0.7 cm (3/16 to ¼ in) long. Pollen is wind dispersed. The female cones ripen from

September through October. There are 1 to 3 seeds per cone. Seeds are yellow-brown and round, 2 to 4 mm in diameter, ridged near the base, and sometimes shallowly pitted. These trees have no natural asexual regeneration mechanisms. Trees reach sexual maturity at around 10 years. Seeds are dispersed by birds and small mammals. Seeds that past through animal digestive tracts germinate earlier. Seedlings are shade intolerant. Growth of young trees is relatively slow, until the age of 15 to 20 years when growth rates increase. Trees are most productive between the ages of 25 to 75 years. Eastern redcedar is a well known invader of the prairie region, but does not survive on sites subject to periodic fire, because it has thin bark, shallow roots, inability to sprout, and highly combustible evergreen foliage.

Downy brome (Cheatgrass)

Downy brome (cheatgrass), *Bromus tectorum* L., is a member of the grass family, Poaceae, and is an introduced, undesirable, winter annual, occasionally a spring annual. Seedlings growth consists of bright green hairy basal leaves 4 to 16 cm (2 to 6 in) long, 2 to 4 mm (0.08 to 0.16 in) wide, followed by development of 2 to 20 tillers. A finely divided, fibrous root system develops early with 7 main roots that grow rapidly, spreading laterally and vertically, initially remaining in top 18 to 20 cm (7 to 8 in), with some later roots penetrating to 87 to 150 cm (34 to 60 in) deep, plus several far reaching lateral roots. Cheatgrass has adaptations that facilitate early and rapid growth with a type of carbohydrate metabolism that permits growth at low temperatures ahead of native plants and causing depletion of soil moisture before native plants break dormancy. Cheatgrass has high water-use efficiency enabling dry matter production at high rates of growth. Inflorescence is a panicle 5 to 20 cm (2 to 8 in) tall, open, compact, and drooping with up to 8 spikelet, 2 to 4 cm (1 to 2 in) long with awns, and 2 to 8 florets per spikelet. Flowers are perfect with male and female parts, usually self fertilized (cleistogamous) but occasionally pollination is by flowers from other plants (xenogamous), and are prolific seed producers. Fruits are caryopses. Each plant can produce 25 to 400 seeds, and under ideal conditions producing 5,000 seeds per robust solitary plant is possible. The quantity of seeds produced can maintain high levels of plant density. Mature plants change color from green to purple to brown, then tan as the plant dries. Cheatgrass stands are susceptible to frequent fires because of the high densities of plants that dry down very early in the summer. Usually sufficient quantities of viable seed survive to reestablish a cheatgrass population.

Japanese brome

Japanese brome, *Bromus japonicus* Thunb., is a member of the grass family, Poaceae, and is an introduced, undesirable, winter annual, occasionally a spring annual. Most seeds are retained on the parent plant until late fall or winter then undergo dormancy, then they need a period of after ripening during the following summer, then these seeds from the previous year's crop can germinate during the fall and produce a vegetative rosette growth form, go into winter dormancy, and produce vigorous vegetative growth during their second spring. Leaf blades can be smooth and hairless (glabrous) or usually with long soft, straight hairs (pilose), 2 to 20 cm (1 to 8 in) long, 1 to 4.5 mm wide, sheaths densely long-pilose, ligules 0.5-2 mm long, auricles absent. The fibrous roots are shallow between 80 and 150 cm (2.7 to 4.7 ft) deep and very dense nearly filling the soil. Plants resume growth very early using available soil moisture before other plants break dormancy. Inflorescence is an open panicle 6 to 17 cm (2 to 6.7 in) long with spreading, flexuous branches for spikelets with 6 to 10 florets that flower during late spring, pollination is self-fertilization (autogamous). Fruit is a caryopses and they are prodigious seed producers. Seeds remain viable for at least several years. Plants die during late June to early July. Fire tends to reduce populations and some seeds killed by fire, usually sufficient seed bank reserves survive to repopulate the area within 2 growing seasons.

Kentucky bluegrass

Kentucky bluegrass, *Poa pratensis* L., is a member of the grass family, Poaceae, tribe, Poeae, and is a naturalized (introduced from Europe by early colonists but more probably around the early 1000's), long lived perennial, monocot, cool-season, mid grass, that is intolerant of drought, intolerant of waterlogged soil, intolerant of dense shade but tolerant of slight partial shade, and is a high water user and a high nitrogen user. The first North Dakota record is Bergman 1910. Early aerial growth consists of basal leaves arising from rhizome tiller buds. Basal leaf blades are generally short 1-15 cm (0.4-6.0 in) long, 0.9-3.6 mm wide, keeled, with tip boat prow shaped. The split sheath has thin, translucent margins that overlap for the lower ½. The collar is narrow and continuous. The membranous ligule is 0.51 mm long, continuous with sheath margins, and has a squared off edge. The auricles are absent. The dense rhizome system forms thick mats. The long creeping rhizomes frequently branch producing several tillers at each node at progressive intervals. The dense shallow root system has very fine branching roots arising from stem crowns and rhizome nodes thickly occupying the top 46 to 61 cm (1.5-2.0 ft) of soil with a few long main roots reaching 91 cm (3.0 ft) deep. Most of the roots and rhizomes are in the top 7.6 cm (3 in) of soil that dries out easily. Regeneration is primarily asexual propagation by crown and rhizome tiller buds. Seedlings are somewhat successful where competition from established plants is nonexistent because viable seed production is frequently high. Flower stalks are erect, slender, wiry, 30-60 cm (12-24 in) tall and round in cross section. Inflorescence is a moderately open, somewhat contracted pyramidal panicle, 5-10 cm (2-4 in) long, with 3-5 branches in whorls at each node. Spikelets are laterally compressed with 3 to 6 florets. Flower period is from mid May to late June. Aerial parts are nutritious only before flowering. Forage biomass production is lower than for native grasses because of the high water use and long summer dormancy period. Fire top kills aerial parts and can consume entire crown when soil is dry with a temperature great enough to kill some of the shallow rhizomes and roots. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density.

Canada bluegrass

Canada bluegrass, (Flatstem bluegrass) *Poa compressa* L., is a member of the grass family, Poaceae,tribe, Poeae, and is a naturalized (introduced from Europe into Canada during the late 1700's), long lived perennial, monocot, cool-season, mid grass, that is moderately tolerant of drought and saline soils, and shade intolerant. The first North Dakota record is Zaczkowski 1970. Early aerial growth consists of basal leaves arising from rhizome tiller buds. Basal leaf blades are short 2-10 cm (0.8-4 in) long, 1.2-3.2 mm wide, bluegreen, with tip boat prow shaped. The split sheath is compressed and strongly flattened and has thin, translucent margins that overlap near base. The collar is yellow, narrow and divided. The membrane ligule is continuous with sheath margins and has 1 mm long ends rising to an acute center at 3 mm long. The auricles are absent. The rhizome system has frequent branching with solitary or usually several tillers produced at each node at progressive intervals. The fibrous root system has fine branching main roots arising from stem crowns and rhizome nodes that extend deep into the soil. Regeneration is primarily asexual propagation by crown and rhizome tiller buds. Seedlings are only successful where competition from established plants is nonexistent. Flower stalks are erect, wiry, hollow, 20-40 cm (8-16 in) tall, and strongly flattened to be 2-edged. Inflorescence is a narrow, compact, oblong panicle, 3-8.5 cm (1.2-3.3 in) long, that opens during flowering and becomes contracted after flowering. Two or a few short branches arise at each node with a few small spikelets, 3-5.5 mm long, that have 2-6 florets each. Flower period is from early to late June, starting about two weeks after Kentucky bluegrass. Aerial parts are highly palatable to livestock. Fire top kills aerial parts and can consume entire crown when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reductions in biomass production and tiller density.

Bulbous bluegras

Bulbous bluegrass, *Poa bulbosa* L., is a member of the grass family, Poaceae, and is an introduced problematic, weed that is easily transported long distances in contaminated seed, feed grain, or hay. It is the only grass that produces bulbs. These basal bulbs are pear shaped, 1 cm long, consisting of a thick, solid node and internode surrounded by layers of scale like leaves, forming tightly packed dense clumps at soil level. Aerial growth of basal leaves and stems starts very early spring arising from the basal bulbs. Basal leaves are flat or rolled in (involute) 5 to 15 cm (2 to 6 in) long, 1 to 3 mm wide, hairless (glabrous), with boat shaped tip. Stems are erect, hollow, smooth, 15 to 60 cm (6 to 24 in) tall. Inflorescence is a contracted panicle, 2-8 cm long, with several single spikelets at tip of short branchlets, each with 2 to 7 florets. Most florets are asexually transformed bulbils, 5 to 15 mm long that contain all the tissue structures to propagate a new plant, sometimes with the lowest 1 or 2 florets normal and fertile but rarely produce a seed. The root system is fairly limited, each basal bulb has 5 to 20 thin roots 1 to 10 cm (0.4 to 4 in) long with numerous, short about 1 mm long, thread like rootlets. At about the time the bulbils are mature, the bases turn purplish and are ready to be shed individually, the plant goes into a period of summary dormancy that is triggered by increasing photoperiod. All the aboveground leaves and stems shrivel and detach from the basal bulbs, and all the roots senesce, thus avoiding dry and drought conditions. The plants do not reappear until early in the following growing season. In higher rainfall areas, like Ohio and Illinois, this plant has a totally different growth form, all of the florets are normal and perfect that can produce viable seeds, with none of the florets producing asexual bulbils. Of course, the taxonomists have separated the two types of growth form into subspecies. The growth form with asexual bulbils if spp. vivipara and the rare growth form with normal florets is spp. bulbosa.

Lesser spikemoss (Clubmoss)

Lesser spikemoss (Clubmoss), *Selaginella densa* Rydb., is a member of the spikemoss family, Selaginellaceae, and is an ancient primitive diminutive nonflowering perennial evergreen forb that originated more than 350 million years ago and has survived three major mass extinction events. It was among the first land plants to successfully develop basic vascular tissue and absorbing true roots. It has several prostate creeping stems that are 2 to 6 in (5 to 15 cm) long, with numerous erect branches, densely packed, that are seldom more than 1 in (2.5 cm) in height, forming thick cushion like mats. The branches are completely covered with tiny lance shaped leaves (microphylls) 1.7 to 2.5 mm long, 0.2 to 0.3 mm wide in ranks of four pressed close to the branch. The lower leaves are a little longer than the upper leaves, which have minute whiteish setae (bristles) that change color with age and form conspicuous tufts at the branch tips. Roots are very fine about 0.008 in (0.2 mm) in diameter, are minutely branched and have small root hairs and a root cap. They do not extend deeper than 0.78 to 2.0 in (2 to 5 cm) below the soil surface. All the roots are adventitious arising at intervals along the horizontal stems and from special short stem branches called rhizophores. The extensive tangle of roots may comprise a high percentage of the plants total dry matter weight. As a result of the extremely shallow root system, growth is limited to periods of the year when moisture is available at shallow depths. Vegetative growth and rate of spreading is slow.

The stems contain no pith. The very simple primary vascular tissue of xylem and phloem collectively are called the stele that is separated from the cortex in a cylindrical cavity arranged in many platelike zones that are suspended by trabeculae (modified elongate endodermal cells) that have Casparian strips on their lateral wall. The Casparian strips secrete salts into the vascular tissue that helps develop a lower hydrostatic pressure in the plant. The stele structure, in cross section, forms a plectostele type vascular system that is continuous with the roots. A single unbranched vein develops from the central stele for each microleaf and has no leaf gap. The plant tissue is comprised of 16.5% silica, which has no nutritional qualities and would be a great deterrent for any animals to eat it. These high quantities of silica must be used to compensate for the low turgor pressure produced by its primitive vascular tissue.

This primitive plant does not produce flowers or seeds during its reproductive processes, it is sporiferous and produces spores. It is heterosporous and produces two different sizes of spores. The megaspores are the female gametes and the microspores are the male gametes. A four-angled strobili that is 1 to 3.5 cm long, is a conelike cluster of sporophylls (leaflike structures of the strobili) that form at the tip of a branch. The megasporangia are the structures that produce the female megaspores and are attached to the axis of the branch towards the lower portions of the strobili. A megasporophyll is a leaflike structure to protect the megasporangia from the outside. A ligule, that is a small flap of tissue, is located between the base of the sporangium and the base of the sporophyll. The microsporangia are the structures that produce the male microspores and are attached to the axis of the branch towards the upper portions of the strobili. A microsporophyll is a leaflike structure to protect the microsporangia from the outside. A ligule, that is a small flap of tissue, is located between the base of the sporangium and the base of the sporophyll. At maturity, the microspores produce microscopic flagellated male sperm cells that are released when there is available water to swim to the female egg cells. Tissue surrounding the fertilized egg can photosynthesize carbohydrates for the developing embryo. A young sporeling consists of a root, a stem, and two young leaves or cotyledons. When there is available water, the developed sporelings are released to fall to the ground. If conditions are perfect, the sporelings are successful.

Table 1. Pestiferous Weeds of the Northern Plains Grasslands.

Leafy spurge, Euphorbia esula L., spurge family
Russian knapweed, Rhaponticum repens (L). Hidalge, aster family
Spotted knapweed, Centaurea stoebe L., aster family
Diffuse knapweed, Centaurea diffusa Lam., aster family
Yellow starthistle, Centaurea solstitialis L., aster family
Canada thistle, Cirsium arvense (L.) Scop., aster family
Bull thistle, Cirsium vulgare (Savi) Ten., aster family
Musk thistle, Carduus nutans L., aster family
Plumeless thistle, Carduus acanthoides L., aster family
Scotch thistle, Onopordum acanthium L., aster family
Absinth wormwood, Artemisia absinthium L., aster family
Dalmation toadflax, Linaria dalmatica (L.) Mill., figwort family
Yellow toadflax, Linaria vulgaris (L.) Mill. figwort family
Eastern redcedar, Juniperus virginiana L. cypress family
Downy brome (cheatgrass), Bromus tectorum L., grass family
Japanese brome, Bromus japonicus Thunb., grass family
Kentucky bluegrass, Poa pratensis L., grass family
Canada bluegrass, Poa compressa L., grass family
Bulbous bluegrass, Poa bulbosa L., grass family
Lesser spikemoss (clubmoss), Selaginella densa Rydb., spikemoss family

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Pestiferous Weed Management Practices

Integrated Pest Management

The Integrated Pest Management (IPM) concept suggested that the use of more than one management practice will be more effective when the timing of the management practices are coordinated to be synergistic rather than antagonistic. The integrated treatments include the initial control practice, mechanical mowing, prescribed burning, chemical management, biological control, prescribed targeted grazing, and implementation of biologically effective grazing management for pestiferous weed invasion prevention.

Initial Control Practice

It is best to start the weed management practices early while the infestation is young. The standard recommended initial control practice, while the early weed infestation is still small, is to use manual hand pulling. This recommendation from academic weed scientists and environmental organizations assumes there are large pools of voluntary labor available to draw from. Most livestock agricultural operations do not usually have large pools to perform tedious manual labor of hand pulling weeds. Fortunately, there is a low cost, simple alternative plan B to kill the early small infestations of problem weeds. All the materials can be put into a small pouch and carried in a pickup, tractor, saddlebags, or an ATV. In a small sealable plastic bag put a quantity of Spike 20P pellets (tebuthiuron) herbicide from cenex (do not get the dry flowable powder form) and combine this bag of pellets with a few disposable latex gloves in a carrying pouch. As you check the pastures, also watch for young pestiferous weeds. If a small patch of weeds is found, take a picture and a GPS reading with the cell phone, put a latex glove on, and place a few pellets of Spike herbicide in one or two rings around the new weeds at a rate of one pellet per square foot which is equal to 0.5 lbs ai/ac. More is not better, any higher rate than 0.8 lbs ai/ac will hurt the grass. Spike (tebuthiuron) is a very effective herbicide that works slowly. Most academic weed scientists do not give spike high recommendations because their weed control studies are short duration of only 1 to 2 years, which works for the fast acting herbicides. But spike works slowly over a longer period of 4 to 6 years, and has a low percent kill in the first year or two (Manske 2006).

Tebuthiuron (spike) is an amide-urea derivative herbicide that is soil activated and absorbed by plants through the roots. It requires rain or good soil moisture to dissolve the pellets and move the chemical to the plant roots. Tebuthiuron interferes with or inhibits the photosynthetic process, causing premature aging and shedding of the leaves. Several leaf defoliation cycles deplete stored nonstructural carbohydrates and result in death of the weed after four to six years depending on the quantity of stored carbohydrates. Tebuthiuron may persist in soils for long periods. It is adsorbed to the organic matter and clay particles in the soil. Tebuthiuron resists photodecomposition and volatilization, and its breakdown by microbial activity is slow.

Spike 20P is a surface applied soil-active pelleted product for control of weedy plants in rangeland, pastureland, and noncropland. This product is also available as a dry flowable wettable powder. This herbicide is toxic to fish and cannot be applied directly to water or to areas with a shallow water table (5 feet or less). This product contains 20% tebuthiuron (20P). The label rates for control of weedy plants on grazinglands are a maximum of 1.0 lb ai tebuthiuron (5 lb product) per acre in regions that receive less than 20 inches annual precipitation and a maximum of 2.0 lb ai tebuthiuron (10 lb product) per acre in regions that receive greater than 20 inches annual precipitation. Rates greater than 0.8 lb ai tebuthiuron (4.0 lb product) per acre cause injury to perennial grasses. The product cannot be applied to an area more than once per year. There are no restrictions for grazing beef and lactating dairy animals. Hay for livestock feed cannot be cut for one year after treatment. Intact treated weedy plants should not be disturbed by mowing or burning for two or more years after treatment because the plants go through several defoliation cycles before stored nonstructural carbohydrates are depleted and death occurs. Additional time of 4 to 6 years for control may be required for weedy plants with large stores of carbohydrates and for lower rates than 0.8 lb ai tebuthiuron per acre (data from product label 2003). If weedy plants are not dead after 5 or 6 years, make a second application of spike pellets at a rate of 0.25 lbs ai/ac or one pellet to two square feet of ground. Tebuthiuron pellets can be used as the primary herbicide for control of forb and woody pestiferous weeds. Each application of one pellet per square foot will last for four to six years. If the weeds contain a large quantity of nonstructural carbohydrates or if new weeds are growing outside of your old perimeter, add some additional Spike pellets to the area. Tebuthiuron is nonselective of grasses. If you have pestiferous grasses mixed among the good grasses, tebuthiuron is not the herbicide to use. But for all weedy forbs and woody plants, Spike at one pellet per square foot will not hurt the grasses and kill the weedy forbs and shrubs.

But at higher rates spike will kill the weedy and good grasses. At one pellet per square foot rate, spike will be about the lowest cost herbicide treatment for the pestiferous weedy forbs and shrubs or trees (Manske 2006).
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Mechanical Mowing

Mowing can be used to remove the aboveground biomass to permit sunlight to reach the understory desirable plants and can reduce seed production when cut before the weeds reach the flower stage. Mowing does not harm the crown and root system from which most plants can produce vegetative replacement stems and new flowers which may require repeating mowing every two to four weeks.

Mowing grasslands cannot activate the grass plant growth mechanisms or the ecosystem biogeochemical processes because mechanical mowing of grasslands removes too much of the total leaf area preventing adequate quantities of carbon energy to be fixed through leaf photosynthesis. Stored carbohydrates are not mobilized for complementary replacement growth following defoliation events (Richards and Caldwell 1985, Briske and Richards 1995).

Regular haying equipment can be used to mow pestiferous weeds that are not amongst large rocks or on steep slopes. Clean the equipment at the weed site to prevent spreading the invasive plants.

Prescribed Burning

Fire can be used to reduce the abundance of weedy species that do not reproduce by vegetative buds. Prescribed burns require trained personnel and special equipment. Every burn program should have a written fire management plan that ensures the safety of people and property and confirms that control of the fire can be reliably maintained within the designated boundaries and has prior approval by local authorities. Repeated prescribed burning can reduce the undesirable weeds but it cannot restore degraded ecosystem processes nor grass plant growth mechanisms.

Repeated prescribed burning can modify the composition of the aboveground vegetation in degraded grasslands which have been invaded by pestiferous weeds. The composition of introduced cool season grasses may change, and early succession and weedy forbs, and shrub aerial stems decrease temporarily after four repeated prescribed burns (Manske 2007, 2011). However, the fundamental problems in a degraded ecosystem of weak nutrient resource uptake, reduced water use efficiency, nonfunctional compensatory physiological mechanisms, impaired vegetative reproduction by tillering, and diminished ecosystem biogeochemical processes will remain in the degraded grassland ecosystem following repeated burning events. None of the biological, physiological, or asexual mechanisms within grass plants and none of the rhizosphere microbes or biogeochemical processes they perform are activated by fire (Manske 2007, 2011). Almost all of the essential elements in the aboveground herbage are volatized when a grassland is burned, and if the soil is dry, some of the belowground essential elements are also lost (Russelle 1992). When the losses of essential elements are greater than the quantity of captured essential elements, the result is degradation of the grassland (McGill and Cole 1981). Fire does not improve grassland ecosystems biologically or ecologically and fire cannot replace the beneficial activation of grass plant mechanisms and ecosystem processes achieved from partial defoliation by grazing graminivores in biologically effective management of healthy and productive grassland ecosystems (Manske 2018).

Chemical Management

Chemical management of pestiferous weeds uses herbicides that interfere with vital physiological processes within the plant. Herbicide active ingredients from different chemical groups affect various plant processes. Effective chemical management requires knowledge of the general properties and characteristics of the herbicides approved for weedy plant control on grazed grasslands. Since I am a range scientist, and I am not a certified weed scientist, I am not authorized to recommend herbicide rates of use. The herbicide rates of use that I had suggested for use on invasive pestiferous weeds in the draft version of this report have been removed from this second version. Follow the label rates of use for problem weeds. I sincerely apologize for this inconvenience.

Herbicide Mode of entry

The herbicide mode of entry is either foliage-active or soil-active.

Foliage-active herbicides are applied directly to leaves and stems of plants by spraying or wiping and they usually have limited residual activity in the soil. Contact foliage-active herbicides kill the plant tissue directly contacted by the chemical. Translocated foliage-active herbicides penetrate the leaves and stems of plants, move through the phloem vascular system, and are translocated to the roots and other organs some distance from the point of entry. A surfactant is usually added to the mixture to aid in penetration of the leaves.

Soil-active herbicides are applied directly to the soil within the vicinity of the root zone of target plant species. Translocated soil-active herbicides must be moved into the soil by rainfall, absorbed by the plant roots, and then moved upward through the xylem vascular system. A few herbicides can be transported both downward through the phloem from the leaves and upward through the xylem from the roots.

Development of new herbicide active ingredients is expensive for chemical companies, and there is a low profit for herbicides specific for grasslands. As a result, there are relatively few chemicals available for use as weedy plant control on grazed grasslands. Some improvements in herbicide efficiency have resulted from the development of synergistic mixtures of existing herbicide active ingredients.

Herbicide Toxicity

Herbicides are intended to be toxic to undesirable plants, but they also may have varying degrees of toxicity to humans and other nontarget organisms. The toxicity of herbicide chemicals is measured by the lethal dose (LD) or lethal concentration (LC) that kills 50% of the test animals, which are usually rats or rabbits. Toxic quantities that are ingested orally, exposed to the dermal layer of skin, and inhaled as vapor are measured separately. The oral and dermal lethal dosage are expressed as milligrams (mg) of toxicant per kilogram (kg) of body weight (mg/kg) and the inhaled lethal concentration is expresses as milligrams (mg) of toxicant per liter (l) of aerosol (kg/l).

Highly toxic herbicides have an LD 50 of 50 to 500 mg/kg for a single oral dose and an LD 50 of 200 to 1000 mg/kg for a single dermal dose. Moderately toxic herbicides have an LD 50 to 500 to 5000 mg/kg for a single oral dose and an LD 50 of 1000 to 2000 mg/kg for a single dermal dose. Slightly toxic herbicides have an LD 50 to 5000 to 15000 mg/kg for a single oral dose and an LD 50 of 2000 to 20000 mg/kg for a dermal dose. None of the herbicides used in the chemical management of grazed grasslands are highly toxic to humans and other mammals and generally a one-time exposure results in minimal irritation. Herbicide applicators need to wear appropriate personal protective equipment described on the respective product labels,

Herbicides used in the chemical management of pestiferous weeds on grazed grasslands have a trade name, a chemical name that is categorized into chemical families, and how these chemicals effect the plants is categorized into mechanisms of action. All these names are listed in tables 2 and 3.

Beef Animal Restriction

Each herbicide used in chemical management of grazed grasslands has grazing and haying use restriction for beef animals which are listed on table 4. The herbicides also have use restrictions for dairy animals which are on the product labels. The grazed grassland herbicides are either nontoxic or have low toxicity to domesticated livestock and have no grazing restrictions at the application rates labeled for pasture use. The restriction period between herbicide application and time of harvest of treated vegetation for hay or silage ranges from zero days to one year. The purpose for any delay to cut the vegetation after application is not the toxicity levels but time for the chemicals to be fully translocated in the weeds. The restriction period required between slaughter of animals and their removal from herbicide treated pastures ranges from zero days to thirty days. This time period is for the animal to eliminate the toxic residue from their bodies.

Table 2. Grassland Herbicides

Trade Name	Chemical Name	Mechanism of Action
Capstone	aminopyralid + triclopyr	Growth Regulators
Chaparral	aminopyralid + metsulfuron	Growth Reg/ALS Inhib
Cimarron Max	metsulfuron + dicamba + 2,4-D	ALS Inhib./Growth Reg
Cimarron Xtra	chlorsulfuron + metsulfuron	ALS Inhibitors
Clarity	dicamba	Growth Regulator
Comet	fluroxypyr	Growth Regulator
Crossbow	triclopyr + 2,4-D	Growth Regulators
Curtail	clopyralid + 2,4-D	Growth Regulators
DuraCor	aminopyralid + florpyranxifen	Growth Regulators
Escort	metsulfuron	ALS Inhibitor
Facet	quinclorac	Growth Regulator
Graslan	picloram + 2,4-D RUP	Growth Regulators
GrazonNext	aminopyralid + 2,4-D	Growth Regulators
Milestone	aminopyralid	Growth Regulator
Outrider	sulfosulfuron	ALS Inhibitor
Overdrive	dicamba + diflufenzopyr	Growth Reg/Auxin Inhib
PastureGard	triclopyr + fluroxypyr	Growth Regulators
Plateau	imazapic	ALS Inhibitor
Rejuvra	indaziflam	Cellulose Inhibitor
Remedy Ultra	triclopyr	Growth Regulator
Spike 20P	tebuthiuron	Photosys. II Inhibitor
Stinger	clopyralid	Growth Regulator
Telar	chlorsulfuron	ALS Inhibitor
Tordon	picloram RUP	Growth Regulator
2, 4-D ester or amine	2, 4-D-dichlorophenoxy acetic acid	Growth Regulator
Weedmaster	dicamba + 2,4-D	Growth Regulators

Table 3. Chemical Family of Grassland Herbicides

Trade Name	Chemical Family
Capstone	Pyridine/Pyridine
Chaparral	Pyridine/Sulfonylurea
Cimarron Max	Sulfonylurea/ Benzoic acid/Phenoxy
Cimarron Xtra	Sulfonylurea/ Sulfonylurea
Clarity	Benzoic acid
Comet	Pyridine
Crossbow	Pyridine/Phenoxy
Curtail	Pyridine/Phenoxy
DuraCor	Pyridine/Arylpicolinate
Escort	Sulfonylurea
Facet	Quinoline
Graslan	Picolinic acid/Phenoxy
GrazonNext	Pyridine/Phenoxy
Milestone	Pyridine
Outrider	Sulfonylurea
Overdrive	Benzoic acid/Semicarbazone
PastureGard	Pyridine/ Pyridine
Plateau	Imidazolinone
Rejuvra	Alkylazine
Remedy Ultra	Pyridine
Spike 20P	Amideureas
Stinger	Pyridine
Telar	Sulfonylurea
Tordon	Picolinic acid
2, 4-D ester or amine	Phenoxy
Weedmaster	Benzoic acid/Phenoxy

Table 4. Beef Animal Use Restrictions

Trade Name	Period Before Grazing	Period Before Haying	Remove Before Slaughter
Capstone	0	14d	3d
Chaparral	0	14d	0
Cimarron Max	0	37d	30d
Cimarron Xtra	0	0	0
Clarity	0	7d	30d
Comet	0	7d	2d
Crossbow	0	14d	3d
Curtail	0	7d	7d
DuraCor	0	14d	0
Escort	0	3d	0
Facet	0	7d	0
Graslan	0	30d	3d
GrazonNext	0	14d	0
Milestone	0	14d	0
Outrider	0	14d	0
Overdrive	0	0	30d
PastureGard	0	14d	3d
Plateau	0	7d	0
Rejuvra	0	40d	0
Remedy Ultra	0	14d	3d
Spike 20P	0	1 yr	0
Stinger	0	0	0
Telar	0	0	0
Tordon	0	14d	3d
2, 4-D ester or amine	0	30d	3d
Weedmaster	0	37d	30d

Data from product labels

Herbicide Properties and Characteristic

Growth Regulators

Phenoxy Herbicides

All of the numerous formulations of 2,4-D are phenoxy herbicides. The ester forms of 2,4-D are more toxic per unit of acid equivalence for most plants and do not mix with water unless emulsified. The amine forms of 2,4-D are generally less toxic than the ester forms, but they have no volatility hazard and they are directly soluble in water. The chlorine salt forms of 2,4-D are less volatile than the ester or amine forms and have low odor. The chlorine forms target weeds as many amine products. Chlorine forms control biennial and perennial broadleaf weeds and several shrubs and half shrubs. The exact mode of action is virtually impossible to ascertain because the physiological effects are so complex. The phenoxy herbicides cause changes in nitrogen metabolism, respiration, photosynthesis, and nucleic acid metabolism; they effect changes in the composition of carbohydrates, lipids, organic acids, ethylene alkaloids, steroids, aromatics, vitamins, pigments, minerals, hormones, nucleic acids, and enzymes; and they stimulate meristematic activity that results in abnormal morphological changes and twisting and curling of stems. Phenoxy herbicides are short lived in the environment and have limited mobility, with movement through soil to ground water unlikely. Phenoxy herbicides are rapidly decomposed by soil microbes, sunlight, and plant metabolism.

2,4-D (2,4-D-dichlorophenoxy acetic acid)

2,4-D, the ester contains 66.2% 2,4-D and the amine contains 47.3% 2,4-D and both with the acid equivalent (ae) of 3.8 lbs/gal. 2,4-D are synthetically produced growth hormones similar to auxin and acts as Growth Regulators that are used to control annual, biennial, and perennial forbs and woody brush labeled for use in pastures, rangeland, CRP acres, and noncropland. Grasses are tolerant.

The label rates of use are 1-4 pt/A. The 1-3 pt/A are the general spring application rate. The 3-4 pt/A rates are for the more troublesome weeds and these higher rates may stunt some grasses. Grasses treated during the boot to milk stages usually fail to produce viable seed. A non-ionic surfactant (NIS) may be used.

There is no grazing restrictions for nondairy animals. Do not harvest hay for 7 days after application. Remove meat animals 3 days prior to slaughter. Most formulation are toxic to aquatic invertebrates. Do not apply directly to water, unless label verifies product registration includes application in water.

Benzoic acid Herbicides

Dicamba is a broad spectrum benzoic acid herbicide. The exact mode of action has not been defined; however, the complex reactions in plants to benzoic acid phototoxicity are similar to those caused by the phenoxy herbicides. Benzoic acid herbicides also disrupt the physiological processes of nucleic acid metabolism and photosynthesis. Dicamba is degraded by microbial activity and remains only a short time in the environment. In warm, moist soil, dicamba has a half-life of<14 days, and in native grasses and litter, the half-life is only 3 to 4 weeks.

Clarity (dicamba)

Dicamba has different formulations (dma) dimethylamine salt (48.2%) and (dga) diglycolamine salt (56.8%) that are selective, translocated herbicides for control of annual, biennial, and perennial broadleaf weeds and woody brush and vine species registered for use in pasture, range, CRP, and non-crop areas.

The label rates of use are 0.5 to 1.0 lb ae dicamba (1 pt to 1 qt product) per acre and no more than 2.0 lb ae dicamba (2 qt product) per acre as a spot treatment. The amount applied cannot exceed a total of 2.0 lb ae dicamba (2 qt product) per treated acre during a growing season. At high rates, bromegrass may be severely stunted, bluegrass and several other grasses are tolerant. Trees, legumes, and broadleaved plants are sensitive to drift and soil residue. This herbicide cannot be applied directly to water. Non-ionic surfactants (NIS) or crop oil concentrates (COC) may be added to spray mixtures.

Do not apply more than 1 qt/A in a single application. Lactating dairy have grazing restrictions at different rates. Nondairy animals have no grazing restrictions. Do not harvest hay for 7 days. Remove meat animals 30 days before slaughter.

Weedmaster (dicamba + 2,4-D)

Weedmaster is a premix containing 12.4% (1 lb/gal) dicamba (amine) plus 35.7% (2.87 lbs/gal) 2,4-D amine is a selective post emergence herbicide that is a Growth Regulator for control of annual, biennial, and perennial weeds and woody brushes labeled for use in CRP land, fallow cropland, grass used for hay or silage, pastures, and rangeland.

The label rates of use are 0.5-4 pt/A. Limited to 2 applications per year with a minimum of 30 days between applications and a total of 8 pints/A during a growing season. Do not apply directly to water.

There is no grazing restrictions for nondairy animals. Do not harvest treated grasses for dry hay or silage within 37 days of treatment. Do not permit meat animals being finished for slaughter to graze treated fields within 30 days of slaughter.

Overdrive (dicamba + diflufenzopyr)

Overdrive contains 50% dicamba plus 20% diflufenzopyr and is a Growth Regulator plus an Auxin Inhibitor for control of annual, biennial, and perennial broadleaf weeds labeled for use in pasture, grass hayland, rangeland, and noncrop sites.

The label rates of use are 4-8 oz/A with a maximum of 10 oz/A per season in noncropland and a maximum of 8 oz/A in pasture, hayland, and rangeland. Use 1 qt NIS (nonionic surfactant) per 100 gal or MSO (methylated seed oil) at the rate of 1.5 to 2 pt/A. Spray is rainfast 4 hr after application. Overdrive may injure buffalograss, and will severely injure alfalfa, clovers, vetch, and other legumes.

There are no grazing and haying restrictions. Remove meat animals 30 days before slaughter.

Pyridine Herbicides

The chemicals aminopyralid, clopyralid, fluroxypyr, and triclopyr are pyridine herbicides. The complex reactions in plants to pyridine phototoxicity are similar to those caused by the phenoxy herbicides. Breakdown of pyridine herbicides occurs in soil by leaching, photodegradation, and microbial activity, with the rate of breakdown related to temperature. Movement through soil to ground water is unlikely, and mobility in runoff water is limited.

Milestone (aminopyralid)

Milestone contains 40.6% aminopyralid and is a Growth Regulator for control of biennial and perennial broadleaf weeds labeled for use in rangeland, grass pastures, CRP acres, non-cropland areas, natural areas, and grazed areas.

The label rates of use are 3-7 oz/A and rate for spot treatments (less than ½ acre areas) can be up to 14 oz/A. Can use a non-ionic surfactant (NIS) at 0.25-0.5% v/v. Do not apply to areas where surface water is present. May be applied around some mature trees, some species are sensitive. Use extra care near leguminous trees. Do not apply within the root zone of trees.

Do not apply more than 7 oz/A per year for broadcast applications or 14 oz/A for spot treatments. There are no grazing restrictions. Avoid mowing for 14 days after application to allow for herbicide translocation in the weeds. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

Capstone (aminopyralid + triclopyr)

Capstone is a premix containing 0.1 lb/gal aminopyralid (Milestone) and 1 lb/gal triclopyr (Remedy) and is a Growth Regulator for control of annual, biennial, and perennial broadleaf weeds labeled for use in pastures, rangelands, CRP, and non-crop areas.

The label rates of use are 4-9 pt/A, apply prior to flowering in spring or early summer. Fall use for perennials that have late season vegetative growth. Use a non-ionic surfactant (NIS) at 0.25-0.5% v/v or methylated seed oil (MSO) at 1 to 2 pt/A.

Do not apply more than 9 pt/A per year. There are no grazing restrictions. Do not harvest hay for 14 days. Remove meat animals 3 days before slaughter. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

Chaparral (aminopyralid + metsulfuron)

Chaparral is premix containing 0.525 lb ae aminopyralid (Milestone) a Growth Regulator + 0.0945 lb metsulfuron methyl (Escort) a ALS Inhibitor for control of biennial and perennial broadleaf weeds and some woody shrubs labeled for use in pastures, rangelands, CRP, and non-crop areas.

The label rates of use are 1.0-3.33 oz/A, apply prior to flowering in spring or early summer. Fall use for perennials that have late season vegetative growth. Use a non-ionic surfactant (NIS) at 0.25% v/v or crop oil concentrate (COC) or methylated seed oil (MSO).

Do not apply more than 3.3 oz/A per year. There are no grazing restrictions. Do not harvest forage for hay within 14 days. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. No not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

DuraCor (aminopyralid + florpyrauxifen)

DuraCor is a premix containing 0.667 lb aminopyralid (Milestone) and 0.067 florpyrauxifen (Rinskor) per gallon and is a Growth Regulator for control of annual, biennial, and perennial broadleaf weeds for use in rangeland, grass pasture, grass hayland, and CRP. May be applied to non-irrigation ditch banks and seasonally dry wetlands, but may not be applied over surface water.

The label rates of use are 12-20 oz/A, applied in early summer or to regrowth in fall when weeds are actively growing prior to the bud to early flowering growth stage. Use a non-ionic surfactant (NIS) at 0.25-0.5% v/v under advanced weed growth stages, or pubescent plants. May be applied around some mature trees, many trees species are sensitive. Do not apply within the root zone of trees. Use extra care near leguminous trees. Never apply over the top of any tree species. Some grasses, such as smooth brome, may be suppressed under some growing conditions.

Do not apply at more than 20 fl oz per acre per year for broadcast applications or 40 fl oz for spot treatments of less than ½ acre. There are no grazing restrictions. Avoid mowing for 14 days after application to allow for herbicide translocation in the weeds. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

GrazonNext (aminopyralid + 2,4-D)

GrazonNext is a premix containing 0.41 lb/gal aminopyralid (Milestone) plus 3.33 lb/gal 2,4-D, and is a Growth Regulator for control of biennial and perennial broadleaf weeds labeled for use in rangeland, grass pasture, grass hayland, and CRP acres.

The label rates of use are 1.2 to 2.1 pt/A. Use a non-ionic surfactant (NIS) at 0.25-0.5% of v/v. Do not apply more than 2.1 pt/A in a growing season, but spot treatments (less than 50% of an acre) may be allowed up to 4.2 pt/A per season. Avoid injury to non-target plants especially desirable legumes.

There are no grazing restrictions. Do not harvest forage for hay within 14 days after application. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

Stinger (clopyralid)

Stinger contains 40.9% clopyralid is a highly selective translocated post-emergence Growth Regulator for control of annual, biennial, and perennial broadleaf weeds labeled for use in rangeland, permanent grass pastures, grass CRP acres and non-cropland areas.

The label rates of use are 0.5-1.33 pt/A. Apply when weeds are young and actively growing. Addition of surfactants, oils, or adjuvants is not necessary. Do not apply directly to water. Advised not to apply where soils have a rapid permeability and where the water table is shallow. Can be used near trees, avoid leaf contact. The larger trees have less risk of injury. Desirable legumes will be injured if sprayed. Allow animals to graze for 7 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

There are no grazing or haying restrictions. Established grasses are tolerant. Effective against many composites, legumes, and smartweeds, but no impact on grasses and crucifers.

Curtail (clopyralid + 2,4-D)

Curtail is a premix containing 0.38 lb clopyralid (Stinger) plus 2 lb 2,4-D amine per gallon and is a highly selective Growth Regulator for control of annual, biennial, and perennial broadleaf weeds labeled for use in grass pasture, rangeland, non-cropland, and CRP grass and fence lines.

The label rates of use are 2 to 4 qt per acre applied when weeds are actively growing. Best to treat early when weeds are small.

No grazing restrictions for non-dairy animals. Do not harvest hay within 7 days after application. Remove meat animals 7 days before slaughter. Effective against many composites, legumes, and smartweeds, but no impact on grasses, and crucifers.

Comet (fluroxypyr)

Comet contains 26.2% fluroxypyr is a selective translocated post emergence Growth Regulator for control of broadleaf weeds for use in rangeland, permanent pastures, and non-cropland areas.

The label rates of use are 0.66-2.66 pt/A. Apply to actively growing weeds prior to bud stage. Do not apply more than 2.66 pt/A per year. Do not contaminate water. Maintain sufficient agitation during application. Desirable legumes will be injured if sprayed.

There are no grazing restrictions. Do not harvest grass for hay or silage from treated areas within 7 days of application. Do not allow meat animals to graze on treated forage within 2 days before slaughter.

Remedy Ultra (triclopyr)

Remedy is a specialty herbicide containing 60.45% triclopyr and is a Growth Regulator for control of annual, biennial, and perennial broadleaf weeds and woody shrubs and some trees labeled for use in rangeland, permanent grass pastures, and CRP acres.

The label rates of use are 0.5-4 pt /A. Apply no more than 4 pt/A per growing season on grazed rangeland, pasture, and CRP. On nongrazed areas rates up to 8 qt/A per year may be used. Mixture of an oil-water emulsion performs more dependably than a straight water dilution. Add oil using diesel fuel, No. 1 or No. 2 fuel oil, Kerosene, or a commercially available basal oil at a rate of 5 to 10% of the total mix, up to a maximum of 1 gallon of oil per acre plus an emulsifier such as Sponto 712 or Triton X-100. Make only 1 application per year. Do not spray desirable forb or legume species. Established grasses are tolerant of this product.

There are no grazing restrictions. Do not harvest hay for 14 days after application. Withdraw livestock from treated area at least 3 days before slaughter.

Crossbow (triclopyr + 2,4-D)

Crossbow is a premix containing 1 lb ae triclopyr (Remedy) and 2 lbs ae 2,4-D ester per gallon and is a Growth Regulator for control of annual, and perennial broadleaf weeds and woody brush labeled for use in pasture, rangeland, CRP, and non cropland. This product is toxic to fish and cannot be applied directly to water. Continuous agitation of spray mixture is necessary because this herbicide forms an emulsion in water, not a solution, and separation may occur.

Lactating dairy do not graze for one season. There are no grazing restrictions for non dairy. Do not harvest hay for 14 days after treatment. Remove meat animals 3 days before slaughter. Do not make more than one application per year.

PastureGard (triclopyr + fluroxypyr)

PastureGard is a premix containing 3 lb/gal triclopyr + 1 lb/gal fluroxypyr and is a Growth Regulator for control of broadleaf weeds and woody plants for use in rangeland and permanent pastures.

The label rates of use are 1-4 pt/A and do not apply more than 4 pt/A product per annual growing season. The use of NIS (nonionic surfactant) or liquid fertilizer at 1-2 qt per 100 gal spray solution may improve weed control. Broadcast or directed foliar spray applications must be made to plants that are in full leaf at the time of application. Do not use from early boot to milk stage if grasses grown for seed production. Avoid spray drift and runoff to surface water or off site exposure.

There are no grazing restrictions. Do not harvest hay within 14 days after application. Withdraw livestock 3 days prior to slaughter.

Picolinic acid Herbicides

Picloram is a picolinic acid herbicide that is a derivative of pyridine and carboxylic acid and interferes with a multitude of vital processes and enzymes systems, disrupts nucleic acid metabolism, and stimulates abnormal meristematic activity that causes twisted stems and death of growing points. Picloram is an effective broad spectrum herbicide because it is readily absorbed both by upper and lower leaf surfaces and by the roots, and it can move through either the phloem or the xylem vascular systems. Picloram degrades rapidly by sunlight; however, degradation by soil microorganisms and plant metabolism is slow and may require 3 to 6 months, with the half-life depending on rainfall and soil temperature. The persistence is longer in cooler climates, and some of the chemical may leach to lower soil depths.

Tordon (picloram) RUP

Tordon contains 24.4% picloram that is a restricted use pesticide (RUP), that is effective as a broad spectrum picolinic acid herbicide, a Growth Regulator for control of biennial and perennial broadleaf weeds and woody vines and shrubs labeled for use in rangeland, permanent grass pastures, CRP acres, and non crop areas.

The label rates of use are 0.5-2 pt/A for broadcast applications. Rate of use for spot treatments that are 50% or less of an acre can be 2 pt-4 pt/A. Do not apply directly to water. Do not use near trees as root uptake will result in severe injury or death. Do not apply where soils have a rapid permeability and where the water table is shallow.

There are no grazing restrictions for non dairy animals. Do not harvest for hay within 14 days after treatment when spot treating with rates of 2 pt/A or more. Meat animals grazing treated areas should be removed 3 days before slaughter.

Graslan (picloram + 2,4-D) RUP

Graslan is a premix containing 0.81 lb picloram (Tordon) + 3 lbs ae 2,4-D Choline per gal. and is a Growth Regulator for control of biennial and perennial broadleaf weeds labeled for use in pasture, range, CRP, and non-crop.

Normal label rates of use are 1.25 pt to 1 qt/A and the rate for problem weeds can go to 2 qt/A. Most grasses are tolerant to rates up to 2 qt/A, but may be seriously damaged at higher rates. Do not apply to grass seed crops. A non-ionic surfactant (NIS) may be used to provide more complete wetting and coverage of the foliage. Do not apply where soils have rapid permeability (such as loamy sand to sand) and where the underlying aquifer is shallow. Do not use near trees as root uptake will result in severe injury or death. Avoid drift to sensitive crops. Avoid contaminating water.

There are no grazing restrictions for non dairy animals. Do not harvest hay for 30 days after treatment. Remove meat animals 3 days before slaughter. Allow animals to graze for 3 days on an untreated pasture before moving to areas with sensitive broadleaf crops. Do not spread manure on areas used for broadleaf crops if animals have grazed treated areas or consumed treated forage or hay.

Quinoline Herbicides

Quinclorac herbicides can be used where tordon cannot be used, on soil with shallow water table and near trees.

Facet (quinclorac)

Facet is a quinoline carboxylic acid acting as an auxin agonist that is a Growth Regulator for control of annual and perennial broadleaf weeds and annual grasses labeled for use in pasture, hayland, rangeland, CRP, and areas of switchgrass.

Normal label rates of use are 22-32 oz/A and the rate for problem weeds is 32 to 64 oz/A and for best performance apply at 32 oz/A with 6 oz of Overdrive plus 2 pt/A of methylated seed oil (MSO) applied only to actively growing weeds when small. Do not apply when wind speeds are more than 10 mph. Maintain constant agitation throughout mixing and application. Do not apply more than a total of 64 oz/A per year of Facet. The restricted entry interval is 12 hours. Can be used near trees and in areas with sandy soils and high water tables. Do not apply directly to water.

There is no grazing restrictions. Do not harvest hay for 7 days. Most perennial grasses are tolerant.

ALS Inhibitors

Imidazolinone Herbicides

Imazapic is an imidazolinone herbicide that blocks acetolactate synthase (ALS) which inhibits the production of the branched-chain aliphatic amino acids, which are required for DNA synthesis and cell growth. The time it takes for a treated plant to die is most likely related to the amount of stored aliphatic amino acids available to the plant. ALS is widespread in plants but the biochemical pathway it catalyzes is not found in animals. Degradation by soil microbes is the primary mechanism, with a typical half-life in soil of 120-140 days.

Plateau (imazapic)

Plateau contains 23.6% imazapic and is an ALS Inhibitor for control of annual and perennial broadleaf weeds and annual grasses labeled for use in pasture, range, non-crop areas, and CRP plantings.

The label rate of use are 2-12 oz/A with rates at 8-12 oz/A used for problem weed treatments. Do not exceed 12 oz/A in one year. The preferred adjuvant is a methylated (vegetable-based) seed oil (MSO) containing 5 or 20% surfactant at the rate of 1.5 to 2 pt/A at a spray volume at 30 GPA or less. Private individuals must operate under a Habitat Conservation Plan if threatened or endangered plants are known to be present on the land to be treated. Product is rain fast one hour after application. Weeds should be growing vigorously at the time of application. Most native grasses and domesticated grasses are tolerant at rate of 8-12 oz/A. Switchgrass and some cool season grasses may suppress growth at rates greater than 8 oz/A. Do not apply directly to water.

There is no grazing restrictions. Do not harvest hay for 7 days after treatment.

Sulfonylurea Herbicides

Chlorsulfuron, metsulfuron, and sulfosulfuron are sulfonylurea herbicides that disrupt enzyme systems rapidly inhibiting growth; with 1 to 3 weeks the meristematic tissue at the growing points dies. Sulfonylurea herbicides are moderately persistent in soil, with a typical half-life of 30 days. Degradation by soil microbes is generally slow; with increased rates at high soil temperatures and high soil moisture. Nonmicrobial hydrolysis degrades the herbicides slowly at high pH and relatively rapidly at low pH.

Telar (chlorsulfuron)

Telar contains 75% chlorsulfuron, is a dry flowable granule mixed with water to be applied for preemergence or postemergence as a ALS Inhibitor for control of annual, biennial, and perennial broadleaf weeds labeled for use in range, permanent pasture, CRP lands, and nongrazed non-cropland.

The label rates of use on grazed range and pasture are 0.5-1.3 oz/A with a maximum rate of 1.3oz/A per year. Annual weeds should be actively germinating or growing and perennial weeds should be actively growing in the bud to bloom stage or during fall in the rosette stage. Blue grama and wheatgrass tolerate rates up to 1.0 oz/A and bluestems, Indiangrass, switchgrass, sideoats grama, green needlegrass, and buffalograss tolerate rates up to 0.5 oz/A. Do not apply directly to water.

There are no grazing or haying restrictions with application rates up to 1.3 oz/A per year and there is no grazing or haying with treatment rates at 1.4 oz/A to 2.6 oz/A per year on non-crop areas only.

Cimarron Xtra (chlorsulfuron + metsulfuron)

Cimarron Xtra is a premix containing 48% metsulfuron methyl + 15% chlorsulfuron (Telar) and is an ALS Inhibitor for control of biennial and perennial broadleaf weeds labeled for use in pasture, rangeland, or established grasses in CRP.

The label rates of use are 0.125-1.25 oz/A, apply to actively growing weeds that are less than 4 inches. Use a non-ionic surfactant (NIS) at 0.25-0.5% v/v or crop oil concentrate (COC) or methylated seed oil (MSO) at 1 gal/100 gal. Do not apply more than the equivalent of 1 oz of chlorsulfuron or 1 oz of metsulfuron per acre per year.

No grazing or haying restrictions when applied at labeled rates. Avoid contact with desirable tree species as injury may occur. Do not use on grasses grown for seed. Do not apply to grass stressed from severe weather conditions.

Escort (metsulfuron)

Escort is a sulfonylurea ALS Inhibitor herbicide for control of annual, biennial, and perennial broadleaf weeds and is labeled for use in range, pasture, CRP, rights-of-way, and non crop areas.

The label rates of use are 0.1-1.66 oz/A with 0.3 oz/A used for most pasture and rangeland situations, the higher rates are for special weed problems. For spot applications, use 1 oz per 100 gal. Use of non-ionic surfactant (NIS) 2 to 4 pt per 100 gal is recommended.

Do not apply more than 1.67 oz/A per year on pasture, range or CRP. If applying more than 1.67 oz/A do not harvest grasses for hay or forage until at least 3 days after application. There are no grazing restrictions at rates less than 1.66 oz/A. For native grasses, rates of 1.66 to 3.33 oz/A allow forage grasses to be cut for hay, fodder, green forage, and fed to livestock including lactating dairy 3 days after treatment. Do not use on grasses grown for seed. Stunting and seedhead suppression may be noted under cool, wet conditions. Broadleaf forages or legumes in pasture may be severely injured or killed. Do not apply on or near desirable trees or plants. Tolerance of grass species varies, bluegrass, bluestem, bromegrass, grama, and timothy have shown good tolerances.

Cimarron Max (metsulfuron + dicamba + 2,4-D)

Cimarron Max is a two part product mixture. Part A contains 60% metsulfuron. Part B contains 10.3% dicamba, with the acid equivalent (ae) of 1.0 lb/gal and 29.6% 2,4-D with the ae of 2.87 lb/gal and is an ALS Inhibitor and Growth Regulator Herbicide for control of biennial and perennial broadleaf weeds and woody brush labeled for use on pastures, rangeland, grass CRP acres, grass hayland, and noncropland. Do not apply more than 1.66 oz/A of Part A per year. A non-ionic surfactant or crop oil concentrate must be used in the spray mixture.

Apply to actively growing weeds that are less than 4 inches.

There are no grazing restrictions. Do not harvest hay for 37 days after treatment. Remove meat animals 30 days prior to slaughter.

Outrider (sulfosulfuron)

Outrider contains 75.0% sulfosulfuron and is a ALS Inhibitor for control of annual and perennial broadleaf weeds labeled for use in grass pasture, rangelands, non-crop areas, and in winter and spring wheat.

The label rates of use are 1.33 to 2 oz/A per application. Do not apply more than 2.66 oz/A per year. Do not make more than 2 applications per year with a minimum of 30 days between applications. A nonionic surfactant (NIS) is required at a rate of 0.25% v/v. Do not apply when wind speeds exceed 10 mph. This herbicide should not be applied to poorly draining soils and soils with shallow ground water.

Grass forage may be grazed immediately after application. Do not mow area to be treated for 14 days before and 14 days after application.

Cellulose Inhibitor

Indaziflam Herbicides

The cellulose biosynthesis inhibitor herbicides selectively inhibit the synthesis of cellulose. Cellulose biosynthesis in higher plants is essential to cell growth and division as well as tissue formation and differentiation. Cellulose is a composite polymer of linked glucan chains and is the main load-bearing structure of plant cell walls. Cellulose is a relatively simple polysaccharide molecule, however, its synthesis is quite complex; a few catalytic and several accessary proteins are necessary for the production and deposition of cellulose. Indiziflam proved to be a major breakthrough in herbicide chemistry, as a preemergent, it inhibited the production of cellulose in the roots and shoots of both monocotyledons and dicotyledones, including stem girdling and radial swelling near the soil line and lignification in abnormal locations. Chemical movement in soil is minimal and volatilization and photodegradation are not a concern.

Rejuvra (indaziflam)

Rejuvra contains 19.05% indaziflam and is a selective preemergence Cellulose Biosynthesis Herbicide for control of annual grass and broadleaf weeds along with some germinating seedlings of perennial weeds labeled for use in rangeland, CRP land, and natural areas grazed or cut for grass hay.

The label rates of use are 3-5 oz/A. Do not apply a second application within 60 days. Do not apply more than 6 oz/A per year in any areas to be hayed or grazed. Maintain sufficient agitation during application to ensure a uniform spray mixture. Wait at least 3 years before making a sequential application. Do not apply directly to water. Alone rejuvra generally does not control weeds that have emerged. For control of emerged weeds, mix with Plateau (imazapic) at a rate of 8-12 oz/A. Rejuvra comes premixed with rimsulfuron as Rejuvra Plus with a restriction of no grazing or haying treated sites for a minimum of 1 year after application.

There are no grazing restrictions. Do not harvest hay within 40 days after application.

Photosystem II Inhibitor

Amideurea Herbicides

Tebuthiuron is an amide urea derivative herbicide that is soil activated and absorbed by plants through the roots. Tebuthiuron interferes with or inhibits the photosynthetic process, causing premature aging and shedding of the leaves. Several leaf defoliation cycles deplete stored nonstructural carbohydrates and resulting in death of the plant. Tebuthiuron may persist in soils for long periods. It is adsorbed to the organic matter and clay particles in the soil. Tebuthiuron resists photodecomposition and volatilization, and its breakdown by microbial activity is slow.

Spike 20P (tebuthiuron)

Spike 20P contains 20% tebuthiuron is a surface applied soil activated pellet absorbed by plants through the roots. Spike is a Photosynthetic II Inhibitor that interferes with or inhibits the photosynthetic process, causing premature aging and shedding of the leaves for control of woody plants and perennial herbaceous weeds. After several leaf defoliation cycles, the stored nonstructural carbohydrates are depleted resulting in death of the plant. Tebuthiuron persists in the soil for long periods (5 to 6 years) labeled use in rangeland, pastures, and noncropland.

Rate of use is recommended to be 0.50 lb ai/A for first application. Some plants store greater quantities of carbohydrates that can be depleted in 5 years and require a second application at 0.25 lb ai/A (Manske 2006). The maximum rate of 1.0 lb ai/A can be applied in regions that receive less than 20 inches annual precipitation and a maximum of 2.0 lb ai/A in regions that receive greater than 20 inches annual precipitation. However, most perennial grasses are injured when rates greater than 0.8 lb ai/A are used. This herbicide does not act fast, it is low cost, and one pellet per square foot is equal to 0.50 lb ai/A will slowly kill most pestiferous weeds and not hurt the grasses. This herbicide is toxic to fish and cannot be applied directly to water nor applied to areas with shallow water table of 5 feet or less. Do not apply more than once per year.

There are no grazing restriction. Hay for livestock feed cannot be cut for one year after treatment. Many difficult weeds will require more than one growing season to deplete their carbohydrates. It is best not to disturb these plants by mowing or burning until they are totally dead.

Biological Control

Biological control of invasive weeds uses the natural enemies, primarily insects, to damage plant structures or interfere with physiological processes in order to reduce the abundance of invasive weeds. These biocontrol agents are nonnative introductions that originate from the same areas that the weeds are native. Biological control is the long-term management of an introduced invasive weed intended to reduce the abundance of, rather than eradication of the offensive plant.

Prescribed Targeted Grazing

Grazing has been a vegetation management tool since livestock agriculture began. Herbivory has the power to be regenerative or destructive depending on timing and intensity. As intended here, if a grassland has a problem of an exotic weed invasion; a specific kind of livestock is targeted at the invasive weed to disrupt its normal growth and development along with reduction of the sexual and vegetative reproductive mechanisms. Cattle and horses tend to select for grasses. Sheep and goats tend to select broadleaf herbs. Goats also tend to select woody species. A proportion of the seeds consumed by grazing animals can survive passage through the digestive system. These animals should be contained in a designated area for three to five or up to nine days before being moved to a weed free pasture. Sheep and goats as weed reducers in a cattle pasture may require special fencing, water equipment, predator protection, and herders. Grazing can reduce the abundance of invasive weeds but usually cannot eradicate the undesirable plants completely.

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Control Management of each Pestiferous Weed

Management of Leafy Spurge

Initial Control Practice

Early detection and elimination are essential in preventing a large infestation. When a few precursor plants are located, use the Spike 20P pellets (Manske 2006). Hand pulling is ineffective because of the extensive root system. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing only controls the top growth and promotes vegetative growth from root buds. The uniform regrowth may benefit greater effective chemical control. Mowing to reduce seed production must be conducted every 2 to 4 weeks during the growing season. Clean the equipment before it is moved away from the infestation area.

Prescribed Burning

Burning has been ineffective at reducing infestation. Fire only top kills the plants and promotes root bud generation of new shoots. The depauperate understory grass plants are greatly reduced by fire.

Chemical Management

Herbicides must be used according to label. Leafy spurge has a waxy layer on leaves and stems which requires the use of surfactants. Follow the label rates of use for problem weeds.

Tordon + Plateau + 2,4-D + MSO
(picloram) + (imazapic) + (2,4-dichlorophenoxy) + (methylated seed oil)
Applied in spring when plants in true flower (June).

Facet + Overdrive + MSO
(quinclorac) + (dicamba + diflufenzopyr) + (seed oil)
Apply when Tordon can not be used in spring at flower or fall before frost.

GrazonNext + Overdrive + MSO
(aminopyralid + 2,4-D) + (dicamba + diflufenzopyr) + (seed oil)
Apply spring at flower (June) or fall before frost (September)

Plateau + MSO
(imazapic) + (seed oil)
Apply in fall for better long-term control, less grass injury at 8 oz/ac or less, can be used under trees.

Biological Control

Biological agents permitted for release in North America

Aphthona lacertosa	black flea beetle	successful
Aphthona nigriscutis	brown flea beetle	successful
Aphthona czwalinae	black flea beetle	low population
Aphthona abdominalis	tan flea beetle	poor establishment
Aphthona cyparissiae	brown flea beetle	low population
Aphthona flava	brown flea beetle	low population
Oberea erythrocephala	longhorn beetle	poor establishment
Spurgia esulae	gall midge fly	poor establishment
Hyles eurphorbiae	hawk moth	Low population

A. lacertosa and A. nigriscutis have been the most successful agents with the larvae feeding on the roots. Eggs are layed near base of stem, larvae burrow into roots to feed, larvae hibernate during winter, then feed again in spring for short period, move into soil and pupate, adult beetles emerge during May to June, live for 45 to 65 days, females lay eggs.

Prescribed Targeted Grazing

Sheep and goats will graze leafy spurge and decrease stem density and the quantity of seed in the soil seed bank. Grazing should start at an early growth stage, remove about 95% of top growth, prevent flowering and seed production, and then graze the new vegetative shoots. Goats tend to eat more plant material than sheep and eat less grass biomass. The roots are reduced but not killed by grazing. Grazing needs to be continued for at least 4 to 5 years.

Integrated Pest Management

Leafy spurge is difficult to kill and one method usually is not sufficient. A possible combination treatment might be to release flea beetles to eat the roots, graze sheep or goats to remove the top growth biomass, and then apply a fall herbicide like Plateau.

Management of Russian knapweed

Initial Control Practice

Early detection and elimination are essential in preventing a large infestation. Use the Spike 20P pellets for early invasive plants (Manske 2006). If a large volunteer force is available, hand pulling with gloves slows the rate of infestation. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing 3 times per year, spring, summer, and fall, for 4 years or more does reduce the carbohydrate reserves but does not eliminate plant population. The vegetative shoots are usually smaller in size and lower in vigor. Clean the equipment at the infestation site.

Prescribed Burning

Burning has been ineffective at reducing infestation. Fire only top kills the plants and promotes root bud generation of new shoots at greater densities.

Chemical Management

Herbicides must be used according to label. All herbicide applications to Russian knapweed should use a surfactant to improve chemical uptake. Follow the label rates of use for problem weeds.

Tordon broadcast or spot + NIS
(picloram) + (non-ionic surfactant)
Apply following several hard frosts, plants dormant with grey stems no leaves, mid-October.

Stinger
(clopyralid)
Apply at bud to full bloom or late fall after frost

Curtail
(clopyralid + 2,4-D)
Apply at bud to full bloom or late fall after frost

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Apply in spring bud to flower stage or full dormant plants

Biological Control

Biological agents permitted for release in North America

Subanguina picridis	gall-forming nematode	low impact
Aulacida acroptilonica	gall-forming wasp	minor impact
Jaapiella ivannikovi	gall midge (fly)	low population

Biological control agents for Russian knapweed are still at the development stage.

Prescribed Targeted Grazing

Cattle generally will not graze it because of the bitter taste. It is toxic to horses. Sheep are reluctant to consume it. Goats prefer young, pre bloom plants. Most weed scientists suggest that grazing is not a control method. However, experienced targeted grazing practitioners claim that sheep and goats can be persuaded to graze Russian knapweed at least during the young growth stages and the animals must have sufficient experience with the plant. To be effective, grazing must remove 80% or more of the plant biomass, repeated at least 3 times per growing season, and for multiple years. As naïve trainer with naïve animals seems risky. If you intend to use prescribed targeted grazing also hire an experienced trainer with experienced animals.

Integrated Pest Management

Burning increases shoot density, effective biological agents are not available yet, and getting grazing animals to consume enough biomass seems questionable. The two viable treatments are to mow the infested area three times each growing season and apply a herbicide after frost or apply Spike 20P pellets at one per square foot once every five years (Manske 2006).

Management of Spotted knapweed

Initial Control Practice

Early detection and effective response are essential in preventing a large infestation. Use the Spike 20P pellets for early invasive plants (Manske 2006). If a large volunteer labor force is available, hand pulling with gloves, three times a year (spring, summer, and late summer) for at least 5 years will successfully control if the entire taproot is removed. If the stem breaks above the crown, sprouts develop and infestation can be reestablished. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing at the bolting to flower stage reduces seed production. New stems and flower heads can develop from leaf axils that remain below the mow height. Repeated mowing would be necessary. Mowing does not kill the crown and taproot. Clean the equipment on site.

Prescribed burning

A severe fire can be hot enough to kill the crown, but a less than severe fire does not damage the crown. Shoots can grow from the crown and produce seeds.

Chemical Management

Herbicides must be used according to label. Do not use a nonselective herbicide that would kill the desirable grasses in the infected area. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to early bud or fall rosette

Curtail
(clopyralid + 2,4-D)
Applied at rosette to early bud or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at rosette to bolting or fall rosette

Capstone + NIS or MSO
(aminopyralid + triclopyr) + (non-ionic surfactant) or (methylated seed oil)
Applied at rosette to flower or fall rosette

Tordon + MSO
(picloram) + (methylated seed oil)
Applied at rosette to mid bolting or fall rosette

Biological Control

Biological agents permitted for release in North America

Seedhead-feeding insects		
Banganstemus fausti	broad-nosed seedhead weevil	attack other insects
Chaetorellia acrolophi	peacock fly	poor established
Larinus minutus	lesser flower weevil	aggressive
Larinus obtusus	blunt flower weevil	effective
Metzneria paucipunctella	seedhead moth	effective
Terellia virens	green clearwing seed fly	poor established
Urophora affinis	banded gall fly	well established
Urophora quadrifasciata	UV seedhead fly	well established
Root-boring insects		
Agapeta zoegana	sulfur root moth	well established
Cyphocleonus achates	root weevil	well established
Sphenoptera jugoslavica	bronze root borer	well established

The Larinus larvae eat the Urophora larvae. Combining larinus and Cyphocleonus increases effectiveness. Root boring insects stimulate release of an allelopathic toxin. Moderate levels of larvae feeding cause compensatory growth in the plants. Mice populations have increased in areas of established seed head larvae because they are the new food source of the mice. Urophora reduce seed production by 50%.

Prescribed Targeted Grazing

Sheep and goats readily consume spotted knapweed during the rosette to bolting stage when crude protein levels are good, the rosette stage has 20% CP and the bolted plant has 12% CP. Some animals will consume the flower buds which will reduce seed production. Mature plants have much reduced palatability because of the presence of a bitter tasting compound (cnicin). The animals will readily consume the young regrowth during late summer.

Integrated Pest Management

None of the potential methods are completely effective alone. Mowing and burning treatments will interfere with the development of the biological agents. Chemical treatment in the fall will help the biological control insects. Chemical treatment in the spring will help the prescribed grazing treatments. Do not handle spotted knapweed without gloves.

Management of Diffuse knapweed

Initial Control Practice

Early detection and effective response are essential in preventing a large infestation. Use the Spike 20P pellets for early invasive plants (Manske 2006). If a large volunteer labor force is available, hand pulling with gloves, three times a year, spring when soil is moist, summer to remove bolting plants, and late summer before seed dispersal, consecutively for 5 years and expect about 98% reduction, if the crown and 3 inches of taproot is removed with each plant. Remaining crowns can develop new shoots and flowers. A few surviving plants can repopulate a large area. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Repeated mowing is required to reduce seed production from the new shoots that develop after each mowing treatment. Mowing every 4 weeks at a 2 inch height can damage some of the desirable grasses growing in the infested area. Clean the equipment before it is moved to clean ground.

Prescribed Burning

The root crown is usually not killed by fire and produces spouts following top kill from fire. Fire also creates a suitable seed bed for seed germination and establishment.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to early bud or fall rosette

Curtail
(clopyralid + 2,4-D)
Applied at rosette to early bud or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at rosette to bolting or fall rosette

GrazonNext + NIS
(aminopyralid + 2.4-D) + (non-ionic surfactant)
Applied at rosette to bolting or fall rosette

Capstone + NIS or MSO
(aminopyralid + triclopyr) + (non-ionic surfactant) or (methylated seed oil)
Applied at rosette to flower or fall rosette

Biological Control

Biological agents permitted for release in North America

Seedhead-feeding insects		
Bangansternus fausti	broad-nosed seedhead weevil	attack other insects
Larinus minutus	lesser flower weevil	aggressive
Larinus obtusus	blunt flower weevil	effective
Metzneria paucipunctella	seedhead moth	effective
Urophora affinis	banded gall fly	well established
Urophora quadrifasciata	UV seedhead fly	well established

Root-boring insects		
Agapeta zoegana	sulfur root moth	well established
Cyphocleonus achates	root weevil	well established
Sphenoptera jugoslavica	bronze root borer	well established

The Urophora have high occupancy rates in the flower heads. Larinus larvae feed upon the seeds and can consume an entire seed head. Larinus adults feed upon stems, branches, leaves, and flower buds. Cyphocleonus larvae feed on taproots. Agapeta larvae feed on the roots. Sphenoptera larvae can weaken the rosettes. Larinus and Cyphocleonus are more effective when used in combination.

Prescribed Targeted Grazing

Sheep and goats readily consume diffuse knapweed during the rosette to bolting stage. Goats will eat to the flower stage. Diffuse knapweed is less palatable than Spotted knapweed. The grazing treatment must be severe enough to prevent flowers and seed production, and it needs to be repeated for three to several years.

Integrated Pest Management

Mowing and burning tend to increase stem density by stimulating growth of vegetative sprouts and enhancing seed germination. Grazing and biological control are incompatible because the livestock consume the seedheads that are where the seedhead feeding insect larvae live. However, the chemical treatments will help the grazing treatments to increase in effectiveness.

Management of Yellow starthistle

Initial Control Practice

Early detection and effective response are essential in preventing a large infestation. The major dispersal method of yellow starthistle is movement by construction equipment or farming equipment with small patches occurring along roads. Roads along landholdings should be monitored during early summer to the start of the flowering period and then repeated at three or four week intervals. The highly recommended practice of hand pulling with gloves all of the above ground stem and as much root as will come is the best practical method for small patches. There is a plan B, to spread the Spike 20P pellets at a rate of one pellet per square foot at and around the initial small patch, will save much valuable time (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. If any stem branch remains, new stems can develop from the axil and produce flowers and seeds. Mowing two or three times per year to prevent seed production can reduce weed biomass if repeated for more than three years. Clean the equipment before it is moved to new ground.

Prescribed Burning

Fire usually consumes or kills aboveground plant parts. However, fire can create favorable conditions for the undamaged seeds in the soil seed bank to germinate and become established. Post fire the site has increased bareground, reduced competition from other plants, increased sunlight at the soil surface, and increased available nutrients.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to mid bolting stage or at fall rosette with higher rate

Curtail + NIS
(clopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to mid bolting stage or at fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at seedling or early rosette to late bolting stage

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to bolting stage or at fall rosette

Cimarron Xtra + Remedy Ultra + oil 10%
(chlorsulfuron + metsulfuron) + (triclopyr) + oil and an emulsifier
Applied at late season after seeds mature for effective preemergent and seedling reduction

Biological Control

Biological agents permitted for release in North America

Seedhead-feeding insects		
Bangasternus orientalis	seedhead weevil	mid impact
Chaetorella australis	peacock fly	mid impact
Chaetorella succinea	false peacock fly	most effective
Eustenopus villosus	hairy weevil	most effective
Larinus curtus	flower weevil	low impact
Urophora sirunaseva	banded gall fly	low impact

Bangasternus larvae typically kill 60% of the seeds within their seedhead. Chaetorellia are small nector feeding flies, the larvae consume seeds and flower ovaries. C. succinea larvae kill 80% of the seeds and decrease pollinator visitation. Eustenopus the larvae kill 100% of the seeds and the adults feed on buds. Larinus the females feed on the pollen as they lay eggs in the flowers. Urophora larvae pupate within a woody gall within the flower and disrupt seed production. Eustenopus and Chaetorellia succinea have increased impact when the combination are released together.

Prescribed Targeted Grazing

Sheep and goats will consume yellow starthistle during the rosette stage to bolting stage. The quantity of crude protein is 17% at the rosette stage, 12% at the bolting stage, and 10% at flowering stage. Goats are the most effective grazers because they will graze yellow starthistle during and after flowering stage when the flowerheads are armed with 1 inch stiff thorns. Cattle are reluctant to consume yellow starthistle post early growth stages. It is highly toxic to horses. It will require several years of grazing by goats to deplete the soil seed bank and reduce plant density.

Integrated Pest Management

None of the management methods are completely effective alone. Burning will most likely increase the infestation. The Biological control insects do not kill all of the seeds. The quantity of seeds not killed is enough to fully replace the population of plants each year. They also need some insects that will consume the roots in the future. A combination of goat grazing with an early flower stage mowing treatment plus both preemergent and post emergent herbicide treatments should greatly reduce any yellow starthistle infestation.

Management of Canada Thistle

Initial Control Practice

Canada thistle is considered to be one of the most tenacious and economically important agricultural weeds that can spread rapidly forming dense infestations by vegetative reproduction. Early detection and effective response are essential in preventing a large infestation. Plants that are older than 3 weeks have extensive root systems, if the aboveground stems are hand pulled that breaks off at ground level, the root buds can regenerate new stems. The plan B is to spread the Spike 20P pellets at a rate of one pellet per square foot at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Large quantities of carbohydrate reserves are stored in the extensive root system. Mowing the aboveground stems activates the root buds to produce new stems and use some of the stored carbohydrates, if the new stems are removed before the leaves can replenish the root carbohydrates. After 4 years of repeated mowing every 7 to 28 days, the carbohydrate reserves may be close to being depleted. The mowing should also be timed to eliminate all flowers so no seeds are produced.

Prescribed Burning

Fire will top kill the aboveground stems, the extensive belowground root system will not be killed and the root buds will produce new stems, at a greater stem density than preburn. The bare ground conditions produced by the fire promotes seed germination and seedling establishment.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to pre bud or fall rosette

Curtail + oil adjuvant
(clopyralid + 2,4-D)
Applied at rosette to pre bloom or fall rosette

Overdrive + NIS or MSO
(dicamba + diflufenzopyr) + (non-ionic surfactant or methylated seed oil)
Applied at rosette to prebud or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic sucfactant)
Applied at rosette to prebud or fall rosette

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to prebud or fall rosette

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to prebud or fall rosette

Biological Control

Biological agents permitted for release in North America

Stem-root crown feeding insects		
Ceutrorhynchus litura	stem weevil	mid impact
Trichosirocalus horridus	crown weevil	good impact
Urophora cardui	stem gall fly	mid impact
Accidental Introduction		
Larinus planus	stem weevil	feed on native thistles

Ceutrorhynchus larvae and adult feed on Canada thistle. Trichosirocalus larvae feeding weaken plants and reduce seed production. Urophora larvae form galls in upper stems that divert plant resources and produce fewer seeds. Larinus larvae feed on seeds and flower receptacle.

Prescribed Targeted Grazing

Cattle and horses avoid the plants and the area around the plants. Most weed scientists suggest that grazing is not a control method. However, experienced targeted grazing practitioners claim that sheep will consume some young plants but goats are the preferred grazing animals. The targeted grazing goats will need to consume enough plant biomass to prevent flowering and seed production and must be repeated for at least three years or more. If too much leaf area remains, the carbohydrate reserves can be fully replenished, and any reduction in stem densities can be regained.

Integrated Pest Management

Fire tends to increase stem densities. The biological control agents cause little decrease in plant biomass and seed production. A combination of targeted goat grazing with supplemental mowing treatments to prevent flowers and seed production and reduce any leaf area that could replace the carbohydrate reserves and stimulate new young stems for the goats to eat along with a vigorous regimen of herbicide treatments should reduce a Canada thistle infestation.

Management of Bull thistle

Initial Control Practices

Early detection and effective response are essential in preventing a large infestation. The standard recommended control method for small initial infestation areas is to hand pull with gloves and as much of the root as possible must also be removed. Working agricultural people do not have this much time to waste. To save time, use the plan B to spread the Spike 20P pellets at a rate of one pellet per square foot which is 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Bull thistles crown and 2 inch stem are capable of resprouting and development of flowers and seeds. Repeat mowing is required to cut the resprouted stems from producing seeds. Continue repeat mowing for three or more years. Clean the equipment before it is moved to clean ground.

Prescribed Burning

Fire usually consumes or kills the aboveground plant parts. Some soil seed bank seeds survive 212° F (100° C). The fire creates favorable conditions for the undamaged seeds to germinate and become established. Post fire, the site has increased bare ground, reduced competition from other plants, increased sunlight at the soil surface, and increased available nutrients.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to mid bolting stage or at fall rosette

Curtail + NIS
(clopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to mid bolting stage or at fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at seedling or early rosette to late bolting stage

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to late bolting stage or fall rosette

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to bud or fall rosette

Overdrive + oil
(dicamba + diflufenzopyr) + (oil adjuvant)
Applied at rosette to prebud or fall rosette

Cimarron Xtra + Remedy Ultra + oil
(chlorsulfuron + metsulfuron) + (triclopyr) + (oil adjuvant)
Applied at preemergent and seedling stage

Biological Control

Biological agents permitted for release in North America

Urophora stylata	seedhead gall fly	low population
Trichosirocalus horridus	crown weevil	effective
Release permit revoked		
Rhinocyllus conicus	seedhead weevil	effective

Urophora larvae feed on flower heads and seeds, galls form in flower head with seeds stuck to gall tissue reducing seed dispersal and the galls divert plant resources from normal plant development. Trichosirocalus adults feed on rosettes in spring and thistle foliage in summer, larvae hatch in early summer and feed on tissue at the root-stem junction. Trichosirocalus also feed on native thistles. Rhinocyllus Adults feeding leaves pits on stems and holes in leaves, larvae feed on flower heads and seeds. Rhinocyllus was originally approved for release but discovered they feed on many native thistles and permit was revoked but still present in many places in northern plains.

Prescribed Targeted Grazing

Cattle and horses avoid the plants and the area around the thistles. Most weed scientists suggest that grazing is not a control method. However, experienced targeted grazing practitioners claim that sheep and goats will graze bull thistle heavily during the rosette to bolting stage and reduce the quantity of flowering and seed production.

Integrated Pest Management

Fire tends to increase stem densities. The biological control agents cause some decrease in plant biomass and seed production but have not eliminated bull thistle infestations. A combination of targeted goat grazing with supplemental mowing treatments to prevent flowers and seed production plus a vigorous regimen of herbicide treatments to reduce seedlings and reduce stem density and to decrease seed production could reduce bull thistle.

Management of Musk thistle

Initial Control Practices

Early detection and effective response are essential in preventing a large infestation. The standard recommended control method for small initial infestation areas is to hand pulling with gloves and 2 to 4 inches of root must also be removed. Fortunately, there is a plan B, spread the Spike 20P pellets at a rate of one pellet per square foot of ground which is equal to 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Musk thistles crown and a 2 inch stem are capable of resprouting and development of flowers and seeds. Repeat mowing is required to cut the resprouted stems from producing seeds. Continue mowing multiple times per year for three or more years. Clean the equipment before it is moved to new ground.

Prescribed Burning

Fire sometimes kills the aboveground plant parts and sometimes not. If the crown, is not killed by the heat of the fire, it can resprout and develop flowers and seeds. Some soil seed bank seeds are killed by fire and some are not. The fire creates favorable conditions for the undamaged seeds to germinate and become established. Post fire, the site has increased bareground, reduced competition from other plants, increased sunlight at the soil surface, and increased available nutrients.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to mid bolting stage or fall rosette

Curtail + NIS
(Clopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to mid bolting stage or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at seedling or early rosette to late bolting stage

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied at early rosette to late bolting stage or fall rosette

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to bud or fall rosette

Overdrive + oil
(dicamba + diflufenzopyr) + (oil adjuvant)
Applied at rosette to prebud or fall rosette

Cimarron Xtra + Remedy Ultra + oil
(chlorsulfuron + metsulfuron) + (triclopyr) + (oil adjuvant)
Applied at preemergent and seedling stage

Biological Control

Biological agents permitted for release in North America

Cheilosa corydon	crown fly	limited population
Trichosirocalus horridus	crown weevil	effective
Release permit revoked		
Rhinocyllus conicus	seedhead weevil	effective

Cheilosa larvae mine into shoots and stems and progressively feed on the material. Establishment is limited in the west. Trichosirocalus adults feed on rosettes in spring and thistle foliage in summer, larvae hatch in early summer and feed on tissue at the root-stem junction. Trichosirocalus also feed on native thistles but release permit not revoked. Rhinocyllus adults feeding leaves pits on stems and holes in leaves, larvae feed on flower heads and seeds. Rhinocyllus was originally approved for release but discovered they feed on many native thistles and permit was revoked but still present in many places in northern plains.

Prescribed Targeted Grazing

Cattle and horses avoid the plants and the area around the thistles. Most weed scientists suggest that grazing is not a control method. However, experienced targeted grazing practitioners claim that sheep and goats will graze musk thistle heavily during the rosette to bolting stage and reduce the quantity of flowering and seed production.

Integrated Pest Management

Fire tends to increase stem densities. The biological control agents require 5 to 10 years to build a great enough population to reduce a musk thistle infestation. A combination of targeted goat grazing with supplemental mowing treatments at the preflower stage to prevent seed production plus a vigorous regimen of herbicide treatments to reduce seedlings and reduce stem density and to decrease seed production could reduce musk thistle.

Management of Plumeless Thistle

Initial Control Practices

Early detection and effective response are essential in preventing a large infestation. The standard recommended control method for small initial infestation areas is to hand pulling with gloves and as much root as possible should be removed. Fortunately, there is a Plan B, spread the Spike 20P pellets at a rate of one pellet per square foot of ground which is equal to 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Plumeless thistles are capable of resprouting and development of flowers and seeds. Repeat mowing is required to cut the resprouted stems from producing seeds. Repeated mowing multiple times per year will need to continue for three or more years. Clean the equipment before it is moved to new ground.

Prescribed Burning

Fire sometimes kills the aboveground plant parts and sometimes not. If the crown is not killed by the heat of the fire, it can resprout and develop flowers and seeds. Some soil seed bank seeds are killed by fire and some are not. The fire creates favorable conditions for the undamaged seeds to germinate and become established. Post fire, the site has increased bare ground, reduced competition from other plants, increased sunlight at the soil surface, and increased available nutrients.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied at rosette to mid bolting stage or fall rosette

Curtail + NIS
(clopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to mid bolting stage or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at seedling or early rosette to late bolting stage

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied at early rosette to late bolting stage or fall rosette

Chaparral + NIS
(aminopyralid + metsulfuron) + (non-ionic surfactant)
Applied at rosette to bolting stage or fall rosette

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to bud or fall rosette

Overdrive + oil
(dicamba + diflufenzopyr) + (oil adjuvant)
Applied at rosette to prebud or fall rosette

Cimarron Xtra + Remedy Ultra + oil
(chlorsulfuron + metsulfuron) + (triclopyr) + (oil adjuvant)
Applied at preemergent and seedling stage

Capstone + NIS
(aminopyralid + triclopyr) + (non-ionic surfactant)
Applied at rosette to bolting stage or fall rosette

Biological Control

Biological agents permitted for release in North America

Cheilosa corydon	crown fly	limited population
Trichosirocalus horridus	crown weevil	effective
Release permit revoked		
Rhinocyllus conicus	seedhead weevil	effective

Cheilosa larvae mine into shoots and stems and progressively feed on the material. Establishment is limited in the west. Trichosirocalus adults feed on rosettes in spring and thistle foliage in summer, larvae hatch in early summer and feed on tissue at the root-stem junction. Trichosirocalus also feed on native thistles but release permit not revoked. Rhinocyllus adults feeding leaves pits on stems and holes in leaves, larvae feed on flower heads and seeds. Rhinocyllus was originally approved for release but discovered they feed on many native thistles and permit was revoked but still present in many places in northern plains.

Prescribed Targeted Grazing

Cattle and horses avoid the plants and the area around the thistles. Most weed scientists suggest that grazing is not a control method. Sheep and goats should be able to graze plumeless thistle heavily during the rosette to bolting stage and reduce the quantity of flowering and seed production.

Integrated Pest Management

Fire tends to increase stem densities. The biological control agents require 5 to 10 years to build a great enough population to reduce a plumeless thistle infestation. A combination of targeted goat grazing with supplemental mowing treatments at the preflower stage to prevent seed production plus a vigorous regimen of herbicide treatments to reduce seedlings and reduce stem density and to decrease seed production could reduce plumeless thistle.

Management of Scotch thistle

Initial Control Practices

Early detection and effective response are essential in preventing a large infestation. The standard recommended control method for small initial infestation areas is to hand pulling with gloves and remove as much root as possible. Fortunately, there is a Plan B, spread the Spike 20P pellets at a rate of one pellet per square foot of ground which is equal to 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Scotch thistles are capable of resprouting and development of flowers and seeds. Repeat mowing is required to cut the resprouted stems from producing seeds. Repeated mowing multiple times per year will need to continue for three or more years. Clean the equipment before it is moved to new ground.

Prescribed Burning

Fire may consume or kill most aboveground plant parts. The crown is usually not killed by the heat of the fire, and it can resprout with the new stem developing flowers and seeds. Some soil seed bank seeds are killed by fire and some are not. The fire creates favorable conditions for the undamaged seeds to germinate and become established at denser levels. Post fire, the site has increased bare ground, reduced competition from other plants, increased sunlight at the soil surface, and increased available nutrients.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Escort + 2,4-D + NIS
(metsulfuron) + (2,4-D) + (non-ionic surfactant)
Applied at rosette to bud growth stage

Cimarron Xtra + NIS
(chlorsulfuron + metsulfuron) + (non-ionic surfactant)
Applied at spring prior to flowering or fall rosette

Telar + PastureGard + NIS
(chlorsulfuron) + (triclopyr + fluroxypyr) + (non-ionic surfactant)
Applied at rosette to early bolt

Chaparral + NIS
(aminopyralid + metsulfuron) + (non-ionic surfactant)
Applied at rosette to bolting stage or fall seedling or rosette

Capstone + NIS
(aminopyralid + triclopyr) + (non-ionic surfactant)
Applied at rosette to bolting stage or fall rosette

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied at rosette to bolting stages or fall rosette

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied at rosette to bolting stages or fall rosette

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied at rosette to bolting stages or fall rosette

Graslan + 2,4-D + NIS
(picloram + 2,4-D) + (non-ionic surfactant)
Applied at rosette or bolting to bud stage

Biological Control

No biological agents approved for release in North America

Release permit revoked		
Rhinocyllus conicus	seedhead weevil	effective

Rhinocyllus was originally approved for release but discovered they feed on many native thistles and permit was revoked but it is still present in many places in northern plains and it will feed on scotch thistle. Rhinocyllus adults feeding leaves pits on stems and holes in leaves, larvae feed on flower heads and seeds.

Prescribed Targeted Grazing

Cattle and horses avoid the plants and the area around the thistles. Scotch thistle infestations become impenetrable thorny barriers. Most weed scientists suggest that grazing is not a control method. However, experienced targeted grazing practitioners claim that goats, if confined to the infested area, will heavily graze scotch thistle during the rosette to bolting and bud stages and will reduce the abundance and decrease buds, flowers, and seed production after several repeat years.

Integrated Pest Management

Fire tends to increase stem densities. The biological control agents have a limited population insufficient to cause much reduction in a scotch thistle infestation. A combination of targeted goat grazing with supplemental mowing treatments at the preflower stage to prevent seed production plus a vigorous regimen of herbicide treatments to reduce seedlings and decrease stem density and to reduce seed production could decrease scotch thistle.

Management of Absinth wormwood

Initial Control Practices

Absinth wormwood is a perennial half shrub. The aboveground stem dies back each year to the underground woody caudex. Hand pulling does not work. But plan B does work by spreading the Spike 20P pellets at a rate of one pellet per square foot of ground around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. The woody caudex has buds that will resprout after each mowing. If the stems are taller than 12 inch tall, the plants can be mowed and herbicides can be applied before the new growth is 12 inch tall.

Prescribed Burning

Fire may consume or kill most aboveground plant parts. The belowground woody caudex will produce new sprouts.

Chemical Management

Herbicides must be used according to label. Foliar applied herbicides should be sprayed onto the plant when it is 12 inches tall and actively growing during spring up to the end of June. Follow the label rates of use for problem weeds.

Stinger
(clopyralid)
Applied foliar before stem is 12 inch tall

Curtail + NIS
(clopyralid + 2,4-D) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Milestone + NIS
(aminopyralid) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Capstone + NIS
(aminopyralid + triclopyr) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Chaparral + NIS
(aminopyralid + metsulfuron) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

DuraCor + NIS
(aminopyralid + florpyrauxifen) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

GrazonNext + NIS
(aminopyralid + 2,4-D) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Overdrive + NIS
(dicamba + diflufenzopyr) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Weedmaster + NIS
(dicamba + 2,4-D) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Graslan + NIS
(picloram + 2,4-D) + (non-ionic surfactant)
Applied foliar before stem is 12 inch tall

Biological Control

No biological control agents for absinth wormwood

Prescribed Targeted Grazing

Absinth wormwood is unpalatable to cattle and horses. If cows eat small amount of it, the milk becomes tainted with odor and taste. Sheep and goats may consume more than cattle but they do not consume enough biomass to kill the plants.

Integrated Pest Management

Mowing, burning, and grazing do not kill absinth wormwood and there are no available biocontrol agents. Herbicides are effective at killing the plant when foliar applied when stem is less than 12 inches tall. If the plants are much taller than 12 inch, the plants can be mowed and apply herbicides to the 12 inch tall regrowth.

Management of Dalmation toadflax

Initial Control Practice

Early detection and effective response are essential in preventing a large infestation. Toadflax are perennial with extensive root systems that has lateral roots with several vegetative buds. Hand pulling only is effective for 2 to 3 weeks after germination. Plan B, is to spread the Spike 20P pellets at a rate of one pellet per square foot of ground which is equal to 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Mowing may reduce the quantity of seeds produced but most likely it activates numerous vegetative buds on the caudex and lateral roots to sprout and produce many new stems.

Prescribed Burning

Fire likely top kills aboveground stems, the deep, extensive root system will survive severe fires and reestablish the population from numerous vegetative buds on caudex and lateral roots.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Escort + oil
(metsulfuron) + (oil adjuvant)
Applied foliar to wet entire actively growing plant.

Telar + NIS
(chlorsulfuron) + (non-ionic surfactant)
Applied late summer at flowering stage

Cimarron Xtra + NIS
(metsulfuron + chlorsulfuron) + (non-ionic surfactant)
Applied foliar to actively growing plant

Plateau + MSO
(imazapic) + (methylated seed oil)
Applied to basal growth after first hard frost in fall

Graslan
(picloram + 2,4-D)
Applied to actively growing plant through full bloom stage

Biological Control

Biological agents permitted for release in North America

Brachypterolus pulicarius	flower feeding beetle Dalmation toadflax biotype	accidental introduced
Calophasia lunula	defoliating moth	first toadflax agent
Mecinus janthinus	stem mining weevil	approved release
Rhinusa antirrhini	seed feeding weevil Dalmation toadflax biotype	accidental introduced
Rhinusa neta	seed feeding weevil Dalmation toadflax biotype	accidental introduced

Brachypterolus adults feed on shoot tips and axillary buds, in June eggs are laid in unopened buds and the larvae feed on pollen, anthers, ovaries, and immature seeds. Calophasia adults feed on flower nector, and larvae feed on young leaves first, then the lower leaves as develop later instar stages. Mecinus adults feed on the succulent foliage and stems beneath terminal buds, larvae tunnel within stems. Rhinusa adults feed on leaf buds, young leaves, and young shoots. R. antirrhini eggs are laid in floral ovaries forming a gall around 8 to 12 seeds that grow to 10 times normal size, the larvae feeds on these large seeds and older instar larvae feed on normal seeds. R. neta eggs do not form a gall, the larvae feed on normal seeds.

Prescribed Targeted Grazing

Cattle avoid dalmation toadflax because it is distasteful. Most weed scientists suggest that grazing it is not a control method. However, experienced targeted practitioners claim that sheep and goats readily consume dalmation toadflax after they learn how to graze it. When it is heavily to severely utilized seed development is prevented. It usually takes a 2 year period for sheep and goats to learn how to graze. It is not known how many grazing years it takes to control it.

Integrated Pest Management

Dalmation toadflax is a short lived perennial forb with a deep taproot and extensive root system with numerous vegetative buds. Mowing, burning, and grazing can kill or remove the aboveground stems, but cannot kill the belowground parts. The biocontrol agents are effective but their populations are not great enough to kill the plants. The viable integrated system is a vigorous regimen of herbicide treatments.

Management of Yellow toadflax

Initial Control Practice

Early detection and effective response are essential in preventing a large infestation. Toadflax are perennial with extensive root system that has lateral roots with numerous vegetative buds. Hand pulling only is effective for 2 to 3 weeks after germination. Plan B, is to spread the Spike 20P pellets at a rate of one pellet per square foot of ground which is equal to 0.5 lbs ai/ac at and around the initial small patch (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing does not kill the plant parts below the mow height. Mowing may reduce the quantity of seeds produced but most likely it activates numerous vegetative buds on the caudex and lateral roots to sprout and produce many new stems.

Prescribed Burning

Fire likely top kills aboveground stems, the deep, extensive root system will survive severe fires and reestablish the population from numerous vegetative buds on caudex and lateral roots.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Escort + oil
(metsulfuron) + (oil adjuvant)
Applied foliar to wet entire actively growing plant.

Telar + NIS
(chlorsulfuron) + (non-ionic surfactant)
Applied late summer at flowering stage

Cimarron Xtra + NIS
(metsulfuron + chlorsulfuron) + (non-ionic surfactant)
Applied foliar to actively growing plant

Tordon
(picloran)
Applies to actively growing plant through full bloom stage

Tordon + Overdrive + oil
(picloram) +(dicamba + diflufenzopyr) + (oil adjuvant)
Applied mid summer during flowering or fall prior to frost

Biological Control

Biological agents permitted for release in North America

Brachypterolus pulicarius	flower feeding beetle Yellow toadflax biotype	accidental introduced
Calophasia lunula	defoliating moth	first toadflax agent
Mecinus janthinus	stem mining weevil	approved release
Rhinusa antirrhini	seed feeding weevil Yellow toadflax biotype	accidental introduced
Rhinusa neta	seed feeding weevil Yellow toadflax biotype	accidental introduced

Brachypterolus adults feed on shoot tips and axillary buds, in June eggs are laid in unopened buds and the larvae feed on pollen, anthers, ovaries, and immature seeds. Calophasia adults feed on flower nector, and larvae feed on young leaves first, then the lower leaves as develop later instar stages. Mecinus adults feed on the succulent foliage and stems beneath terminal buds, larvae tunnel within stems. Rhinusa adults feed on leaf buds, young leaves, and young shoots. R. antirrhini eggs are laid in floral ovaries forming a gall around 8 to 12 seeds that grow to 10 times normal size, the larvae feeds on these large seeds, and older instar larvae feed on normal seeds. R. neta eggs do not form a gall, the larvae feed on normal seeds.

Prescribed Targeted Grazing

Cattle, horses, and sheep avoid yellow toadflax plants and goats are very reluctant to eat it. Yellow toadflax contains alkaloids and glucosides that may be toxic to grazing animals if eaten in large quantities. Using targeted grazing to reduce yellow toadflax not recommended as a control method.

Integrated Pest Management

Yellow toadflax is a short lived perennial forb with a deep taproot and extensive root system with numerous vegetative buds. Mowing and burning can kill or remove the aboveground stems, but cannot kill the belowground parts. Grazing as a control method is not recommended because of the toxins. The biocontrol agents are effective but their populations are not great enough to kill the plants. The viable integrated system is a vigorous regimen of herbicide treatments.

Management of Eastern redcedar

Initial Control Practice

Eastern redcedar is a Dr. Jekyll and Mr. Hyde plant. In eastern United States and Canada it is a valued ornamental and shelterbelt tree. New cultivars are being developed at many eastern nurseries for future use. In the grasslands of the North American Great Plains, Eastern redcedar is a serious, persistent, aggressive invasive, problem weed. If it is an initial visual problem, hand pulling is not effective, use plan B and spread the Spike 20P pellets under the dripline at a rate of one pellet per square foot of space which is equal to 0.5 lbs ai/ac (Manske 2006). Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Control

Eastern redcedar does not have vegetative buds on its roots and after it is cut down it does not sprout new shoots. However, the living stump, or the remainder of the trunk, can produce epicormic branches from latent or dormant buds. If the stump is killed by bark applied herbicide treatment it can become a nuisance and will need to be dug or pulled out.

Prescribed Burning

Eastern redcedar is susceptible to fire kill because of its thin bark, shallow roots, and highly combustible evergreen foliage. However, mortality decreases as tree size increases due to relatively thicker bark and greater vertical height of the upper foliage from lethal temperatures

Height class	< 3 ft	3-7 ft	7-10 ft	> 10 ft
Mortality	88%	60%	35%	10%

If the trees are clustered in a definable area, plan to leave adequate surface fuel between the trees and use a spring broadcast burn with live trees. Or the larger trees can be girdled a year ahead of the prescribed spring burn. If the trees are widely spaced and the fine fuel is used as forage for livestock, a propane torch can be use to ignite each live or dead standing tree. If the equipment is large enough, each tree can be pulled out of the ground, put in a pile, and burned during the winter after the trees dry.

Chemical Management

Eastern redcedar is resistant to most foliar applied herbicides except 2 mixes tested in Tennessee. Follow the label rates of use for problem weeds.

Tordon + Comet + Remedy Ultra + NIS
(picloram) + (fluroxypyr) + (triclopyr) +(non-ionic surfactant)
Applied late spring to early summer to actively growing foliage completely wet

Cimarron Xtra + Clarity + NIS
(chlorsulfuron + metsulfuron) + (dicamba) + (non-ionic surfactant)
Applied to actively growing foliage of total plant

Soil applied within drip line

Spike 20P 1 pellet/sq ft=0.5 lb ai/ac (Manske 2006)
(tebuthiuron)
Applied to soil under drip line

Basal Bark applied to < 6 inches diameter; on lower 12 to 18 inches, all sides

Remedy Ultra + 20 to 30% diesel
(triclopyr) + (diesel oil)
Applied during growing season

PastureGard + 75% diesel
(triclopyr + fluroxypyr) + (diesel oil)
Applied during growing season

Crossbow + 4% diesel
(triclopyr + 2,4-D) + (diesel oil)
Applied during growing season

Hack and Squirt-use a machete or hatchet cut through thick bark to sapwood at 45% angle around trunk then add herbicide to cup.

Remedy Ultra 50% + 50% water
(triclopyr) + (water)
Apply 1 ml to each cup around the trunk

PastureGard 50% + 50% water
(triclopyr + fluroxypyr) + (water)
Apply 1 ml to each cup around the trunk

Crossbow 50% + 50% water
(triclopyr + 2,4-D) + (water)
Apply 1 ml to each cup around the trunk

Biological Control

No biological control agents for Eastern redcedar

Prescribed Targeted Grazing

Cattle, horses, and sheep generally avoid Eastern redcedar because its essential oils and monoterpenes that give the plant its distinct odor. Goats will eat young current years growth and if they are fed a high energy/protein supplement they may eat some older branches. Boer and Spanish goats are better than Angora goats. Goats do not remove enough biomass to kill the trees.

Integrated Pest Management

There are no easy ways to kill and remove Eastern redcedar from a grassland. Fire will kill small trees but only about 50% of the trees 5 foot and taller. Several herbicides will kill Eastern redcedar at about 50% in one application. The Spike 20P pellets will take 5 or more years to kill it. A chain saw can cut it down, and then haul it to a pile and burn it in the winter. With heavy equipment the trees can be pulled out of the ground.

Management of Downy brome

Initial Control Practice

The exclusion of invasive plants before they invade, or at least early detection and rapid response, are the most cost-effective and successful ways to prevent impacts of cheatgrass infestations. It is crucial to maintain native vegetation and soil biologically active by management that makes more water and soil nutrients available. There is a window of opportunity early in the invasion of cheatgrass where eradication is both possible and economically feasible by implementation of the integrated approach with combining chemical control, mechanical control, vegetative suppression, and proper livestock management to keep the cheatgrass plants constantly under stress and reducing its ability to flourish and spread. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Early spring mowing should be able to reduce viable seed production if conducted after seedhead elongation but before the plants turn purplish in color. If mowing is conducted after the plants turn purple most plants will be dead but the seed would already be viable and added to the soil seed bank. Improper timed mowing generally benefits expansion of cheatgrass and elevates the fire risk is the reason most scientists consider mowing to not be a control method.

Prescribe Burning

Prescribed fire prior to seed maturation was at earlier times suggested as a method of cheatgrass control. But fire decreases native vegetation which has a longer recovery period than cheatgrass, fire eliminated organic litter may decrease seed germination, but also increase erosion and development of noxious weeds. Hot fire may burn some seeds but early spring fires do not reach high enough temperatures and fire reduce cheatgrass for a short time, without eliminating the soil seed bank, cheatgrass populations are fully restored in a year or two. Cheatgrass produces seeds early and the plants are dead by early June which present a high fire risk over the summer into the fall. The use of fire decreases native vegetation and usually increases cheatgrass.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Rejuvra
(indaziflam) preemergent, active for more than a year
Applied several weeks prior to weed seed germination fall or spring

Rejuvra + Plateau + MSO
(indaziflam) + (imazapic) + (methylated seed oil)
Applied several weeks prior to weed seed germination fall or spring

Outrider + NIS
(sulfosulfuron) + (non-ionic surfactant)
Applied at early vegetative stage, actively growing spring or fall

Telar + Escort + NIS
(chorsulfuron) + (metsulfuron) + (non-ionic surfactant)
Applied at early vegetative stage, actively growing fall or spring

Biological Control

No biological control agents for downy brome

Several microorganisms have been tested for biocontrol of cheatgrass and all have been found to be ineffective at suppressing cheatgrass expansion.

Prescribed Targeted Grazing

Livestock grazing at higher than proper stocking rates is one of the conditions that benefitted cheatgrass expansion. The early control methods were ineffective at cheatgrass reduction. The livestock producers figured out how to use cheatgrass as livestock forage. Targeted grazing strategies are met with preconceived judgement. Experienced targeted grazing practitioners suggest that grazing for a short period just after flowering and prior to seed formation just before the plants start to turn purple can damage or kill cheatgrass plants and inhibit seed production. The grazing should not be heavy enough to harm the desirable perennial plants. Repeat grazing is required for the cheatgrass plants that regenerate seedheads and try to produce seed later. The targeted grazing practices that show promise have been small scale trials and should be given an opportunity to demonstrate large scale effectiveness.

Integrated Pest Management

Fire tends to expend cheatgrass and there are no effective biological control insects or microorganism pathogens. However, there are several recent herbicides that show great promise and recently developed targeted grazing practices that have good potential and need expanded use in combination or separately.

Management of Japanese Brome

Initial Control Practice

The exclusion of invasive plants before they invade or at least early detection and rapid response, are the most cost-effective and successful ways to prevent impacts of Japanese brome infestations. It is critical to maintain native grassland vegetation and soil biologically active by management that makes more water and soil nutrients available. There is a window of opportunity early in the invasion of Japanese brome where eradication is both possible and economically feasible by implementation of the integrated approach with combining chemical control, mechanical control, vegetative suppression, and proper livestock management to keep the annual brome plants constantly under stress and reducing its ability to flourish and spread. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Early spring mowing should be able to reduce seed production if conducted after seedhead elongation but before the plants turn purple in color. If mowing is conducted after the plants turn purple most plants will be dead but the seed would already be viable and some seed added to the soil seed bank, however, much seed remains on the inflorescence late into the fall. Improperly timed mowing generally benefits expansion of annual brome and is the reason most scientists consider mowing to not be a viable control method.

Prescribed Burning

Prescribed fire prior to seed maturation was at earlier times suggested as a method of Japanese brome reduction, which would last one to two years. But fire decreases native vegetation which has a longer recovery period than annual brome, fire eliminates organic litter which may decrease seed germination, but also increases erosion and development of other noxious weeds. Hot fire may burn some seeds, but early spring fires do not reach high enough temperatures, and fires reduce annual bromes for a short time, without eliminating much of the soil seed bank, Japanese brome populations are fully restored in a year or two. Japanese brome produces seeds early and the plants are dead by early June which presents a fire risk over the summer into the fall. The use of fire decreases native vegetation and usually increase Japanese brome.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Rejuvra
(indaziflam) preemergent, active for more than a year
Applied several weeks prior to weed seed germination fall or spring

Rejuvra + Plateau + MSO
(indaziflam) + (imazapic) + (methylated seed oil)
Applied several weeks prior to weed seed germination fall or spring

Outrider + NIS
(sulfosulfuron) + (non-ionic surfactant)
Applied at early vegetative stage, actively growing spring or fall

Telar + Escort + NIS
(chlorsulfuron) + (metsulfuron) + (non-ionic surfactant)
Applied at early vegetative stage, actively growing fall or spring

Biological Control

No biological control agents for Japanese brome

Prescribed Targeted Grazing

Japanese brome has high forage quality during the fall, in the spring for short periods before it matures and decreases to 2 to 4% crude protein. Livestock select for Japanese brome during these short growth periods. Japanese brome retains some seeds in the inflorescence into the fall, some livestock select these inflorescence as feed. Grazing at the appropriate periods can reduce stem density and biomass and reduce the quantity of viable seeds added to the soil seed bank.

Integrated Pest Management

Fire tends to expand Japanese brome infestations and there are no effective biological control agents.

However, there are several recent herbicides that show great promise. Even though, in the past, grazing as a control measure has had variable results, new concepts of targeted grazing are showing positive results on small scale trials. The new herbicides and targeted grazing concepts need expanded use in combination or separately.

Management of Kentucky bluegrass

Initial Control Practices

The initial infestation occurred a long time ago. The best that can be done is to reduce the rate of increase and decrease the quantity to a low value. Using it early and using it heavy is why we have the problem, it is not the method to reduce it. Kentucky bluegrass has developed highly effective defoliation mechanisms which are slightly better than the defoliation mechanisms developed by native grasses. Thus Kentucky bluegrass will survive short mowing and heavy grazing better than the native grasses. However, native grasses have developed two mechanisms better than Kentucky bluegrass, these are the nutrient resource uptake and the water use efficiency mechanisms. These can be activated by removing 25% to 33% of the aboveground leaf and stem of 60% to 80% of the lead tillers at vegetative growth stages after the 3 and a half new leaves and before the flowering stage. This requires a stocking rate of 90% of the seasonlong stocking rate or greater. And the soil microbes need to be converting 100 lbs/ac of organic nitrogen into mineral nitrogen. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Kentucky bluegrass can tolerate severe mowing treatments

Prescribed Burning

Kentucky bluegrass can be reduced 64% by four repeated burns conducted every-other-year but retains enough shoot frequency to recover when the burn treatments stop.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Plateau + MSO
(imazapic) + (methylated seed oil)
Applied at growing vegetative stage before boot stage for suppression

Select Max + NIS
(clethodim) + (non-ionic surfactant)
Applied at growing vegetative stage, selective for most annual and perennial grasses

Biological Control

No biological control agents for Kentucky bluegrass

Prescribed Targeted Grazing

Kentucky bluegrass cannot be grazed heavily enough to remove it from native grass community and all of the desirable species would be hurt more. But by partial defoliation that removes 25% to 33% of the aboveground foliage at greater than 90% of seasonlong stocking rate can increase rhizosphere microorganisms to a level that converts 100 lbs/ac of mineral nitrogen from organic nitrogen and activates the native grass internal growth mechanisms to out compete Kentucky bluegrass for soil nutrients and water.

Integrated Pest Management

Kentucky bluegrass is hard to control. It cannot be mowed out. It cannot be burned out. It cannot be grazed out. There are no herbicides designed to kill it. There are no biocontrol agents. But it can be managed by improving the native grasses, and ecosystem so the native grasses can out compete Kentucky bluegrass by implementation of Biologically Effective grazing management strategies.

Management of Canada bluegrass

Initial Control Practice

Poa compressa was first recognized in western North Dakota in 1970 and was classified as scarce from three specimens and its remained at low abundance for the next 20 years. Poa pratensis was first recognized in western North Dakota in 1910 and was classified as common from numerous specimens and was growing throughout the entire area and easily located. During the dry period of 1988 to 1992, no Poa compressa or P. pratensis samples were quantitatively collected on the sandy, shallow, or silty collection sites. Poa compressa made great increases since 1999 but Poa pratensis has remained at low abundance ever since the return of normal precipitation. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Canada bluegrass has an extensive rhizome system and can tolerate severe mowing treatments,

Prescribed Burning

Canada bluegrass can be reduced by repeated burn treatments but can not be removed from a community by fire.

Chemical Management

Herbicides must be used according to label. There are no herbicides that can selectively remove Canada bluegrass from a native plant community without damage to native grasses.

Biological Control

No biological control agents for Canada bluegrass.

Prescribed Targeted Grazing

Canada bluegrass cannot be grazed heavy enough to remove it from a native grass community and all of the desirable species would be hurt more. Canada bluegrass is not as aggressive as Kentucky bluegrass. Canada bluegrass does better in nongrazed areas than in grazed areas. On the nongrazed sites Canada bluegrass has a 14 year mean basal cover of 4.9%, on the grazed seasonlong site the mean basal cover is 1.1%, and on the grazed twice-over site the mean basal cover is 0.5%.

Integrated Pest Management

Canada bluegrass is hard to control. It cannot be mowed out. It cannot be burned out. It cannot be grazed out. There are no herbicides designed to kill it. There are no biocontrol agents. But it can be managed by improving the native grasses and ecosystem so the native grasses can out compete Canada bluegrass by implementation of Biologically Effective grazing management strategies.

Management of Bulbous bluegrass

Initial Control Practice

Bulbous bluegrass is easily overlooked. Each tiller grows from a basal bulb usually in a cluster just below the soil level, with spring growth starting very early in late March or early April. It can out complete desirable perennial grasses for early soil water. The florets in the inflorescence do not produce seeds, but vegetative bulbils that are mature during May and shed in June. The bulbils can be moved long distances by wind, animals, and vehicles. The plant is completely dried by July. O.A Stevens documented that bulbous bluegrass was well established at the Dickinson research center in 1912. It is considered to be naturalized in western North Dakota and South Dakota, Nebraska, and other western states. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

Mowing is not considered to be an effective control method.

Prescribed Burning

Fire can top kill the aboveground parts, but has no impact on the bulblets in the soil and would not reduce the population density.

Chemical Management

Herbicides must be used according to label. Follow the label rates of use for problem weeds.

Plateau + MSO
(imazapic) + (methylated seed oil)
Applied at early growing vegetative stage

Matrix + NIS
(rimsulfuron) + (non-ionic surfactant)
Applied at early growing vegetative stage

Telar + Oust + NIS
(chlorsulfuron) + (sulfometuron) + (non-ionic surfactant)
Applied as preemergence and early post emergence just prior to bulblet start of growth

Outrider + NIS
(sulfosulfuron) + (non-ionic surfactant)
Applied very early spring as bulblet start growing, before perennial grass growth

Biological Control

No biological control agents for bulbous bluegrass

Prescribed Targeted Grazing

Cattle rarely eat bulbous bluegrass. The grazing period would need to start about mid March and end by mid May when the bulbils are mature. The perennial native grasses would be severely injured and the spring wet soil would be compacted.

Integrated Pest Management

Bulbous bluegrass is hard to control. It cannot be mowed out. It cannot be burned out. It cannot be grazed out. There are no biocontrol agents. There are no specific herbicides to kill it within a native grass community. The only tools are a few herbicides that can reduce it. The spots where it grows will need to be marked by a stake or telephone GPS, and very early each spring these spots will need to be sprayed with an effective herbicide.

Management of Lesser Spikemoss

Initial Control Practice

We have missed the initial infestation of Lesser spikemoss (clubmoss) by 350 million years. These plants are older than the dirt in the Northern Plains. These plants have survived three major mass extinction events. The growth rate of lesser spikemoss is very slow about 0.4 inches (1 cm) per year. It takes decades for lesser spikemoss to develop into a problem plant. Implement biologically effective grazing management for pestiferous weed invasion prevention.

Mechanical Mowing

The primary branches are horizontal at soil level with upright stems about 1 inch tall with 86% of the plant weight below ground. Mowing treatments are ineffective. Mechanical pitting, furrowing, and ripping treatments are costly and cause extensive damage to grassland ecosystems that require decades or centuries to recover.

Prescribed Burning

Hot fire on dry soil cause some rate of death loss of lesser spikemoss plants, but cool spring fires on shallow sites with low grass biomass and moist soil would have little death loss of lesser spikemoss.

Chemical Management

Some studies from the 1960's and 1970's claim effective reduction of lesser spikemoss with atrazine, paraquat, and bromcial, but these herbicides also killed other desirable vegetation that reduced grass biomass yield.

Biological Control

No biological control agents for Lesser spikemoss (clubmoss).

Prescribed Targeted Grazing

Lesser spikemoss does not provide forage, it is 16.5% silica.

Integrated Pest Management

Lesser spikemoss occupies space that forage plants could grow. Spikemoss can grow and outcompete grasses of shallow soils because when managed by traditional practices shallow soils have a functionality problem with low microbial activity, low available mineral nitrogen, and extremely low water holding capacity. Spikemoss has lower water and nutrient requirements than grass plants and when soil water is low spikemoss has the ability for complete or nearly complete summer dormancy and it can regulate its recovery rate from partial to full depending on the amounts of precipitation received.

When grasses transform into summer dormancy because of the lack of soil water, they cannot develop into complete dormancy, they tend to maintain the same quantity of active tissue as during winter dormancy. Because grasses cannot develop complete dormancy, when the shallow soil water is used up and the interval between rain events is long, a greater biomass of grass dies compared to the percent of spikemoss. Spikemoss maintains a spot in the grassland community, because it can develop into very near to complete dormancy when the shallow soil water dries up.

The problems with the shallow soil functionality need to be corrected. The old traditional style management needs to be changed to biologically effective management that was designed to increase soil microbial activity by transferring the surplus carbohydrates produced by vegetative grass tillers through the roots to the soil microbes, the resulting increase in microbial activity would increase the quantity of available mineral nitrogen that would help activate the internal grass growth mechanisms that would replace the lost grass stems and leaves producing greater quantities of soil organic matter. Also the increased microbial activity would improve soil aggregation that with the increased organic matter would increase the water holding capacity of the soils. These improved changes in soil functionality would give grass plants a competitive advantage over the spikemoss and gradually reduce the land space occupied by the spikemoss.

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