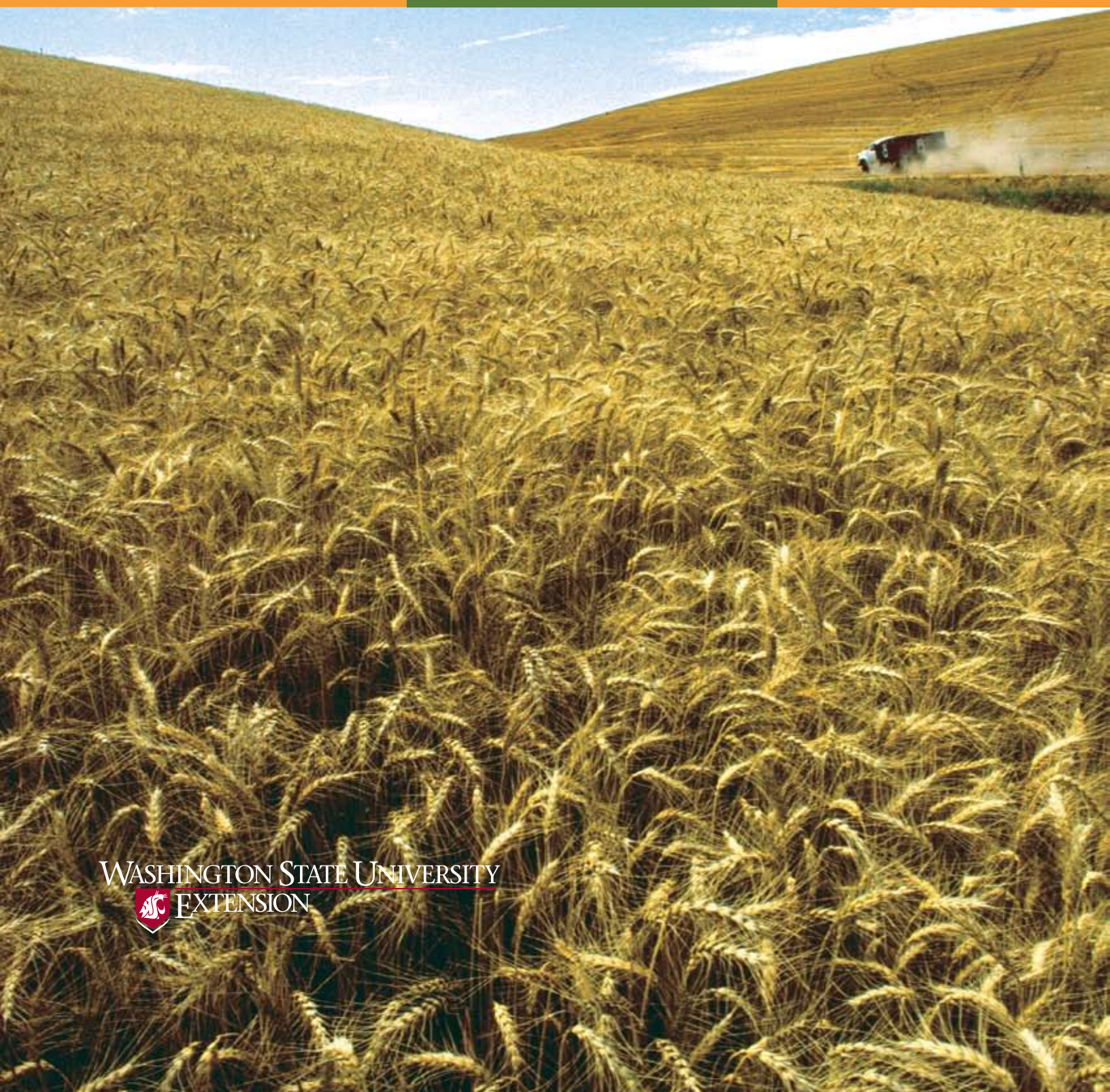




Integrated Management of Jointed Goatgrass in the Pacific Northwest



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Overview

Jointed goatgrass (*Aegilops cylindrica*) is an annual invasive grass weed that is particularly troublesome in winter wheat fields in the western United States. The severity of the infestation has increased over the past 50 years in many areas to levels that reduce yield and quality significantly. Native to southeast Europe, jointed goatgrass is believed to have been introduced into the United States in contaminated wheat in the late 1800s. Spikelets of jointed goatgrass cannot be completely removed from contaminated wheat grain with conventional sieves or with special length-grading seed cleaners. This has prompted the grain industry to increase the penalty when goatgrass spikelets are part of the dockage which further lowers the market price of contaminated wheat.

Although jointed goatgrass is a major problem in most winter wheat growing areas west of the Mississippi River, the climate and cropping patterns of the Pacific Northwest

(PNW) are unique and may influence the choice of options available for effective management of this pest. In particular, producers have noted that by adopting direct seed/reduced tillage management systems, both the number of jointed goatgrass infestations and the densities of these infestations tend to increase.

Jointed Goatgrass Biology

Jointed goatgrass is a winter annual grass weed that closely mimics the life cycle of winter wheat, and has a similar life cycle to other grass weeds of importance such as downy brome and, to a certain extent, wild oat. Jointed goatgrass can be distinguished from these other grass weeds by the presence of short, stiff hairs on its leaf margins (Figure 1). As with most winter annual grasses, seeds germinate in the fall with emerged plants overwintering and resuming growth in the spring. Although jointed goatgrass seeds typically germinate in the fall, it can also



Figure 1. Collar region and seed of jointed goatgrass (far left), wild oat (center), and downy brome (right). Note hairs along edge of leaf; the small ligule (membrane located behind the stem where the leaf blade meets the leaf sheath); and short, stiff hairs at the collar region and along leaf margins of jointed goatgrass.

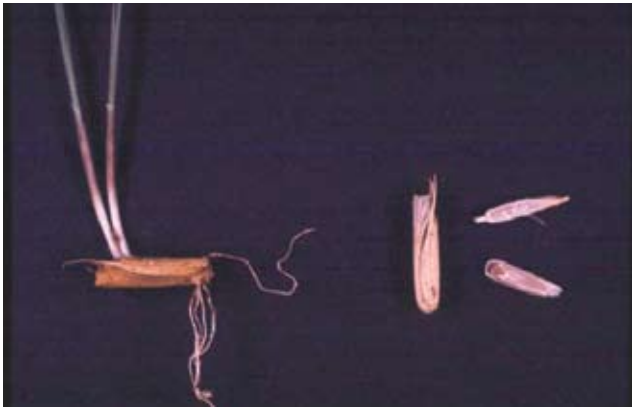


Figure 2. On the right side is a single intact jointed goatgrass spikelet (joint) with two seeds that have been removed from a spikelet. On the left is a single spikelet with two seedlings emerging from seed which are inside.

germinate during March and April and still produce viable seed. Spring-germinated plants usually mature and produce seed later than fall-germinated plants. As jointed goatgrass plants mature, intact spikelets (joints) (Figure 2) shatter and fall to the soil surface beginning about three weeks prior to wheat harvest and continue to do so up to wheat harvest. Scientists in Washington recently discovered that jointed goatgrass can produce seed without vernalization (an overwintering chilling period). It seems clear that merely rotating to a spring cereal may not completely eliminate jointed goatgrass seed production

in that crop, without additional production changes.

Seed can remain viable in the soil for up to five years (Figure 3), especially in drier regions and when deeply buried. Seed will typically decay faster in a region with higher precipitation. A study in the PNW showed that seed remained viable for more than five years in a 10-inch rainfall area, compared to less than three years in a 22-inch rainfall area. In addition, most jointed goatgrass seed will germinate and emerge from soil depths as great as two inches. Approximately 80% of the seed placed between the surface and a depth of two inches will germinate within three years. Some seed will emerge from depths of two to three inches, but very few will emerge from soil depths greater than four inches. The optimum temperature for seed germination is 68°F and the optimum range is 50°F to 86°F. Some germination may occur as low as 36°F and as high as 104°F.

For more general information on jointed goatgrass, there are several general discussion publications available covering jointed goatgrass biology, ecology, genetics, and control tactics. These bulletins are available either on-line at www.jointedgoatgrass.org or in print from PNW Land Grant Universities.

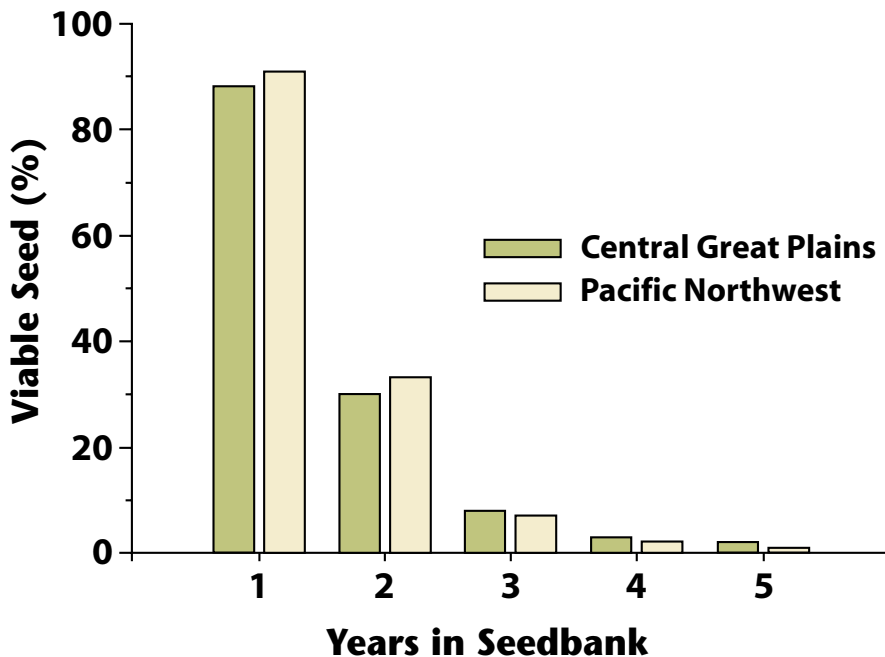


Figure 3. Average jointed goatgrass seed longevity in soil, for two winter wheat production areas.

Importance of Integrated Management

The need for an integrated management system for jointed goatgrass has been demonstrated both in academic research trials and from on-farm grower experience. There is no single “silver bullet” that can be counted on to keep this pest below economic threshold levels. When basic principles of jointed goatgrass management are understood and used in the proper combination, a cumulative effect on reducing jointed goatgrass infestations is observed. Integration of multiple management methods allows better utilization of resources and averts disaster, should one method fail to perform as expected. An integrated approach at times may require a producer to step outside their traditional production routine or use a greater diversity in their crop rotation system.

Prevention

A key to any successful weed management program is to be proactive in keeping the weed from being introduced into your fields. The structural characteristics (size, shape, weight) of the jointed goatgrass spikelets allow for multiple methods of seed transport into a field.

Specific tactics to consider in prevention include:

- Use certified seed. Jointed goatgrass-free seed is assured in that current certification standards specify zero tolerance of jointed goatgrass or hybrid plants at inspection of certified seed fields in the Pacific Northwest.
- Thoroughly clean equipment prior to entering a field. Combines, tillage implements, and vehicle frames often transport seed unknowingly and lead to establishment of new infestations.
- Eradicate known border infestations or new discoveries.
- Prevent seed production on roadsides

and in waste areas. Management programs must consider measures such as mowing or spot-spraying beyond field borders.

- Tarp transport vehicles. During transport, the less dense jointed goatgrass spikelets will work their way to the surface of loads and can be blown onto fields and roadsides.
- Be on the watch for jointed goatgrass by constantly scouting fields and adjacent areas.
- When new minor infestations are discovered, every effort should be made to contain or eradicate jointed goatgrass from these areas.

These are important operations that need to be implemented on an ongoing basis. For a more detailed discussion of this topic, see “Jointed Goatgrass Control Tactics” (EB1935), available at <http://pubs.wsu.edu/cgi-bin/pubs/>.

Mechanical Control Tactics

Tillage, historically, has been the means for control of agricultural weeds, including jointed goatgrass. Tillage may either disrupt the growth of existing plants or prevent emergence of seedlings by burial of the spikelets.

Moldboard plowing can provide a significant reduction in jointed goatgrass in the year after plowing, if done so that it completely buries jointed goatgrass seed. Studies have shown that jointed goatgrass seed are unable to emerge when buried to depths greater than four inches. Moldboard plowing buries deeply about 90% of the spikelets laying on the soil surface and greatly reduces jointed goatgrass seedling density in the following winter wheat crop. However, repeated moldboard plowing can return buried seed to shallower depths from which it can emerge. Only shallow secondary tillage should be used after deep plowing to reduce the risk of bringing spikelets back near the soil surface.

Moldboard plowing should not be done more than once every four years because the benefits of jointed goatgrass deep seed burial may be minimized. Excessive moldboard plowing also has other negative effects such as reduced organic matter, increased soil erosion, degraded soil structure, and reduced water infiltration rates. However, moldboard plowing may be useful for selectively controlling dense infestations in small areas.

Conversely, minimum or no-till systems tend to favor winter annual grass weeds, such as jointed goatgrass, by leaving weed seed on or near the soil surface where it is more able to germinate and establish an infestation when adequate soil moisture is available. The greater amount of surface crop residues in minimum and no-till systems also provides a favorable environment for jointed goatgrass germination and seedling establishment, and can tie up herbicides applied to control jointed goatgrass.

It has been suggested that post-harvest and fallow tillage operations can improve jointed goatgrass seed contact with soil and thus stimulate seed germination, subsequently allowing jointed goatgrass to be controlled with a non-selective herbicide or with tillage. However, studies conducted in winter wheat-fallow rotations in Oregon, Utah, and Nebraska indicated that single or multiple light tillage operations at various times following harvest were inconsistent both in reducing jointed goatgrass seed bank density or improving subsequent wheat yields. Therefore, post-harvest tillage operations are not generally recommended for the sole purpose of managing jointed goatgrass. However, if light, postharvest tillage is being considered for residue management or other reasons, it will not have a negative effect on jointed goatgrass management.

Tillage alone will not eliminate jointed goatgrass. Producers need to integrate tillage along with more diverse crop rotations, competitive wheat canopies, and chemical control for most effective management of jointed goatgrass.

Mowing jointed goatgrass patches is effective in preventing seed development along roadsides, fencerows, and non-cropland areas, but timing is critical. Two separate mowing operations at proper times during the season are required to prevent jointed goatgrass seed production. Mowing is most effective just before jointed goatgrass seed heads begin to emerge. Mowing too early allows jointed goatgrass plants to recover and produce seed. If mowing is conducted too late, viable jointed goatgrass seed can already have been produced, since terminal spikelets flower soon after they have emerged from the boot. Therefore, mowing prior to spikes becoming visible is critical to prevent viable seed development. If plants continue to grow following the first mowing, a second mowing just prior to seed head emergence is needed.

Burning, although commonly used in the past, has recently been restricted or prohibited in many areas. Effectiveness of this practice in controlling jointed goatgrass in whole fields is greatly dependent on the amount of residue present in the field. Unless surface residue is sufficient, burning will not significantly reduce jointed goatgrass seed viability. However, in an early study conducted in the PNW, field burning reduced seed viability more than 90% at several PNW locations (Table 1). Seed that are shallowly buried or those even partially buried will not be affected by field burning. Burning crop residue also destroys surface organic matter, resulting in decreased soil aggregation, decreased moisture infiltration, and increased soil erosion. However, burning isolated

Location	Viable jointed goatgrass seed (per square foot)	
	Non-burned	Burned
Idaho	8	2
Oregon	360	25
Washington	60	2

Table 1. Stubble-burning effect on number of viable jointed goatgrass seed on the soil surface at three locations in the Pacific Northwest.

jointed goatgrass patches in small areas such as swales, after harvesting the crop around them, can reduce jointed goatgrass seedling density the following season. Consult local regulations and restrictions before planning any burning regime.

Proper combine adjustment can help in removing additional jointed goatgrass seed from the field by collecting it along with the wheat, but this may come at the cost of greater dockage. Individual growers must decide whether this practice will minimize seed return to the field. This might be worth doing if fields are in the initial stages of infestation. Any greater dockage could be offset by blending infested grain with cleaner grain to reduce dockage. Setting the combine to cut low and turning down the air blower will allow greater collection of spikelets. Of course, raising the cutting bar height and increasing the air blower will decrease spikelet collection. Research in the PNW has shown that at a normal harvest timing, approximately 40% of jointed goatgrass seed will already be on the ground or will shatter free of the combine during the harvest process. Thus, collecting the seed with the combine will be only 60% efficient at most.

Cultural Control Tactics

Cultural control of weeds requires managing the wheat crop or the cropping system in a way to reduce weed seed production and reduce seed in the soil seed bank. Cultural control practices can also increase the ability of the crop to compete with or tolerate the presence of weeds. We will discuss seed production and seed bank management approaches separately.

Reducing jointed goatgrass seed production, the soil seed bank, and jointed goatgrass plant density can be done by altering crop rotations. Crop rotations that extend the period between winter grain crops to three years or longer are a primary method for reducing the jointed goatgrass soil seed bank and resulting infestations. It is

critical to obtain maximum control of jointed goatgrass plants during seasons not in winter wheat production so that the seed bank is not replenished.

Where winter wheat-fallow is the dominant crop rotation, extending the rotation may be as simple as replacing one or two winter wheat crops with a spring cereal. Since the expected seed life of jointed goatgrass is three to five years, it is important to make sure no seed is produced during the fallow period or in the alternative crop. When preparing fields for spring crops, remember that tillage by itself will not completely destroy all of the jointed goatgrass, particularly with moist soils. A preplant burndown or aid-to-tillage application of glyphosate should be made at least two weeks before planting spring crops to reduce root disease or the green bridge effect.

Research in the PNW indicates that planting a spring crop as early as possible still allows some jointed goatgrass establishment and seed production. It is best to plant spring crops at a normal date or up to two weeks later than normal spring planting time to reduce or eliminate jointed goatgrass seed production. Note: this may result in a yield penalty since delayed seeding of spring wheat or barley can reduce yield potential.

Delaying fall seeding can provide an opportunity to control jointed goatgrass. However, in most areas of the PNW, this will depend on conditions at planting. If rains occur at, or just ahead of, normal planting time, delaying planting to allow jointed goatgrass seed germination can reduce the weed density. Jointed goatgrass seedlings can be easily controlled by tillage or by using non-selective herbicides prior to planting wheat. A drawback to delayed seeding in order to control jointed goatgrass is that yield potential is reduced as seeding is delayed.

Increasing the ability of the crop to compete with or tolerate weeds by timing winter wheat planting and emergence relative to the germination and emergence

of the weed is critical. Research has shown that jointed goatgrass seedlings emerging before or at the same time as wheat seedlings cause the greatest crop yield loss and dockage (Figure 4). A Colorado study showed that 15 jointed goatgrass plants per square yard reduced wheat yields 27% when they emerged at the same time as winter wheat, 17% when they emerged 42 days after wheat, and 6% when they emerged in the spring, 150 days after winter wheat emergence. Similar studies showed delayed emergence of jointed goatgrass dramatically reduced its tiller and spikelet production. While growers do not normally want to delay crop seeding, it may offset losses due to weeds if seeding can be delayed a few days or a week to ensure control of jointed goatgrass seedlings prior to wheat emergence.

Improved crop competition with, or tolerance of, jointed goatgrass can be accomplished by selecting and planting tall, fast growing winter wheat varieties. However, wheat height alone will not ensure maximum competition from the wheat crop. Research conducted in the PNW showed that differences in mature wheat height were not detected until May or June which was

seven to eight months after planting and two to three months before harvest. The critical period of weed/crop competition generally occurs in the first few weeks or months following crop emergence. The most competitive wheat varieties are those that emerge quickly and have rapid shoot and root growth. Thus, once competitive varieties have an emergence and early growth advantage, they are better able to crowd out jointed goatgrass plants. Additionally, early emerging and fast-growing wheat varieties will have a more developed root system which allows it to reach soil moisture and nutrients more quickly than jointed goatgrass. Later in the season, after being out-competed for moisture, nutrients, and space, tall wheat varieties will shade the flag leaf of the jointed goatgrass better than short varieties, thus reducing jointed goatgrass seed production. Planting tall wheat varieties may also allow a higher cutting height which can reduce dockage due to jointed goatgrass spikelets.

The differential early competitiveness of wheat varieties is even more important when resources such as soil moisture or nutrients are in short supply. A USDA-ARS study in Washington State showed that some wheat

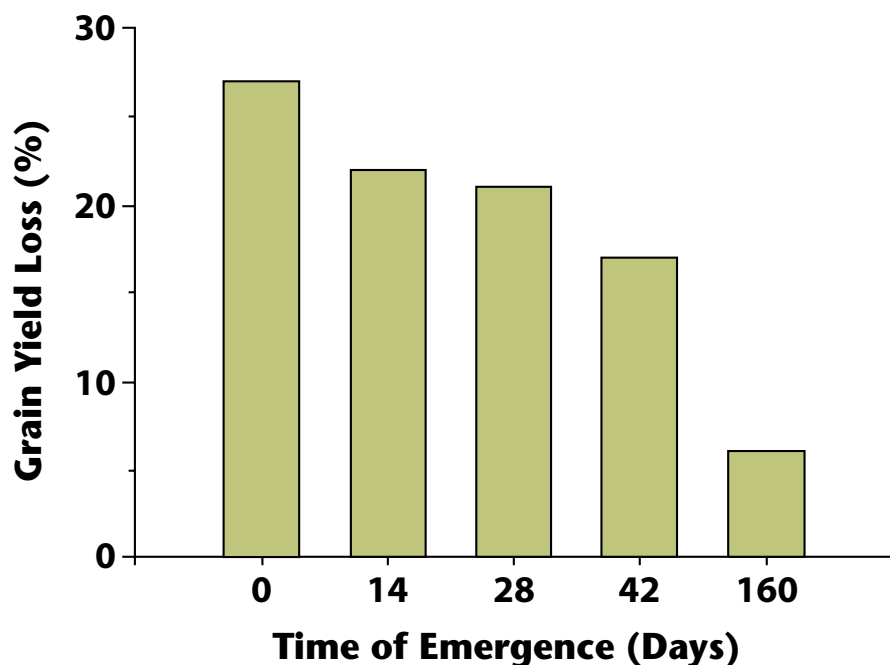


Figure 4. The influence of timing of jointed goatgrass plant emergence relative to winter wheat plant emergence on grain yield loss.

varieties are more competitive with jointed goatgrass than others. This study also demonstrated how jointed goatgrass is much more competitive with winter wheat under dry conditions. University-conducted winter wheat yield trials often provide information on wheat plant height and early seedling vigor. (For instance, see <http://variety.wsu.edu>.) This information can be used to select wheat varieties with a greater competitive ability against jointed goatgrass.

Planting wheat at recommended or greater than normal seeding rates and narrowing the row spacing can increase crop competition with jointed goatgrass. Generally, an increased seeding rate is considered an option with higher rainfall and in areas practicing annual or continuous crop production. In wheat production regions with greater annual precipitation, increasing the wheat seeding rate for greater crop competition can be done with little risk to wheat yield. However, wheat-fallow cropping regions with low rainfall may not benefit from increased seeding rates due to the risk of reduced crop yield and test weight that can occur if the greater crop density depletes soil moisture prior to grain fill. Nevertheless, increasing winter wheat seeding rate is a simple and direct method for increasing crop competitiveness. Narrowing the row spacing can also increase crop competitiveness and better utilize resources necessary for wheat growth. Again, higher seeding rates and narrow row spacing by themselves will not necessarily increase crop competition and yield. However, when integrated with other cultural practices such as using tall, early competitive wheat varieties and banding nitrogen fertilizer, these practices can minimize crop loss due to jointed goatgrass competition and also reduce weed seed production (Figure 5).

Maintaining healthy, vigorously growing winter wheat can be highly effective without additional expense. Crops suppress weeds by shading. Management strategies that hasten shading of weeds will

ultimately lead to a more competitive crop and less weed seed production. Along with more competitive wheat varieties planted at greater densities, the wheat crop can gain a competitive advantage over jointed goatgrass by proper amount and placement of fertilizer. Applying fertilizer in a band with the seed and at depths that make it available to the developing crop will give the wheat an even greater competitive advantage over jointed goatgrass. Research in eastern Oregon showed that winter wheat was more competitive with jointed goatgrass and produced greater wheat yield when a phosphorus starter fertilizer (16-20-0) was banded below the wheat seed at planting.

Jointed goatgrass plants emerge from seed that are scattered randomly and at depths near the soil surface. Broadcasting fertilizer across the soil surface mimics this distribution of weed seed. Crop seed, of course, are planted at a uniform depth, spacing, and density by grain drills. Research has shown that broadcast application of nitrogen (N) fertilizer allows weeds to more quickly access the fertilizer, whereas banding fertilizer below the crop allows for preferential uptake by the crop, thereby giving the crop a competitive advantage over weeds (Figure 5).

Oregon (OSU) research also demonstrated that the timing of N fertilizer application is important in reducing the impact of winter annual grass weeds in a winter wheat-fallow rotation. These studies showed that applying N fertilizer during the fallow period or at planting, rather than as an in-season or top-dress application, favored the winter wheat crop more than annual grass weeds, especially when soil moisture was adequate. In these studies, the most beneficial N fertilizer application method for promoting a competitive winter wheat crop was to apply N fertilizer near the wheat seed at time of planting.

The impact of using an integrated system to manage jointed goatgrass is shown in a summary graph (Figure 6) that represents the

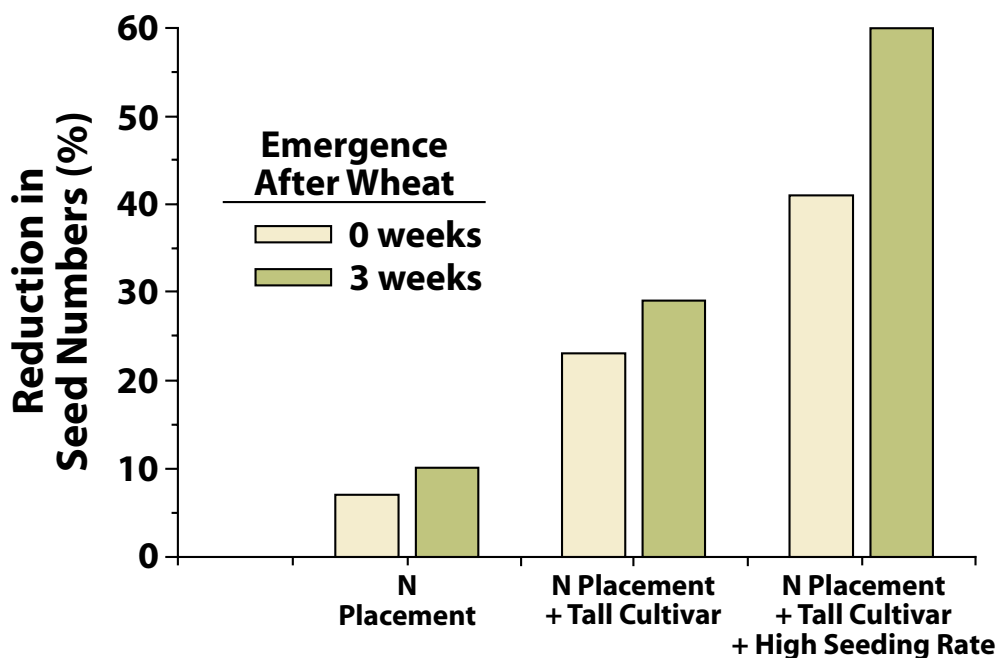


Figure 5. The influence of integrating cultural practices such as banding of nitrogen (N) fertilizer, and planting a competitive wheat cultivar on seed production of jointed goatgrass.

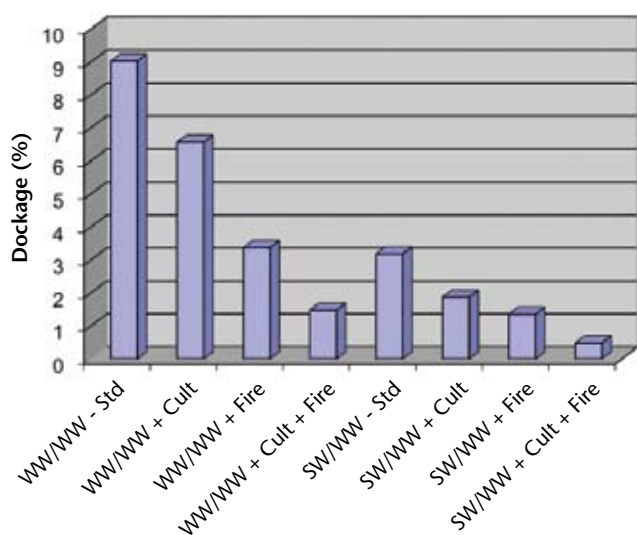


Figure 6. The influence of crop rotation, stubble burning, and integrated management on jointed goatgrass dockage in winter wheat.

WW/WW = winter wheat–fallow–winter wheat; SW/WW = spring wheat–fallow–winter wheat. Std = standard wheat planning practices; Cult = integrated planting practices including a phosphorus (P) starter fertilizer banded below the wheat seed at planting, narrow row spacing, and increased wheat seeding rate. Fire = open field burn before planting winter wheat.

percentage dockage for a winter wheat crop as measured at study locations in Washington and Oregon. Introduction of cultural practices such as narrow row spacing, applying phosphorus (P) starter fertilizer, or using an

extended spring crop rotation greatly reduced dockage due to jointed goatgrass compared to standard management practices. Note that the greatest reduction was only attained when multiple practices were applied to the system.

Herbicide options

Chemical control of jointed goatgrass can be selective or nonselective. Nonselective herbicides entail the use of herbicides such as glyphosate, paraquat, or glufosinate. These products are also known as burndown herbicides because they kill all existing vegetation or are used as an aid to tillage for control of weeds. In the PNW, nonselective herbicides are normally applied during fallow or immediately prior to planting a crop. Glyphosate is the most widely used nonselective herbicide because it is safe, effective, and controls a broad spectrum of weeds including jointed goatgrass.

Nonselective control of jointed goatgrass should first be considered in the fall following wheat harvest. If rainfall is adequate to initiate jointed goatgrass germination, late fall applications of glyphosate or other nonselective herbicides are most effective in controlling emerged jointed goatgrass plants.

Spring applications of glyphosate are also effective in controlling jointed goatgrass. In a winter wheat–fallow rotation, herbicide applications are most effective when applied after jointed goatgrass, other grass weeds, and volunteer wheat are completely emerged. In tilled, fallow systems, nonselective herbicides are generally applied just ahead of initial summer fallow tillage treatments. In chemical fallow systems, applications are generally made in March, April, or May when all grasses have emerged, and then followed later in the season with additional herbicides for controlling broadleaf weeds. Sequential applications of nonselective herbicides in the fall followed by spring applications have been shown to be extremely effective at controlling grass weeds, particularly in direct-seed cropping systems. Fall herbicide application will often allow a grower to delay spring herbicide application, thereby lessening work load during the busy spring season.

Burndown herbicide treatments are also used to control jointed goatgrass prior to planting a spring cereal or broadleaf crop. In direct seed systems, applications must be made at least two weeks ahead of spring cereal planting to reduce root disease or the green bridge effect. Again, if fall rains bring on jointed goatgrass emergence, a late fall application of a nonselective herbicide should be considered. However, when rotating to a spring crop in heavily infested fields, extremely early burndown applications should be avoided or delayed as long as feasible. Studies have shown the spring-emerging jointed goatgrass was able to produce seed when planted as late as March 31 at Lind, Washington, and Pendleton, Oregon, or April 30 at Pullman, Washington.

Selective and effective control of jointed goatgrass in broadleaf crops can be achieved by using herbicides. In winter or spring peas, winter or spring lentils, and chickpeas, herbicides such as Assure II (quizalofop), Poast (sethoxydim), or Select Max can control jointed goatgrass effectively. Poast is not registered for use on chickpeas. These

same herbicides may be used in winter- or spring-seeded canola. Consult with your local agronomist or Extension specialist to determine the best rate and application timing for these products to control jointed goatgrass, and for other local precautions that need to be considered. Since labels frequently change, consult the herbicide label for up to date information regarding the safety and legality of any application. Don't forget to consult herbicide labels or other data bases for possible effect of your herbicide programs for crops grown in rotation.

Imazamox is another herbicide that can provide effective and selective jointed goatgrass control in dry peas (as Raptor™), or in certain varieties of spring canola or winter wheat (as Beyond™) that contain a herbicide-resistance trait (Clearfield™) (Figure 7). (Note: Clearfield varieties are not genetically modified organisms [GMOs]) Beyond and Clearmax are the only imazamox-containing herbicides labeled for the selective control of jointed goatgrass in Clearfield varieties of wheat.

Growers should pay particular attention to the frequency of use of imazamox within their crop rotations, regardless of the imazamox product applied. Imazamox is a group 2 herbicide that kills plants by interfering with the acetolactate synthase (ALS) enzyme system. Group 2 herbicides have been prone to the development of populations of herbicide-resistant weed biotypes. The potential for making imazamox useless due to the development of resistant weed populations is relatively great. Thus, due to the danger of resistance development, it is best to limit the use of imazamox to Clearfield wheat to minimize this potential. In addition, there is a slight potential for the herbicide-resistance trait in Clearfield wheat to transfer into a jointed goatgrass population over several generations, due to the ability of wheat and jointed goatgrass to cross-pollinate and create hybrids (Figure 8). The spread of the herbicide-resistance trait from Clearfield wheat to jointed goatgrass is considered to be a minor



Figure 7. Jointed goatgrass control with imazamox in CLEARFIELD™ winter wheat (foreground). Note the untreated plot in the background.

possibility in commercial wheat production.

Currently, glyphosate can provide effective control of jointed goatgrass in Roundup-Ready™ varieties of winter and spring canola. Again, while Roundup-Ready varieties of winter canola provide an opportunity to control jointed goatgrass, they also present a potential hazard in the form of overuse of a single herbicide mode of action and the development of herbicide-resistant weeds.

As of 2008, the Beyond and Clearmax herbicides can be used in Clearfield wheat varieties as the only methods for selective herbicidal control of jointed goatgrass in a winter wheat crop. Growers considering using the Beyond/Clearfield system should consider the following:

- Design crop rotations or weed management programs that limit the use of imazamox (Raptor or Beyond) to no more than once in every three years.
- Currently, there are fewer than 10 varieties of Clearfield wheat that have been developed for PNW wheat production. Suitable varieties of Clearfield wheat may not be available

for an individual grower's production environment, let alone for a particular market class. Growers should not plant non-adapted varieties simply because it contains the Clearfield trait.



Figure 8. Spike of jointed goatgrass (right) compared with that of wheat (left) and jointed goatgrass/wheat hybrids (center three).

- The cost of limited yield or quality due to growing a non-adapted variety could exceed losses due to jointed goatgrass infestations or the difference in the values of alternatives.

That said, the Clearfield/Beyond system has proven to be effective for selective control of jointed goatgrass. Jointed goatgrass control is frequently greater than 90% when Beyond is applied according to label directions, with corresponding reductions in dockage. Please consult your agronomist or local Extension personnel for specific results on control of jointed goatgrass and other weeds using the Beyond/Clearfield system.

Summary

Integrated management of jointed goatgrass is the only long-term solution to the problem. Benefits of integrated management will also be seen with suppression of additional annual grass and other weeds. Moreover, benefits will also be seen in better utilization of fertilizer, tillage operations, fuel inputs, and other resources. Ultimately, integrated management of jointed goatgrass and other weeds will result in a more profitable sustained farming operation.

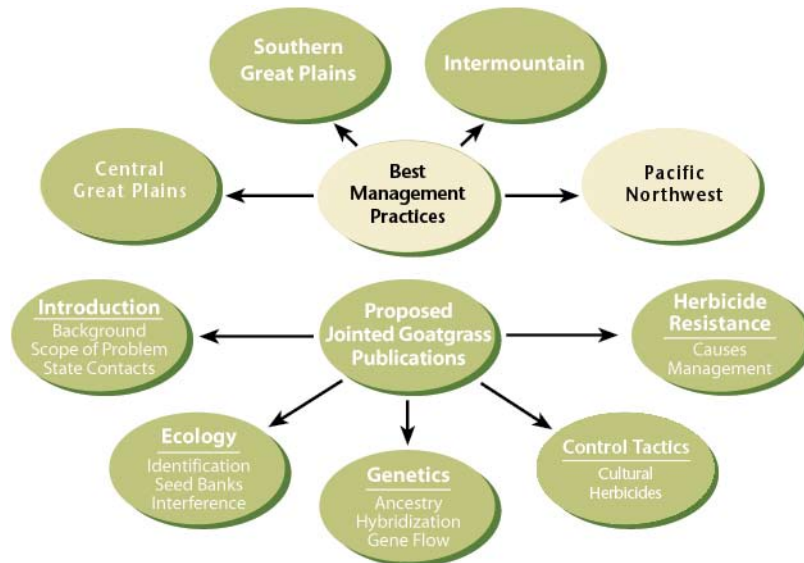
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- 1—Colorado—Colorado State University, Ft. Collins
- 2—Idaho—University of Idaho, Moscow & Twin Falls
- 3—Kansas—Kansas State University, Hays & Manhattan
- 4—Montana—Montana State University, Bozeman
- 5—Nebraska—University of Nebraska, North Platte & Scottsbluff
- 6—Oklahoma—Oklahoma State University, Stillwater
- 7—Oregon—Oregon State University, Corvallis & Pendleton
- 8—Texas—Texas A&M University, Vernon
- 9—Utah—Utah State University, Logan
- 10—Washington—Washington State University, Pullman
- 11—Wyoming—University of Wyoming, Laramie

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