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Role of Herbicides in Invasive Plant Management Systems

Robert A. Masters
Dow AgroSciences, LLC

Byron B. Sleugh
Dow AgroSciences, LLC

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Role of herbicides in invasive plant management systems

Robert A . Masters and Byron B . Sleugh
Dow AgroSciences LLC , 9330 Zionsville Road , Indianapolis , Indiana 46268 , ramasters@ dow .com

Key points : Invasive plants alter ecological processes , displace desirable species , and reduce wildlife habitat quality , riparian area integrity , and rangeland value . Invasive plant presence is often symptomatic of management problems that need correcting before long-term rangeland improvement can occur . Control of invasive plants may open niches for establishment of other undesirable plants unless desirable plants are present to fill vacated niches . Integrated weed management employs planned , sequential use of multiple tactics (e .g . chemical , biological , cultural , and mechanical control measures) to improve ecosystem function and structure while reducing invasive plant impacts below desired thresholds . Sustainable integrated invasive plant management strategies require assessing plant impacts , understanding and managing the processes influencing invasion , and knowledge of invasive plant biology and ecology .

Key words : restoration , integrated invasive plant management , noxious weed

Introduction

Invasive plants can cause adverse impacts as they spread through terrestrial and aquatic ecosystems . Many of the estimated 5000 alien plants that now occur in natural ecosystems in the United States were introduced for food , fiber , or ornamental purposes (U .S . Congress , Office of Technology Assessment , 1993) . While many of these plants are of great value to U .S . society , a small number have become invasive and a major threat to natural ecosystems . Predicting which plants will be invasive and which ecosystems will be invaded is highly desirable , but identifying salient characteristics of invasiveness and invasibility remains illusive (Rejmanek and Robinson , 1996) . Those plants that become invasive disrupt ecosystem processes and reduce the capacity of ecosystems to recover to a desirable state after disturbance and provide the goods and services required by society (Costanza et al . , 1997 ; Pimental et al . , 2000) .

The presence and spread of invasive plants on rangeland is often symptomatic of underlying management problems that need correction before sustainable progress toward rangeland restoration can be achieved . Disturbance is a key factor that drives the invasion process . Disturbance often increases safe site availability for invasive plant establishment (Harper , 1977) . White and Pickett (1985) defined disturbance as any discrete event in time that disrupts ecosystem , community , or population structure , and changes resource availability or the physical environment . Events that affect resource availability and ecosystem processes include fire , storms , floods , grazing management , and fertilization . Disturbances associated with global change (global warming , increasing atmospheric CO_2 , increasing nitrogen deposition etc .) will likely influence invasive plant distributions (Vitousek et al . , 1997) . Community susceptibility to invasion increases when disturbances deviate from historical patterns because the resident species are not adapted to the new disturbance regime (Burke and Grime , 1996) . Managing invasive plants requires manipulating disturbance regimes to favor desirable species .

The use of any single technology to control invasive plants is often not successful over the long-term in restoring degraded rangeland communities . Removing or suppressing an invasive plant species with a single control measure may only open niches for other undesirable species to occupy or to be reinvaded by the same species unless the vacated niches are filled by desirable species . Where desirable species are either not present or in low abundance , plant community recovery will be slow or will not occur without revegetation (Masters et al . , 2001) . Instead of relying on a single vegetation management technology , integrated invasive plant management programs that involve the coordinated use of multiple tactics to assure stable ecosystem function and structure , while reducing invasive plant impacts below economic levels and minimizing hazard to humans , animals , plants , and the environment should be used (U .S . Congress , Office of Technology Assessment , 1993) . Developing effective integrated invasive plant management programs requires an understanding of the biology and ecology of the invasive plant and invaded community . Information about plant demography , propagule dynamics , seedling recruitment , plant growth and development , and methods of reproduction will help identify vulnerabilities that can be exploited to optimize integrated management programs (Radosevich et al . , 1997) .

All available tools should be considered during development of integrated invasive plant management programs and those selected should optimize attainment of management objectives . Integrated management emphasizes management of rangeland ecosystem function and structure rather than a specific weed or control method (Scifres , 1987) . The goals of invasive plant management should be to restore degraded rangeland communities so they can resist re-invasion by invasive plants , be resilient to disturbance , and better meet land use objectives (Masters and Sheley , 2001) . Sequential application of complementary and possibly synergistic tactics will accelerate achievement of these restoration goals .

Weed Management Strategies

Prevention , control , and eradication are three basic weed management strategies . Prevention is probably the most economical and practical way to manage weeds . Prevention includes removing weed seed and vegetative material from implements used to manage rangeland vegetation and planting seed that is not contaminated with weed seed . Preventing weed introduction by restricting movement of propagules from infested areas can minimize invader dispersal into new habitats . Control is the process of minimizing weed interference with desirable plants to meet land manager ecological and economic goals . Eradication involves complete elimination of a weed and requires removal of living plants and destruction of seed in the soil . In practice , eradication is difficult to achieve except on a small scale where an invasive plant outbreak is quickly recognized and intense management and monitoring are feasible .

Invasive Plant Control Methods

Biological Biological control is the planned use of living organisms to reduce a plant's reproductive capacity , density , and effect (Quimby et al . , 1991) . Classical biological control is the planned relocation of natural enemies of exotic weeds from their native habitats onto weeds in their naturalized habitats . This strategy seeks to reestablish weed and natural enemy interactions that reduce the weed population and impacts to an acceptable level (DeBach and Rosen , 1990) . Synchrony in the life cycles of host plant and agent , adaptation of the agent to a new climate and habitats , ability of the agent to find the host at varying densities , capacity of the agent to reproduce rapidly , and the nature , extent , and timing of the damage caused by the agent are among the factors that determine biocontrol agent effectiveness . The release of imported biological control agents on invasive plants is not without risk (Louda et al . , 1997) . Biocontrol involves release of exotic organisms to control other exotic organisms . Use of native relatives of the exotic weeds by the introduced natural enemy is a potential detrimental effect of biological control . Harm to native plants can be reduced by targeting weeds with few or no close relatives that are native in the region where the exotic weed occurs .

Cultural Cultural practices include fire , grazing , revegetation or reseeding , plant competition , and fertilization . These methods are generally aimed at enhancing desirable vegetation complexes . Fire , along with climate and herbivory , are important factors that form and maintain grassland ecosystems (Wright and Bailey , 1982) . Fire effects on ecosystems are influenced by its frequency , intensity , season of occurrence , and interactions with other disturbances . Diet selectivity by herbivores alters competitive interactions within plant communities (Luken , 1990) . Grazing by animals preferring invasive plants can shift the plant community toward more desired species (Walker , 1995) . In contrast , excessive cattle grazing without periodic rest can selectively reduce grass competitiveness , shifting the competitive advantage to less palatable weedy species (Svejcar and Tausch , 1991) . Establishing desirable grasses , forbs , and legumes may suppress invasive plants , enhance plant community resistance to further invasion , and improve rangeland forage production and quality (Lym and Tober , 1997 ; Masters et al . , 2001 ; Whitson and Koch , 1998) .

Mechanical Mechanical treatments involve either removal of the aerial plant portions or removal of enough of the root and crown to kill the plant . Annuals and some biennials and perennials can be suppressed or controlled if mowing occurs before fruits mature and viable seeds form . Mowing perennial herbaceous or woody plants that have the capability to reproduce vegetatively often exacerbate plant interference with ecosystem function by stimulating production of new stems from vegetative buds below the cut surface . Perennial plants that reproduce vegetatively can be severely damaged or killed by tillage , bulldozing , root-plowing , or grubbing (Vallentine , 1989) . The high cost and levels of site disturbance caused by these mechanical treatments can be a constraint to their use .

Chemical Herbicides are assigned to groups according to their chemistry and mode of action (Ross and Lembi , 1999) . Mode of action refers to the system , process , or tissue affected by the herbicide . An herbicide is usually selective only within certain rates , environmental conditions , and methods of application . Foliar-active herbicides are applied directly to the leaves or stems of plants where they are absorbed and translocated in the plant . These herbicides may or may not remain active once moved into the soil . Soil-active herbicides are absorbed by the roots from the soil water solution .

Herbicides serve as catalysts to expedite desired shifts in botanical composition over the short-term and desired changes in ecosystem function and structure over the longer-term when integrated into vegetation management programs . A variety of herbicides are currently available and provide several options to control weeds , restore rangeland communities , and minimize negative effects on desired plants (Table 1) . Rate , timing , method , and frequency of application , herbicide mode of action , and use of adjuvants influence herbicide selectivity and can be manipulated to alleviate adverse impacts of herbicides . Herbicides can be either broadcast-applied or applied to individual plants . Broadcast treatments can be applied using ground equipment or aerially by fixed-wing aircraft or helicopter . Individual plant treatments can be efficient , cost-effective alternatives to broadcast applications to control brush , shrubs , vines , and small patches of herbaceous plants . Selectivity achieved with individual plant treatments can often reduces injury to desirable plants and reduce the amount of herbicide applied per unit area .

Individual plant treatments include foliar sprays , basal sprays , direct injection , cut-stump sprays , and soil treatment (Bovey , 2001) . Foliar sprays involve application of diluted herbicide solution to the plant foliage . To optimize efficacy the spray should be applied after full leaf expansion and should thoroughly cover foliage of the target plant . Basal sprays can be used to selectively control woody plants that are too large for foliar applications . Low volume basal sprays are comprised of mixtures of

20 to 30% herbicide in 70 to 80% oil and applied to the lower 35 to 50 cm of the trunk. These treatments are most effective when controlling trees with a main trunk that is 15 cm in diameter or less. When trees are larger than 15 cm in diameter, control can be achieved by applying herbicide solution to notches cut in the tree bark or the cut surface after the tree is cut down and directly injecting the herbicide solution into the tree. A cut-stump spray comprised of herbicide in water or oil can be applied to the cut surface of a felled tree. The stump should be treated immediately after cutting if a water-based spray solution is used. When using an oil-based spray solution application can be delayed after cutting. Water-or oil-based spray solutions should be applied to thoroughly wet the sides of the stump and cut surface, but not to the point of runoff. Low volume basal and cut-stump sprays can be applied any time of the year, except when snow or water prevents spray contact and penetration into the bark or cut-surface.

Table 1 *Selected herbicides for use on rangeland.*[1,2]

Chemical group	Common name	Mode of action
Benzoic acid	Dicamba	Auxin-type growth regulator
Benzonitrile	Bromoxynil	Photosynthetic inhibitor
Bipyridilium	Paraquat	Photosystem 1 energized cell membrane disrupter
Semicarbazones	Diflufenzopyr	Auxin transport inhibitor
Imidazolinone	Imazapic, Imazapyr	Branched-chain amino acid inhibitor
Phenoxy acid	2,4-D	Auxin-type growth regulator
Phenylurea	Tebuthiuron	Photosynthetic inhibitor
Pyridine carboxylic acid	Aminopyralid, Clopyralid, Fluroxypyr, Picloram, Triclopyr	Auxin-type growth regulator
s-Triazine	Hexazinone	Photosynthetic inhibitor
Sulfonylurea	Chlorsulfuron, Metsulfuron-methyl	Branched-chain amino acid inhibitor
Unassigned	Glyphosate	Aromatic amino acid inhibitor

[1] Chemical group and mode of action from Ross and Lembi (1999) and common names from Weed Science Society of America.
[2] Refer to herbicide product label for proper use instructions.

There are several examples of vegetation management strategies in which herbicides have been integrated to successfully manage invasive plants and improve rangeland communities (Table 2). Revegetation is an important component of integrated approaches because it is essential that desirable plant species, rather than another invasive plant species, fill the niche vacated by the controlled invader. Herbicides reduce interference of invasive plants with establishment of desirable plant species used during the revegetation process.

The desired plant community serves as the goal for rangeland invasive plant management programs and is defined as, "... of the several plant communities that may occupy a site, the one that has been identified through a management plan to best meet the plan's objectives for the site" (Task Group on Unity in Concepts and Terminology, 1995). This concept recognizes that plant community succession for a given site can progress along multiple trajectories that result in different outcomes. Factors that influence these outcomes include past management, plant and animal dispersal from adjacent areas, climatic conditions, disturbance regimes (past, present, and future), and species selected for revegetation projects. The desired plant community concept is consistent with prevailing state and transition (Westoby et al., 1989) and threshold (Friedel, 1991) models of vegetation change. These non-equilibrium models of succession have superseded the unidirectional Clementsian climax community model (Clements, 1916).

Table 2 *Examples of integrated strategies for control of invasive plants on rangeland.*

Invasive plant	Strategy components	Citation
Acroptilon repens	Tillage, herbicide, revegetation	Bottoms and Whitson, 1998; Benz et al., 1999
Bromus tectorum	Tillage, herbicide, revegetation	Eckert and Evans, 1967; Whitson and Koch, 1998
Centaurea solstitialis	Herbicide, revegetation, biocontrol	Enloe and DiTomaso, 1999
Cirsium arvense	Herbicide, revegetation	Wilson and Kachman, 1999
Euphorbia esula	Herbicide, biocontrol	Nelson and Lym, 2003
Euphorbia esula	Tillage, herbicide, revegetation	Lym and Tober, 1997
Euphorbia esula	Grazing, herbicide	Lym et al., 1997
Euphorbia esula	Herbicide, burning, revegetation	Masters and Nissen, 1998; Masters et al., 2001
Lepidium latifolium	Mowing, herbicide	Renz and DiTomaso, 1999
Taeniatherum caput-medusae	Tillage, herbicide, revegetation	Young et al., 1969

The desired plant community is an appealing concept for rangeland management because it empowers land managers to design a plant community that meets management objectives . In the context of invasive plant management , resistance to alien plant invasion is a key criterion when designing a desired plant community . Obtaining the desired plant community involves managing succession , which requires knowledge of the 3 general causes of succession : site availability ; differential species availability ; and species performance (Pickett et al . , 1987 ; Luken , 1990) . These three components can be modified by using designed disturbance , controlled colonization , and controlled species performance (Pickett et al . , 1987) . Designed disturbances include activities that create or eliminate site availability for plant colonization . In successional management , designed disturbances are used to alter successional trajectories and to minimize reliance on external inputs . Controlled colonization is the intentional alteration of availability and establishment of plant species by influencing seed banks , propagule pools , and regulation of safe sites for germination and establishment of desirable species . Invasive plant seed banks can be depleted through attrition if seed production is prevented or reduced . Controlled species performance results from manipulating growth and reproduction of plant species . Various tactics including biological and chemical weed control , grazing , mowing , fertilization , and planting competitive species can influence differential species performance in manner that enables land management goals to be achieved .

Conclusions

Invasive plants can have adverse effects on rangeland ecosystems by disrupting ecosystem processes and reducing ecosystem capacity to recover after disturbance . Disturbance is an important factor affecting ecosystem function and structure , which can facilitate plant invasion . Managing invasive plants requires manipulating disturbance regimes to favor desirable species . Integrated invasive plant management provides a context for managing vegetation that focuses on restoration of ecosystem processes and not on particular plant species or control practices . The advantages and disadvantages of vegetation control tactics will vary according to the invasive plant and invaded site characteristics . The merits of each control measure and the potential for complementary or synergistic interactions when applying measures in appropriate sequences and combinations should be considered when developing integrated weed management programs . The reasons for the arrival , establishment , and spread of invasive plants must be understood before sustained progress can be made toward controlling invasive plants and restoring rangeland ecosystems . Simply removing invasive plant species with selected control measures may only open niches for other undesirable species to occupy if desirable species are not present . An appropriate goal of invasive plant management programs should be to restore desirable native or introduced species communities that resist invasion and are resilient to disturbance .

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