EB2003

Jointed Goatgrass Best Management Practices (BMP) Intermountain Region

Jointed goatgrass (*Aegilops cylindrica*) is an annual invasive grass weed that infests winter wheat fields in the western United States, resulting in reduced wheat yield and quality. Native to southern Europe and Russia, jointed goatgrass is believed to have been introduced into the United States in contaminated wheat in the late 1800s. Most recent estimates place the number of infested acres in the U.S. at five million, across several western and Midwestern states. Research has shown that jointed goatgrass infestations can reduce wheat yields up to 30%. In 2003, yield losses due to jointed goatgrass infestations for the Intermountain region, including Utah, southern Idaho, and parts of Nevada, were approximately 139,000 bushels of winter wheat. Spikelets of jointed goatgrass cannot be completely removed from contaminated wheat grain with conventional sieve-type, or special length-grading seed cleaners. This results in increased dockage and a lower market price when marketing the wheat grain.

Jointed goatgrass identification and management are complex issues. Similarity to wheat in appearance and life cycle make jointed goatgrass difficult to accurately identify in the field. Additionally, genetic similarities to wheat make it difficult to selectively control with herbicides. Under conditions of adequate precipitation, wheat is more competitive for resources than jointed goatgrass. However, this relationship reverses once moisture becomes limiting. This is of particular concern in the Intermountain region because of severely limited moisture available for dryland cropping systems. In areas where annual precipitation is less than approximately 15 inches per year, producers generally use a winter wheat-fallow rotation to ensure sufficient moisture for maximum crop yields.

Management Practices

Management practices fall into two categories: prevention and control. The best management technique for control of jointed goatgrass is to avoid an infestation in the first place. This is the most effective and cost-efficient strategy available. However, once jointed goatgrass is present, measures need to be taken to prevent spread to uninfested areas.

Prevention

The most fundamentally important element in preventing jointed goatgrass infestations is education. Learning how to identify jointed goatgrass, as well as understanding its life cycle and seed dispersal characteristics, are crucial to any management program. Seed dispersal is the only means of jointed goatgrass dissemination. Therefore, a good management practice is to plant high quality seed that is free of both weeds and diseases. A survey performed in Utah found jointed goatgrass spikelets in 6% of 450 drill-boxes sampled. Certified seed is best, but if you must plant bin-run seed, thoroughly inspect the seed lot to ensure it is free from jointed goatgrass spikelets. Early detection is essential for minimizing the spread of jointed goatgrass. Fields must be scouted in order to locate small or isolated populations of jointed goatgrass before they become a bigger problem.

Increased care during field operations can also reduce the spread of jointed goatgrass. Planting, tillage, and harvesting equipment should be cleaned before moving from field to field. Trucks transporting grain should be

Jointed Goatgrass Management Toolbox

- Prevent initial infestations
- Plant jointed goatgrass-free certified seed
- Optimize tillage timing and technique
- Consider integrating Clearfield® technology into your program
- Integrate multiple management practices to battle jointed goatgrass

covered to prevent seed dispersal along roadways. Eliminate jointed goatgrass growing in field borders and adjacent areas such as set-aside acres, fence rows, roadsides, and ditch banks before head emergence. Fine-grind roller mill contaminated grain before feeding to animals. Used in combination, these practices can minimize the spread of jointed goatgrass seed.

Research has shown that jointed goatgrass and wheat can hybridize. However, it is not known if jointed goatgrass will hybridize with all commercial wheat cultivars. If wheat is the female parent, the hybrid seeds appear to be indistinguishable from wheat seed and only reveal themselves as hybrid plants in the ensuing wheat crop (Figure 1). This is a serious problem for certified wheat seed producers in states with zero tolerance for jointed goatgrass seed. It is also a challenge, although probably less so, for producers of food or feed wheat varieties.

Scientists once believed that plants produced from jointed goatgrass and wheat crosses were sterile. However, recent studies have shown that while the hybrids are indeed male sterile, about 1 to 2% viable seed set does occur on the hybrids due to cross pollination from adjacent wheat or jointed goatgrass plants.

Herbicide-resistant wheat and jointed goatgrass are genetically related and some cross pollination may occur (1 to 2%). If the resulting hybrid is then allowed to backcross to jointed goatgrass, a herbicide-resistant biotype can occur. Naturally-resistant biotypes may also be selected for in jointed goatgrass populations. Repeated application of herbicides with the same mode of action creates a selection pressure that favors biotypes resistant to that mode of action. This includes different herbicides with the same mode of action used to control weeds in other crops in the same field. Research has shown that rotating the use of herbicides with differing modes of action is an effective strategy in slowing the development of resistant weed populations.

Figure 1. Left to right: wheat, wheat x jointed goatgrass hybrids (3 hybrid spikelets shown), and pure jointed goatgrass.

Cultural Control

Cultural practices that have shown the most promise for jointed goatgrass control include crop rotation, fertilizer placement, cultivating competitive wheat varieties, higher seeding rate, large-sized seed, altered planting dates, and improved soil moisture management.

Crop Rotation. Crop rotation is one of the most important tools for controlling jointed goatgrass. A winter wheat-fallow rotation is the most common rotation used in dryland wheat production in the Intermountain region. It also creates one of the most challenging situations for jointed goatgrass control. Alternative crops, such as safflower, canola, camelina, and sunflower, disrupt the life cycle of jointed goatgrass and allow for periods of selective jointed goatgrass control. Recent research in Utah and Idaho showed that by including safflower as an alternative crop in a wheat-fallow rotation, jointed goatgrass populations were reduced to near zero in two separate five-year studies (Tables 1 and 2). In comparison, jointed goatgrass plant density in a wheat-fallow rotation (without safflower) continued to escalate and was 5.4 and 9.5 times higher in the fifth year than the initial density at Location 1 (Table 1) and Location 2 (Table 2), respectively.

Economic impact estimates from 1994 to 1999 (Table 1) suggest that net profit could have been increased by 34% simply by adding safflower to the rotation system. In the second study (Table 2), profits increased by 45% over a five year period with the addition of safflower. Thus, adding safflower to the rotation provided positive income in four of six crop years, whereas the wheat-fallow system only provided income in three of six years. More detailed

Table 1. Jointed goatgrass plant density, crop yield, and economic impact estimates in two wheat rotations during a six-year crop rotation in northern Utah and southern Idaho (Location 1), 1994-1999.[a]

					Economic Impact Estimates[d]		
Rotation	Year	Crop Phase[b]	JGG Plant Density	Crop Grain Yield[c]	Gross Profit	Expenses	Net Profit
			no./ sq. ft.				
W-F	1994	Fallow	-	-	-	$17.00	($17.00)
	1995	Wheat	29	89	$469.56	$70.20	$399.36
	1996	Fallow	-	-	-	$17.00	($17.00)
	1997	Wheat	84	66	$204.91	$70.20	$134.71
	1998	Fallow	-	-	-	$17.00	($17.00)
	1999	Wheat	156	68	$162.68	$75.15	$87.53
					W-F Rotation Net Profit (1994-1999)		**$565.60**
W-S-F	1994	Fallow	-	-	-	$17.00	($17.00)
	1995	Wheat	63	89	$469.56	$70.20	$399.36
	1996	Safflower	12	1165	$157.00	$65.85	$91.15
	1997	Fallow	-	-	-	$17.00	($17.00)
	1998	Wheat	21	117	$358.80	$77.15	$279.65
	1999	Safflower	<1	860	$90.30	$65.85	$24.45
					W-S-F Rotation Net Profit (1994-1999)		**$760.61**

[a] Abbreviations: W, wheat; F, fallow; JGG, jointed goatgrass; S, safflower.
[b] Jointed goatgrass counts were not taken during the fallow period.
[c] Wheat yields shown in bushels per acre, whereas safflower yields listed as pounds per acre.
[d] Dollar amounts are calculated per acre. Gross profit calculated from grain yield only. Grain prices used to calculate gross profit consisted of the average market price at the time of harvest for the given year. Numbers in parenthesis denote lost revenue. Economic impact calculations include only estimated costs for weed control in fallow and during the cropping season, crop seed, and other equipment fees associated with planting and harvesting the crop. These figures are only an example of economic impact and should be used as part of a more detailed analysis to evaluate the effectiveness of these practices in large scale production systems.

Table 2. Jointed goatgrass plant density, crop yield, and economic impact estimates in two wheat rotations during a six-year crop rotation in northern Utah and southern Idaho (Location 2), 2000-2005.[a]

					Economic Impact Estimates[d]		
Rotation	Year	Crop Phase[b]	JGG Plant Density	Crop Grain Yield[c]	Gross Profit	Expenses	Net Profit
			no./ sq. ft.				
W-F	2000	Fallow	-	-	-	$17.00	($17.00)
	2001	Wheat	4	44	$145.30	$58.00	$87.30
	2002	Fallow	-	-	-	$17.00	($17.00)
	2003	Wheat	8	34	$126.17	$58.00	$68.17
	2004	Fallow	-	-	-	$17.00	($18.00)
	2005	Wheat	38	63	$218.75	$61.00	$157.75
						W-F Rotation Net Profit (2000-2005)	**$261.22**
W-S-F	2000	Fallow	-	-	-	$17.00	($17.00)
	2001	Wheat	1	45	$150.00	$58.00	$92.00
	2002	Safflower	3	1073	$187.78	$55.00	$132.78
	2003	Fallow	-	-	-	$18.00	($18.00)
	2004	Wheat	38	49	$162.69	$61.00	$101.69
	2005	Safflower	<1	1083	$146.20	$59.00	$87.20
						W-S-F Rotation Net Profit (2000-2005)	**$378.67**

[a] Abbreviations: W, wheat; F, fallow; JGG, jointed goatgrass; S, safflower.
[b] Jointed goatgrass counts were not taken during the fallow period.
[c] Wheat yields shown in bushels per acre, whereas safflower yields listed as pounds per acre.
[d] Dollar amounts are calculated per acre. Gross profit calculated from grain yield only. Grain prices used to calculate gross profit consisted of the average market price at the time of harvest for the given year. Numbers in parenthesis denote lost revenue. Economic impact calculations include only estimated costs for weed control in fallow and during the cropping season, crop seed, and other equipment fees associated with planting and harvesting the crop. These figures are only an example of economic impact and should be used as part of a more detailed analysis to evaluate the effectiveness of these practices in large scale production systems.

crop planning and economic analysis must be done to evaluate the specific economic benefits of adding safflower to your wheat-fallow rotation system.

Planting spring wheat or barley into a winter wheat-fallow rotation can also provide opportunities for control of jointed goatgrass through shifting away from an environment favorable to winter annual weeds. Jointed goatgrass germinating in the spring can produce viable seed in spring wheat. In this case, delaying spring wheat seeding by only a few weeks can provide an opportunity to control these spring biotypes before the planted crop emerges. One of the disadvantages of planting a spring cereal following a winter wheat crop is the uncertainty of having adequate soil moisture to produce a successful crop.

Broadcast fertilizer applications benefit jointed goatgrass by supplying nutrients to the weed as well as the crop. Banding fertilizer between paired rows or deep banding near the row make nutrients most readily available to wheat, giving it a competitive advantage over jointed goatgrass. Timing of fertilizer application can also reduce the impact of jointed goatgrass in a winter wheat-fallow rotation. Research in Colorado has shown that broadcast fertilizer applications in April of the fallow season, rather than at fall planting, favors winter wheat over jointed goatgrass. Nitrogen applied in the spring of the fallow season leaches deeper into the soil profile than that applied later in the season. This deeper nitrogen is less available to surface germinating weeds, such as jointed goatgrass, than to winter wheat.

Figure 2. Semi-dwarf (left) and tall wheat (right) cultivar stands in the field.

In the Intermountain region, winter wheat varieties that gain height quickly are more competitive against jointed goatgrass, especially in drier years (Figure 2). When grown in competition with jointed goatgrass, cultivars with this early growth trait have greater yield and reduce jointed goatgrass seed production more than other cultivars. Varieties such as Juniper, UI Darwin, Eltan, and Gary have early growth characteristics and may be more competitive with jointed goatgrass. These same varieties can also yield well in low precipitation areas. However, variety selection should not be based solely on competitive ability. Factors such as disease resistance, maturity, and cultural practices can influence the performance of any variety and must be considered when making a selection.

Seeding Factors. Increased seeding rates can decrease jointed goatgrass biomass and seed production in winter wheat. Studies conducted in Wyoming showed that grain dockage due to jointed goatgrass was reduced 6% for every nine additional wheat plants above a density of 64 plants per square yard. This response appears to be more pronounced in environments where competition for resources is more severe, such as those in the Intermountain region.

Delaying winter wheat seeding in the fall by only a few weeks allows more time to control jointed goatgrass with non-selective herbicides or tillage before planting. This can provide effective jointed goatgrass control and allow for wheat stands to escape competition during early development. Additionally, early planted wheat generally results in a more vigorous seedling population that is more competitive with weeds (like jointed goatgrass) later in the season. In some regions, the impact on jointed goatgrass control of altering planting date hinges on weather. If an early fall flush of jointed goatgrass is stimulated by rainfall, delaying planting until after tillage or spraying can be advantageous. However, if soil moisture at planting is good and dry fall conditions are predicted, earlier planting dates will enable the wheat crop to establish quickly and escape early competition with later germinating jointed goatgrass. Since both early and late seeding dates can adversely affect wheat yields, individual growers must make their planting decisions based upon their knowledge of local weather patterns and weed populations.

Physical Control

Tillage. Tillage is one of the oldest and most effective means of weed control. Studies have shown that jointed goatgrass is unable to emerge from depths greater than 4 inches. Research conducted in eastern Colorado found that moldboard plowing provided 95% jointed goatgrass control, compared to 75% control with V-blade sweeps or disking. Continual moldboard plowing is not a common practice in the Intermountain region, especially in dryland areas. Excessive moldboard plowing reduces soil moisture, degrades soil structure, increases soil erosion problems, and disrupts soil microbial activity. Conversely, minimum or no-till systems tend to favor winter annual grass weeds like jointed goatgrass by providing a more favorable environment for germination in the crop residue. This residue may also intercept herbicides applied to control jointed goatgrass seedlings in fallow.

The most effective way to reduce jointed goatgrass populations with tillage is to optimize timing and technique. However, post-harvest tillage timing seems to be dependent on fall moisture. In fallow, studies conducted in Utah revealed that jointed goatgrass was controlled best with chisel plowing in the spring followed by repeated summer rod weeding before jointed goatgrass plants started to tiller.

Roguing or hand weeding individual plants or small populations can be an extremely effective way of controlling new jointed goatgrass infestations. Combined with effective scouting, this simple technique can eliminate new jointed goatgrass infestations before they become a problem.

Mowing. Mowing can control jointed goatgrass, particularly in field borders, isolated patches in fields, and waste areas. With mowing, timing is once again a key element. Recent studies indicated that jointed goatgrass florets can produce viable seed as early as two days after flowering. Since jointed goatgrass spikes can flower before they are completely emerged from the boot, it is imperative that mowing occur before spikes become visible in order to prevent viable seed development. Additionally, a single mowing may not provide effective control. Jointed goatgrass plants can regrow and produce seed if mowed too early in the growing season.

Burning. Field burning, although commonly practiced in the past, has recently been restricted or prohibited in many areas. Efficacy of this practice in controlling jointed goatgrass in whole fields is greatly dependent on the amount of residue present in the field. Research has shown that at least 5,000 pounds of residue per acre are required to reach temperatures lethal to jointed goatgrass. Burning controls only the seed lying on the soil surface—any buried seed is sheltered by the soil. Bare soil left after burning is more susceptible to erosion, particularly on slopes. However, in small areas, such as swales and isolated patches, burning infested stands after harvesting around them can reduce jointed goatgrass seedling density as much as 90%. Consult local regulations and restrictions before beginning any burning regime.

Chemical Control

The genetic relationship between jointed goatgrass and wheat makes selective control with herbicides difficult. Although some herbicides can suppress jointed goatgrass in winter wheat, control is usually poor (less than 50%) and crop injury is often severe. Generally, jointed goatgrass establishes itself from spikelets near the soil surface, so herbicide treatments that are incorporated above the wheat seed can provide some selectivity. However, even applications of these types of herbicides only provide marginal control.

One of the most effective ways to chemically control jointed goatgrass is to use herbicides during summer fallow or non-crop periods. Preemergence applications of metribuzin or pronamide in summer fallow can provide residual jointed goatgrass control. Metribuzin labels allow this use only in Washington, Oregon, Idaho, and Utah; pronamide labels allow this use in Washington, Oregon, and Idaho. Postemergence applications of non-selective glyphosate or paraquat herbicide are also highly effective against jointed goatgrass. The success of these applications is highly dependent on jointed goatgrass growth stage and plant vigor. Control with herbicides applied postemergence is best when the plants are small and actively growing. Chemical control of jointed goatgrass infestations in ditches, roadsides, and around field borders will also reduce the risk of encroachment into nearby fields.

Selective jointed goatgrass control in winter wheat can now be achieved using herbicide-tolerant Clearfield® wheat technology. These varieties are tolerant to Beyond® herbicide (imazamox). This herbicide controls jointed goatgrass and many other winter annual and broadleaf weeds. Clearfield® wheat varieties have not been developed as a genetically modified organism (GMO) and may be processed with other conventional wheat varieties. Although Beyond® can be effectively applied in the fall or spring, scientists have found that a fall application after the first wheat tiller begins to develop provides optimum control of jointed goatgrass. Clearfield® wheat technology is not a cure-all and must be carefully managed to prevent the build-up of naturally-resistant and hybridized-resistant jointed goatgrass biotypes.

Herbicides that inhibit the acetolactate synthase (ALS) enzyme, such as Beyond®, are susceptible to rapid development of resistance in weed populations. In order to delay the onset of resistance, avoid continuous use of Clearfield® wheat on the same or adjoining land and limit applications of ALS-inhibiting herbicides (group 2), such as Maverick, Glean, etc., that target the same weed species. Increasing the time between uses of ALS-inhibiting herbicides will reduce the risk of developing resistance and prolong the utility of Clearfield® technology. Control jointed goatgrass escapes and establish jointed goatgrass-free buffer areas around fields planted with Clearfield® wheat to further reduce the risk of resistance development.

Biological Control

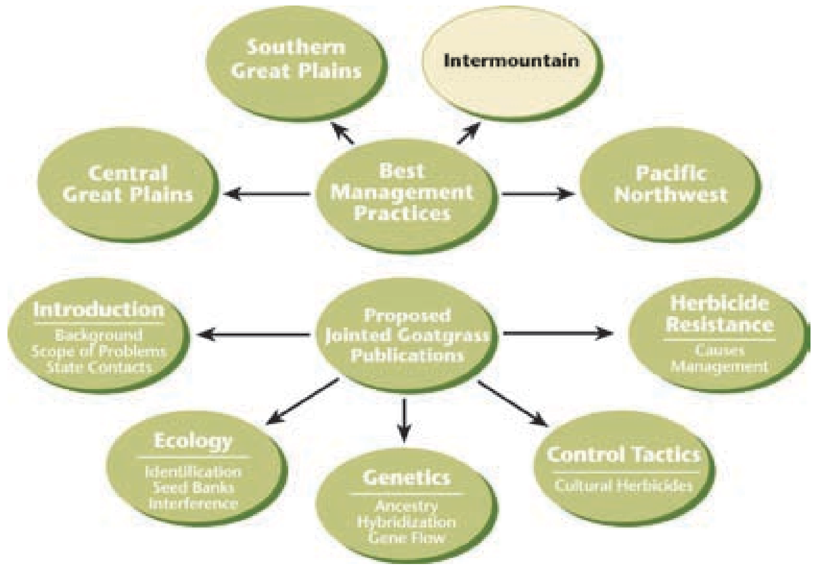
Currently, there are no traditional biological control methods available for jointed goatgrass. Its close genetic relationship and similar life cycle to wheat make it an unlikely candidate for future selective biological control agents. Scientists in Kansas and Washington have had limited success developing naturally-occurring bacterial strains as biological control agents for jointed goatgrass. When applied in concentration to small test plots, these bacteria have inhibited jointed goatgrass by up to 75% without harming winter wheat. Unfortunately, field studies have been inconsistent because the bacteria are unable to rapidly colonize weed roots and thus insure survival of the biological control agent. Currently, this technology has not been developed on a commercial level.

Integration of Practices

No single control component alone will eliminate jointed goatgrass. The only effective way to manage jointed goatgrass populations is with an integrated management program, beginning with prevention. If fields are free of jointed goatgrass, keep them that way. Simple practices, such as thoroughly cleaning planting, tillage, and harvest equipment before moving to new fields and covering transported grain, can substantially reduce seed dispersal. Regularly scout fields and non-crop areas and immediately remove individual plants or small infestations by hand rouging or spot treating.

Best management practices (BMPs) consist of multiple control measures to eliminate the visible jointed goatgrass population and reduce the size of the seedbank. Because jointed goatgrass seed can remain viable in the soil for several years, a BMP plan should include using control tactics for multiple years. Lengthening the time period between winter wheat crops by planting alternative or spring crops will provide the greatest opportunity to reduce jointed goatgrass populations. Crop rotation lays the foundation for an effective control plan upon which a cultural, physical, and chemical control framework can be built.

There is no single management program effective on all populations of jointed goatgrass. Each situation is unique and may require a different course of action. The key to effective management is the integration of control tactics over multiple years. In many cases, jointed goatgrass density has been reduced more than 90% with integrated management programs.



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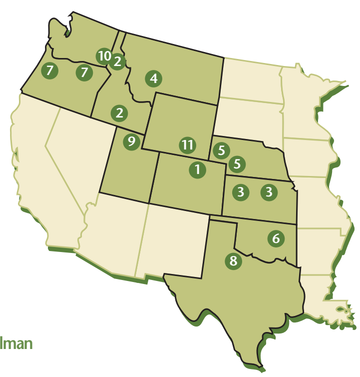

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