

# JOINTED GOATGRASS: BEST MANAGEMENT PRACTICES SOUTHERN GREAT PLAINS



## Abstract

Jointed Goatgrass is an invasive weed that is closely related to wheat and can have a negative impact on wheat profitability. This publication details the best management practices in a multi-practice approach, specific to the Southern Great Plains region, for successful control of jointed goatgrass.

## Introduction

Jointed goatgrass (*Aegilops cylindrica* Host) is an invasive, winter annual grass weed that is closely related to wheat. Research has shown that winter wheat infested with as few as 18 jointed goatgrass plants per square yard can suffer a yield reduction of nearly 30 percent. Problems with jointed goatgrass typically increase as producers adopt conservation tillage or no-till systems, unless these systems include rotation to crops other than winter wheat.

The emergence and growth pattern of jointed goatgrass and winter wheat are similar. Both species germinate together and seedlings can emerge from the same soil depths. However, jointed goatgrass is more winter hardy than winter wheat. Jointed goatgrass seeds generally mature before or with winter wheat.

If left uncontrolled, jointed goatgrass will eventually choke out wheat, reducing wheat yields in parts of a field to zero. In addition to yield losses, wheat grain contaminated with jointed goatgrass spikelets (joints) will be discounted for dockage when it is delivered to an elevator. Jointed goatgrass in wheat grain may also be counted as foreign material, resulting in additional discounts. If contamination is high enough to cause a grade loss, there will be still further discounts.

The purpose of this bulletin is to help wheat producers avoid such economic losses by providing information on Best Management Practices (BMP) for the control of jointed goatgrass in winter wheat. The practices described in this bulletin are intended for dryland continuous-crop wheat producers in the southern Great Plains. This includes the regions of Oklahoma and south-central Kansas where continuous winter wheat is the predominant crop.

Information on jointed goatgrass control for summer fallow wheat producers can be found in "Jointed Goatgrass, Best Management Practices, Central Great Plains" (Washington State University EB2033) available at [www.jointedgoatgrass.org](http://www.jointedgoatgrass.org) or from university Extension specialists.

## DOLLAR LOSSES FROM FAILURE TO CONTROL JOINTED GOATGRASS CAN BE SEVERE! NOTE THIS EXAMPLE!

If a producer delivers a 1000-bushel load of wheat that contains 3% dockage from jointed goatgrass, it is reasonable to assume that the field suffered a 15% yield loss as a result of the jointed goatgrass infestation. With a 3% dockage discount of 18 cents per bushel, and additional foreign matter and grade discounts (caused by the jointed goatgrass contamination) of up to 18 cents per bushel, the producer lost \$360.00 (1000 bu x \$0.36/bu) from discounts. In addition, at \$6.00/bu wheat, \$900.00 was lost from reduced production (1000 bu x 15% yield loss x \$6.00/bu).

### JOINTED GOATGRASS COST THIS PRODUCER OVER \$1250.00 ON JUST ONE TRUCKLOAD!

If the producer harvested 20,000 bushels of similar wheat, total losses would be over \$25,000. At higher wheat prices, losses are even greater. For every \$1.00/bu increase in the price of wheat, losses from the above example would increase more than \$150.00 per load.

## Introduction to a Multi-practice Approach for Jointed Goatgrass Control

Wheat producers have several practices to choose from for jointed goatgrass control. All of these practices require prior planning, as opposed to waiting until jointed goatgrass has infested a wheat crop and then trying to salvage the crop. Use of a single practice may provide acceptable control in a particular year, but is not likely to be dependable year after year because of varying rainfall, temperature, and different levels of jointed goatgrass emergence.

To successfully control jointed goatgrass and other problem weeds, producers should use a **multi-practice** approach. Using this system, a producer combines a number of management practices to achieve better weed control than could be obtained by relying on only one practice.

A checklist of possible practices is provided below to show the options that are available for the control of jointed goatgrass. Often, these same practices will help control

other grass weeds such as true cheat (*Bromus secalinus*) and volunteer cereal rye or feral rye (*Secale cereale*). In addition, many of these practices will increase wheat production and profitability.

Since many management practices are most appropriate at a specific time during the year, this bulletin discusses them in a timeline arrangement. This timeline begins at wheat harvest, the point at which many producers first notice a jointed goatgrass infestation, and then progresses through the cropping cycle. However, producers should review the entire sequence, as successful use of a given practice may depend on the use of other practices earlier or later in the cropping cycle.

## IDENTIFICATION AND BIOLOGY

### Plant Identification

Jointed goatgrass, like winter wheat, is a winter annual. It typically germinates and emerges in fall (or in late summer if moisture is favorable) and heads out to produce seed the next spring. Jointed goatgrass may also germinate and emerge in winter or early spring. When plants are small, it is easiest to locate jointed goatgrass in



**Figure 1.** Wheat on left, jointed goatgrass on right. Wheat leaves are generally hairless. If hairs do appear on wheat leaves they will be sparse, longer, and more randomly spaced than hairs on jointed goatgrass leaves.



**Figure 2.** Jointed goatgrass seedling with attached spikelet (joint).



Figure 3. Jointed goatgrass head (spike), and head separated to show individual spikelets (joints).

wheat fields by looking between the wheat rows. Jointed goatgrass seedlings look very similar to wheat seedlings, except jointed goatgrass leaves have uniformly spaced visible hairs growing along the edge of the leaf (Figure 1). Wheat leaves are generally hairless. If hairs do appear on wheat leaves, they will be sparse, as well as longer and more randomly spaced than the hairs on jointed goatgrass leaves. To positively identify jointed goatgrass in the early seedling stage, dig up a plant and look for the spikelet (joint) attached to the seedling (Figure 2).

Jointed goatgrass may also be growing alongside other grass weeds such as cheat, downy brome (*Bromus tectorum* L.), Italian ryegrass (*Lolium perenne* L. ssp. *multiflorum*, Lam Husnot), Japanese brome (*Bromus japonicus* Thunb.), rescuegrass (*Bromus catharticus* Vahl), wild oat (*Avena* spp.), and feral rye. Pictures and other characteristics that can be used to identify these weeds can be found in "Identification of Grasses Commonly Found in Oklahoma Wheat Fields" (Oklahoma State University L-316). This publication and accompanying slide set is available at <http://wheat.okstate.edu/wheat-management/weed-control/index.htm/>.

As jointed goatgrass begins to head, it is easy to identify. The head of jointed goatgrass, also called the spike, is a long narrow cylinder. This spike is made up of a number of spikelets, also called joints (Figure 3). Each spikelet or "joint" is about one-half-inch long and contains from one to three seeds. At maturity, which normally occurs before wheat is mature, the jointed goatgrass spike will often break apart and the upper spikelets will fall to the ground. Spikelets that remain attached to the jointed goatgrass stem, and that are harvested with the wheat, will look like short pieces of straw in the combine bin. Additionally, wheat straw is hollow while jointed goatgrass spikelets are closed at both ends.

### Important Characteristics

One key to controlling jointed goatgrass is understanding the survival of its seeds in the soil. Jointed goatgrass seeds exhibit two important characteristics: **staggered seed dormancy** and **multi-year seed life**.

With staggered seed dormancy, not all seeds germinate at the same time. This can apply to seeds that come from different spikelets on the same head, or even to different seeds that come from within the same spikelet.

With multi-year seed life, dormant seeds lying on or in the soil may still be viable, germinate, and produce a seedling after several years.

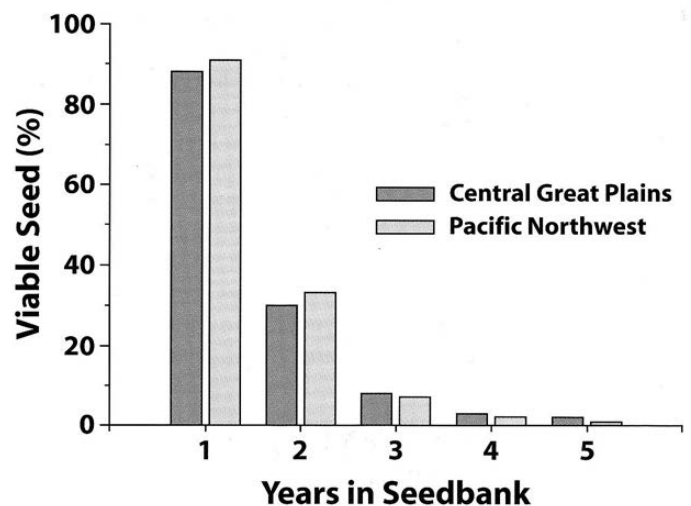


Figure 4. Longevity of seeds of jointed goatgrass in soil. Research conducted at sites in the Central Great Plains and Pacific Northwest, where rainfall ranged from 15 to 18 inches per year.



Staggered seed dormancy and multi-year seed life are the major reasons that jointed goatgrass is so hard to control in continuous wheat. A few jointed goatgrass seeds germinating in a wheat crop result in plants that produce many more seeds. Some of these new seeds may germinate before planting the next wheat crop, and the seedlings can be destroyed. However, because of staggered seed dormancy, some of these seeds will wait to germinate and seedlings will emerge in the next crop. Because of multi-year seed life, some jointed goatgrass plants may emerge several years later (Figure 4). These seeds add to the **soil seed bank**, the reservoir of seed on and in the soil. As the soil seed bank increases, the cycle repeats itself, causing ever increasing weed problems and reducing wheat yields severely.

Although jointed goatgrass spikelets lying on the soil surface can germinate and produce seedlings, tillage to shallowly incorporate spikelets into the soil may stimulate jointed goatgrass germination. Jointed goatgrass that germinates and produces seedlings in the late summer and early fall can be destroyed with tillage or herbicide (glyphosate) prior to wheat seeding. This helps to deplete the soil seed bank, reducing both future infestations and new seed production.

The success of using tillage to incorporate spikelets and stimulate jointed goatgrass germination varies with the amount of summer rainfall and the quality of spikelet-soil contact. If spikelets simply sit in dry soil, or if they are in very cloddy soil with poor spikelet-soil contact, germination will be poor. There are almost certainly other factors, as yet not understood, that affect seed dormancy, seed life, and germination of jointed goatgrass. Some researchers believe that seed dormancy of incorporated spikelets is less in the southern Great Plains than in the central Great Plains or Pacific Northwest.

Jointed goatgrass generally heads earlier than wheat does. Anthesis (the growth stage where flowers in the emerged head are pollinated and become viable seeds) is much longer for jointed goatgrass than for winter wheat. Anthesis in both plants is identifiable when anthers (small, yellow cylinders of pollen) are visible on the heads. A long anthesis gives jointed goatgrass a better opportunity for favorable weather during anthesis and helps ensure seed production.

Jointed goatgrass can produce viable seeds shortly after heading. The first heads to emerge on a jointed goatgrass plant may produce viable seeds before other heads on the same plant have even emerged. This means that jointed goatgrass plants must be destroyed in a timely manner to prevent production of additional seed.

Producers should remember that one jointed goatgrass plant can produce dozens or even hundreds of seeds, leading to many more jointed goatgrass plants in future wheat crops. Jointed goatgrass populations and wheat yield losses from these populations can quickly become severe.



**Figure 5.** Left to right: wheat, wheat x jointed goatgrass hybrids (3 hybrids shown), and jointed goatgrass.

Jointed goatgrass reduces wheat yield by competing with wheat for sunlight, soil moisture, and soil nutrients. It is an especially good competitor under conditions of stress, such as drought.

Finally, wheat and jointed goatgrass can cross and produce hybrid plants. When mature, this hybrid will share the appearance of both parent plants (Figure 5). Typically, seed production by hybrid plants is low, with approximately 2% of the flowers producing seeds; however, hybrids are difficult to clean from harvested wheat and typically are considered foreign material at the elevator.

## Management at Wheat Harvest

### *Note Infestations*

During harvest, watch for and note wheat fields that contain jointed goatgrass, including patches of jointed goatgrass on the edges of otherwise clean fields. Look

along the edges of county, oil-well, and trail roads. Pay particular attention to areas where water drainage from adjoining fields may have deposited jointed goatgrass seed during runoff.

If GPS is available on the combine, infestation maps of jointed goatgrass can aid in its further management.

During harvest, producers should also note if the jointed goatgrass infestation in a field is a **critical population** or a **background population**.

A **critical population** is one in which the jointed goatgrass is so dense, and accumulated jointed goatgrass seed in the soil seed bank is so high, that yield of the next wheat crop will be severely reduced unless major corrective action is taken. Critical populations are at or above the economic threshold where **intensive** reclamation practices need to be used. These intensive **reclamation practices** are discussed in the next section of this bulletin.

A **background population** is one in which the level of jointed goatgrass is low and has been low for several years. Therefore, the accumulated jointed goatgrass seed in the soil seed bank is not likely to cause a significant reduction in yield of the next wheat crop. However, producers should implement practices to prevent background populations from expanding and becoming critical populations. Remember, without proper management, background populations of jointed goatgrass can quickly become critical populations.

### ***Avoid Seed Spread***

Practices to control jointed goatgrass by preventing the spread of seeds should begin at harvest:

- 1) Tarp your trucks to prevent spikelets from blowing off loads and infesting the edges of other fields. (Spikelets are less dense than wheat and may work their way to the surface of loads during transport.)
- 2) Consider harvest timing. Although much jointed goatgrass typically shatters onto the ground before harvest, enough heads are likely to remain standing to contaminate combines. If only some fields are infested, try to harvest fields containing jointed goatgrass last, especially if those fields have critical populations. Also, abandon or cut infested backswaths last in fields that are otherwise clean. This will help prevent carrying spikelets to uninfested areas with the combines. In some instances, if a producer has an infested field that has matured early enough so the jointed goatgrass hasn't shattered onto the ground, it may be possible to harvest many spikelets with the grain. This may help remove weed seed from the field, but discounts for dockage will increase.
- 3) If infested fields or backswaths must be cut before clean fields, clean the combine before moving to the uninfested field. Obviously, time isn't often available during harvest to thoroughly clean the combine, but

at least run the machine empty with the air wide open for a little bit. Then shut the machine off, walk around it, and brush off any chaff and straw accumulations that are likely to fall off in the next field. A leaf blower does a good job of quickly removing material from the exterior of the machine.

### ***Spread Straw and Chaff***

During harvest, adjust and maintain straw and chaff spreaders to distribute threshed straw and chaff uniformly over as much of the header width as possible. Otherwise, jointed goatgrass and other grass weed seedlings that emerge in dense bands, partially covered with heavy amounts of straw or chaff, are difficult to control with either herbicides or tillage. If stubble burning is planned, evenly spread residue will help provide an even burn across the field.

### ***Harvest Weed Seed Control***

Jointed goatgrass plants retain a majority of seed in the spikes (heads) at the time of wheat harvest, which makes harvest weed seed control a viable option for management. A combine equipped with an impact mill system can destroy the jointed goatgrass seed in the chaff fraction before it is spread behind the combine, which reduces the soil seedbank and helps prevent infestation of jointed goatgrass in future wheat crops. Another method of harvest weed seed control is chaff lining, which buries the weed seed in a thick layer of wheat chaff at the time of wheat harvest.

### ***Consider Cutting Height***

Finally, avoid cutting too low if you are planning to moldboard plow. A thick layer of loose material on the soil surface may trap jointed goatgrass spikelets and roll onto the top of the adjoining furrow when plowing. This will prevent adequate burial of the spikelets. If there are concerns that leaving tall stubble means missing heads and leaving too much grain in the field, remember that many low heads are small and often contain only a few kernels of light grain. The actual bushel losses from leaving a few of these heads are insignificant. In addition, the light grain in small, low heads can reduce the test weight of grain for the entire field, resulting in price discounts.

## **Management after Harvest until Seeding**

### ***Plan Actions Based on Infestation***

The period between wheat harvest and planting of the next crop is a key time for management of jointed goatgrass and other grass weeds. Field operations during this time can have a large influence on the soil seed bank and, ultimately, on weed populations in the next crop. The evaluations at wheat harvest—noting if fields infested with jointed goatgrass had critical populations or background populations—should now be used to plan future management.

Fields with a **critical population** of jointed goatgrass are those where the jointed goatgrass was so dense, and accumulated jointed goatgrass seed in the soil seed bank is so high, that yield of the next wheat crop will be severely reduced unless major corrective action is taken.

Fields with a **background population** of jointed goatgrass are those where the level of jointed goatgrass is low and has been low for several years. Therefore, the accumulated jointed goatgrass seed in the soil seed bank is not likely to cause a significant reduction in yield of the next wheat crop. These fields should be managed to prevent increases in weed populations.

### ***Managing a Critical Population***

For fields with a critical population of jointed goatgrass, major corrective action will be required before another wheat crop can successfully be grown. This action involves the use of one or more **intensive reclamation practices**. Combining practices when possible will increase success.

The intensive reclamation practices are:

- Crop rotation
- Moldboard plowing
- Clearfield® wheat (which allows in-crop use of Beyond® herbicide)
- Graze-out + glyphosate
- CoAxium® wheat (which allows in-crop use of Aggressor® herbicide)

### ***Crop Rotation***

Crop rotation is one of the best methods to reclaim fields from a critical infestation of jointed goatgrass, true cheat, and many other grass weeds. The ability to combine crop rotation with other intensive reclamation practices, along with its multi-year aspect, makes it especially effective when unfavorable weather may reduce the effectiveness of a single practice.

Suitable alternative crops interrupt the life cycle of jointed goatgrass by permitting its control in the spring and preventing seed production. This control requires the jointed goatgrass to be destroyed prior to heading in the spring by one of two methods.

The first method of crop rotation is planting a fall-seeded crop, such as winter canola, that has in-crop herbicides which will control jointed goatgrass. Information on winter canola production can be found at [www.canola.okstate.edu](http://www.canola.okstate.edu). Alternatively, fall or spring planted annual forage crops, such as winter triticale or spring oats can also be utilized for grazing purposes.

The second method of crop rotation is to seed a spring-planted crop such as dryland corn, grain sorghum, or sunflower, after using spring tillage or glyphosate herbicide to destroy any emerged jointed goatgrass plants.

Glyphosate is the common name for the active ingredient in numerous products such as Roundup®, Buccaneer®, Gly Star™, etc. Further information on glyphosate use is discussed in Appendix A of this bulletin.

NOTE: When using either of the above methods of crop rotation to control jointed goatgrass, it is essential that the jointed goatgrass be destroyed prior to its heading out in the spring. Jointed goatgrass can produce viable seed even before a head has fully emerged from the boot.

### ***Moldboard Plowing***

Using a moldboard plow to bury spikelets (and the seeds within them) too deep for successful seedling emergence can dramatically reduce jointed goatgrass populations in the next wheat crop. It can also significantly reduce populations of other grass weeds such as true cheat.

For successful spikelet burial, plowing should be done 6 to 8 inches deep. Remember, the loose soil after plowing will compress, and jointed goatgrass can emerge through 4 inches of soil. The plow must also fully invert the soil and thoroughly cover all surface material. If the plow bottoms don't cover thoroughly, don't invert soil completely, or if the plow cannot be pulled deeply enough, this practice will not be successful in preventing emergence. Once spikelets are buried, use shallow tillage for later operations to avoid bringing spikelets back up to a level from which seedlings can successfully emerge. Also, avoid plowing again for at least two years to allow time for the buried seeds to decompose or die.

### ***Burning***

Burning stubble before plowing or other tillage is a controversial approach to controlling jointed goatgrass and other grass weeds. Burning can kill seeds lying on the soil surface, thus reducing the soil seed bank, but burning stubble is not always successful in killing jointed goatgrass and other weed seeds. In a survey conducted in north-central Oklahoma, stubble burning reduced true cheat in the next wheat crop less than half of the time. In studies conducted in the Pacific Northwest, extremely heavy straw cover was required before fire temperatures were hot enough to destroy or sterilize jointed goatgrass seeds. However, research in Nebraska showed that stubble burning was effective in controlling jointed goatgrass when the burn was a slow moving, hot fire.

Many factors affect the success of burning in reducing the soil seed bank, including the amount of fuel (heavy straw cover or light straw cover), soil moisture (moist soil may keep the surface too cool for weed seed destruction), the speed of the fire front, and evenness of fuel distribution. Jointed goatgrass spikelets that are shallowly buried or even partially buried will not be sterilized or destroyed by fire. Similarly, spikelets that have fallen into cracks or hoof prints in the soil may not be affected.

If stubble is burned, nitrogen in the stubble will be lost to the atmosphere rather than returned to the soil. Burning the stubble from a 40 bu/ac wheat crop will remove approximately 18 lbs of nitrogen from the field. At a nitrogen cost of \$.50/lb, \$9.00/ac of additional fertilizer will be needed to replace the nitrogen lost from burning. In addition to nitrogen losses, burning stubble will oxidize phosphorous in the straw into compounds unavailable to plants. This will require further expenditures for additional phosphorous fertilizer.

Finally, burning stubble will destroy soil organic matter, resulting in decreased soil aggregation, decreased moisture infiltration, and increased erosion. Producers should consider all of the above when deciding on the use of burning as a control method for jointed goatgrass and other grass weeds.

### ***Chisel/Disk Tillage***

Chiseling stubble in a field with a critical population will not adequately bury jointed goatgrass spikelets, but will simply distribute them throughout the tilled soil, leaving many at a depth from which seedlings can successfully emerge. Chiseling may also leave the soil cloddy, which reduces spikelet-soil contact and inhibits weed control by delaying the emergence of many weed seedlings until after wheat is planted.

Like chiseling, disking stubble as the first operation after harvest will not bury jointed goatgrass spikelets deep enough to prevent seedling emergence. However, if disking leaves soil less cloddy than chiseling, better spikelet-soil contact will likely result in more jointed goatgrass seeds germinating before wheat planting. Tillage or spraying can then destroy these seedlings, helping to deplete the soil seed bank. Disking (to stimulate germination) is not likely to be as effective as moldboard plowing in controlling a critical infestation, but it may be effective in the management of background populations.

### ***No-till***

It is not advisable to use no-till in fields with a critical population of jointed goatgrass or other grass weeds, unless Clearfield® wheat, CoAXium® wheat, crop rotation, or graze-out + glyphosate are also planned. To successfully grow a wheat crop in fields with a critical population of jointed goatgrass, seeds in the soil seed bank must be buried too deep for successful emergence or must germinate early enough so that large numbers of seedlings can be destroyed before they infest the next crop—or seedlings must be controlled by either in-crop use of imazamox herbicide on Clearfield® wheat or Aggressor® herbicide in CoAXium® wheat. No-till, like chiseling, fails to bury seeds and may not provide enough seed-soil contact for germination prior to wheat seeding.

Note: Avoiding no-till in fields with a critical population of jointed goatgrass or other grass weeds does not mean that no-till is an unacceptable method of crop

production. Also, chiseling, rather than disking or plowing, is still appropriate for many situations. Just use no-till or chisel systems where grass weeds are not a problem, or where Clearfield® wheat, CoAXium® wheat crop rotation, or graze-out can also be used.

### ***Clearfield® and CoAXium® Wheat***

Another practice for reclaiming a field from a critical population of jointed goatgrass is the use of herbicide-resistant wheat. Clearfield® wheat varieties allow the growing wheat to be sprayed with imazamox, the active ingredient in Beyond® herbicide. CoAXium® wheat varieties are now also available that allow growers to use POST applications of quizalofop-p-ethyl (an active ingredient in Aggressor® herbicide) for in-season control of jointed goatgrass and other grass weeds. However, imazamox is still the preferred active ingredient for susceptible jointed goatgrass populations.

### ***Graze-out + Glyphosate***

The final intensive reclamation practice, graze-out + glyphosate herbicide, is done by aggressive grazing, and then removing the cattle early enough in the spring to allow the complete control of any remaining wheat and weeds with a herbicide application. Glyphosate herbicide is preferred over tillage after graze-out because spring conditions often make tillage ineffective at complete weed control. Complete details on Graze-out + Glyphosate can be found in the Management in the Growing Wheat section of this bulletin.

### ***Managing a Background Population***

As we said earlier, fields with a background population of jointed goatgrass are those where the level of jointed goatgrass is low, and has been low for several years. Therefore, the accumulated jointed goatgrass seed in the soil seed bank is not likely to produce enough jointed goatgrass plants to cause a significant reduction in yield of the next wheat crop. These fields should be managed to prevent increases in weed populations.

Throughout the remainder of this bulletin, a number of **background control practices** will be discussed. These practices are used to help keep background populations of jointed goatgrass from increasing and becoming critical populations. The major control practices include field border sanitation, competitive wheat varieties, in-row banding of starter fertilizer, drill row spacing, and proper seeding rates.

As many background control practices as possible should become part of a producer's normal farming methods. The use of these practices will not only suppress jointed goatgrass and other winter annual grass weeds, but will enhance wheat production and profitability in uninfested fields.

Background control practices and intensive reclamation



practices are complementary, so appropriate background control practices should always be used when an intensive reclamation practice is being implemented. The use of background control practices will help the more intensive practices reclaim land from a critical population of jointed goatgrass. Similarly, an intensive reclamation practice, such as crop rotation or moldboard plowing, could occasionally be used on a field with a background population of jointed goatgrass to ensure that the jointed goatgrass doesn't become a critical population.

### Nitrogen Fertilization

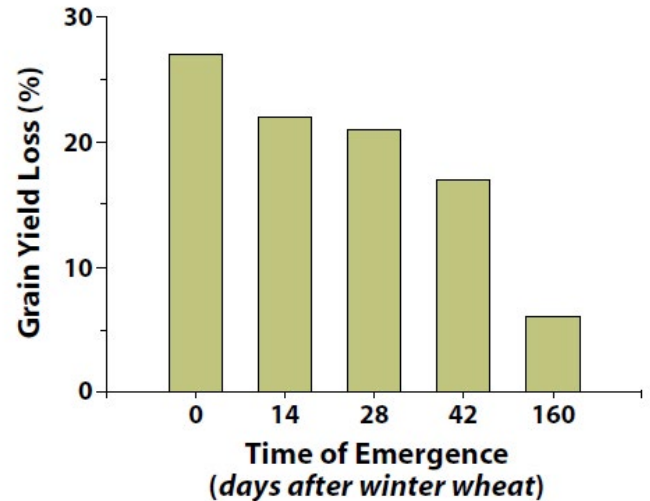
Timing, rate, and placement of nitrogen fertilizer is an important practice for the management of both jointed goatgrass and other grass weeds. Nitrogen fertilizer, other than starter fertilizer used at seeding, should be applied as early as practical in the time between harvest and seeding. Rainfall can then move nitrogen deeper into the soil profile. This will allow wheat roots to access the nitrogen before roots of later germinating jointed goatgrass can reach it. Nitrogen that has moved down into the soil profile is also less accessible to the shallow root system of true cheat.

One exception to the early application of nitrogen would be the use of seeding equipment that can band high rates of nitrogen below and to the side of the row at seeding. Nitrogen placed this way will be deep enough in the soil profile that wheat can access it before later germinating weeds can reach it.

Spring topdressing of nitrogen fertilizer onto growing wheat is not recommended when wheat is heavily infested with jointed goatgrass or other grass weeds. Research has shown that these weeds are very effective in capturing surface-applied nitrogen which increases their competitiveness with wheat. An exception to this guideline is the use of UAN nitrogen solution diluted with water as the carrier when spraying Beyond® herbicide. In this instance, the herbicide will control most jointed goatgrass and many other grass and broadleaf weeds, thus the nitrogen will not be used by the weeds. Research has shown increases in the effectiveness of Beyond® herbicide when the amount of UAN added to the carrier solution is greater than the minimum required by the label. Note, however, that there is a maximum amount of carrier-solution nitrogen allowed by the label for Beyond®. **Follow label instructions.** Remember also, Beyond® can be used only on Clearfield® wheat—Beyond® herbicide will kill or severely damage other wheat varieties.

### Management at Wheat Seeding

At seeding, producers should pay particular attention to management practices that enhance crop competitiveness: the ability of a thick, vigorous, healthy stand of wheat to out-compete jointed goatgrass and other grass weeds by capturing more of the sunlight, soil moisture, and soil nutrients available for plant growth. A competitive crop results in fewer and smaller jointed goatgrass plants that don't significantly reduce wheat yields. Smaller



**Figure 6.** Jointed goatgrass time of emergence vs. wheat yield loss. Wheat was planted in September; jointed goatgrass density was 18 plants per square yard.

jointed goatgrass plants also produce fewer spikelets and seeds, reducing infestations in subsequent wheat crops. A competitive crop alone will not reclaim a field from a critical infestation of jointed goatgrass, but it will enhance the use of crop rotation, moldboard plowing, Clearfield®, and/or CoAXium® wheat in reclamation. For fields with a background population of jointed goatgrass, growing a competitive crop is one of the most important things a producer can do to help keep these background populations from becoming critical infestations.

Earlier we discussed a **multi-practice** approach to control jointed goatgrass. With this approach, a producer combines several management practices to achieve better jointed goatgrass control than could be obtained by relying on only one or two practices. If used alone, many practices have a limited effect on grass weed control. When practices are combined and used over a period of years, the results are significant. In addition, adoption of these practices will increase wheat yields or reduce costs even where grass weeds are not a problem.

Increasing crop competitiveness, by using as many of the following background control practices as possible, is one of the best ways to implement a multi-practice approach.

### Eliminate Weed Seedlings at Planting

Wheat will be far more competitive against jointed goatgrass and other weeds if the wheat has emerged and established before other weeds emerge (Figure 6). Weeds that have emerged before wheat is planted, or weeds that have germinated without emerging before wheat is planted (dig in the soil and look) will have an advantage over the wheat. If jointed goatgrass or other problem weeds have germinated



or emerged prior to seeding wheat, it is obvious that they should be destroyed.

In some instances, such as a hard rain immediately after seeding, it may be necessary to destroy the first planting and reseed the wheat. In this situation, wheat and weeds will be germinating and emerging at the same time so the competitive ability of the wheat will be reduced, especially if the stand of wheat is thin. In making the decision on destruction and reseeding, producers need to consider if they are still seeding early enough for the wheat to become well established, as wheat that emerges too late in the fall can also be a poor competitor against weeds.

### ***Plant Competitive Varieties***

Varieties with rapid fall growth and prolific tillering suppress jointed goatgrass better than varieties that don't exhibit these characteristics. It is also important to plant a variety that is adapted to the producer's region. A variety with rapid fall growth will provide little weed suppression if it has poor winter survival.

### ***Consider Soil pH***

Some wheat varieties are more tolerant of low soil pH than other varieties. In a 1999 trial near Enid, Oklahoma, yield differences between tolerant and intolerant varieties were greater than 25bu/acre. A variety that has poor yields in a low pH soil will also be a poor competitor with weeds in that soil. Oklahoma State University publication PSS-2240 has information on managing low pH (acid) soils for wheat production. Information on the tolerance of many wheat varieties to acid soil conditions can be found at [www.wheat.okstate.edu](http://www.wheat.okstate.edu).

### ***Use Clean Seed***

Make sure wheat seed doesn't contain jointed goatgrass spikelets or other weed seeds. **Do not create a problem by planting contaminated wheat seed.** Producers purchasing certified seed should make sure it contains no jointed goatgrass spikelets. It is important to physically examine certified seed as some states allow goatgrass contamination in certified seed. Producers using bin-run seed (which may have a greater chance of jointed goatgrass contamination) should use or hire cleaners that have length graders or other devices that will remove jointed goatgrass spikelets. Conventional rotary screen cleaners will not do an adequate job of removing spikelets. To determine if jointed goatgrass is present in wheat seed, place a seed sample into a pail, cover the sample with water, and stir. Wheat seeds sink, whereas jointed goatgrass spikelets typically float.

### ***Consider Seed Size***

The size of wheat seed can be described using the number of seeds per pound. Seed from 13,000 to 16,000 seeds per pound can be considered large, seed from 16,000 to 20,000 seeds per pound considered medium, seed from 20,000 to 22,000 seeds per pound considered small, and seed with more than 22,000 seeds per pound considered very small.

Note: as the number of seeds per pound increases, seed size is decreasing.

Avoid using very small seed. It may also be best to avoid small seed, although this can be difficult with some varieties or in certain years. A survey in Oklahoma showed fields planted with seed smaller than 22,700 seeds per pound to have significantly lower emergence than fields planted with larger seedlots.

It is easy to determine the number of wheat seeds per pound. Most grain elevators have a digital scale accurate to 0.1 grams that is used for dockage measurements. A scale at least this precise is needed for accurate results. Count 250 seeds and have them weighed in grams. Use the following formula to convert from this weight in grams to seeds per pound:  $(250 \div \text{weight in grams}) \times 454 = \text{seeds per pound}$

### ***Consider the Seeding Date***

Most areas have a 7- to 14-day period that is considered optimum for wheat planting. In order to cover all of their acres, producers often begin planting before the optimum period and/or finish planting after the optimum period. Fields in which jointed goatgrass is a concern should be planted during the optimum period to ensure a competitive stand of wheat. If fields are planted too early, as is often done for grazing, there is a risk of missing a flush of jointed goatgrass that could be destroyed before seeding. If fields are planted too late, the wheat will emerge too late and be less competitive with jointed goatgrass. Even though late seeding might slightly increase the chances of eliminating a flush of jointed goatgrass before seeding, this event is very weather dependent. Over several years, any gains from killing an occasional flush of jointed goatgrass are more than lost by the decreased competitiveness of wheat that is seeded too late.

### ***Adjust Seeding Rates***

Adjust seeding rates (pounds/acre or seeds/acre) for seeding date and for weed suppression. Increase your seeding rates as the seeding date becomes later. Also, for any given seeding date, seeding rates should be increased at least 20 percent over the normal seeding rate for that date if suppression of jointed goatgrass is desired.

### ***Apply Starter Fertilizer as Needed***

Many soils in the southern Great Plains (the region covered by this bulletin) have phosphorous levels too low for optimum wheat production. Other soils have received many applications of phosphorous fertilizer and have adequate levels of this nutrient. Producers should use soil tests to determine if phosphorous or other nutrients should be applied at seeding.

Unless specialized seeding equipment is available to band nitrogen below the seed, the majority of nitrogen fertilizer should be applied as early as practical during the time between harvest and seeding the next crop. Reasons for this were discussed earlier in this bulletin. Phosphorous

fertilizer, however, can be band applied with the seed. Banding phosphorous fertilizer with the seed, in amounts based on soil test recommendations, is one of the most important practices to promote vigorous, early growth and maximum yields of wheat.

Typical rates of phosphorous fertilizer don't contain enough nitrogen to inhibit germination, even when the fertilizer is placed directly with the seed. This makes it relatively easy to retrofit older seeding equipment to apply liquid phosphate fertilizer (Figure 7). Note, make sure that fertilizer placed with the seed DOES NOT contain ammonium thiosulfate, 12-0-0-26. This product will severely reduce seedling germination. Fertilizer dealers can supply information on retrofitting seeding equipment. Also, some producers apply phosphorous fertilizer with older seeding equipment by simply blending dry 11-52-0 or 18-46-0 with the seed.

### Consider Row Spacing

In general, a narrow row spacing of 6 to 7.5 inches is more effective in suppressing jointed goatgrass and other weeds than wider row spacing. As with the other background control practices that can be used at seeding, narrow row spacing by itself will not suppress a background population, nor will it reclaim land from a critical infestation. Over several years, however, when used in conjunction with other background control practices, narrow row spacing can help suppress a background population of jointed goatgrass or help an intensive reclamation practice be more effective.

It is unlikely that changing seeding equipment to obtain additional weed control from narrow row spacing would be cost effective, especially if the producer has implemented the other background management practices suggested for use at seeding. However, if equipment is being changed for other reasons, narrow row spacing should be considered.

Producers should also use markers or other guidance systems when seeding to avoid gaps between adjoining passes with the drill. Even if a space between drill rounds is only a few feet long, it can provide an area of reduced competition where weeds can grow and produce seed. Remember, a single jointed goatgrass plant growing without competition can produce dozens or even hundreds of spikelets.

### Clearfield® or CoAXium® Wheat

In addition to background control practices, producers have the option of planting a Clearfield® or CoAXium® wheat variety. Clearfield® or CoAXium® wheat can be used as an intensive reclamation practice, or can occasionally be used simply as a background control practice. Clearfield® wheat varieties allow the growing wheat to be sprayed with Beyond® (imazamox). Imazamox herbicide will suppress or control jointed goatgrass in the growing wheat. CoAXium® wheat varieties allow the growing wheat to be sprayed with Aggressor® (quizalofop-p-ethyl) herbicide. Aggressor® herbicide applied at the recommended field-use rate will control jointed goatgrass in growing wheat.



Figure 7. Disc drill modified to place liquid starter fertilizer in the seed row.

Research has shown that fall applications of imazamox are often more effective than spring applications as smaller weeds are more easily controlled. (See the product label for use instructions and for information on control or suppression of other weed species.) Recent research with CoAXium® wheat in the southcentral Great Plains has shown that Aggressor® herbicide applied in fall or spring can provide effective control of jointed goatgrass (See Aggressor® label for specific use instructions and for controlling other winter annual grass weeds.) Because Clearfield® and CoAXium® wheat varieties contain a gene or genes that makes them tolerant to imazamox and quizalofop-p-ethyl, respectively, they may be sprayed with imazamox (on Clearfield®) and quizalofop-p-ethyl (on CoAXium®) herbicides with minimal risk of crop injury. Winter wheat varieties that do not contain this gene (that provides tolerance to imazamox or quizalofop-p-ethyl) will be severely injured or killed if treated with one of these herbicides. Clearfield® or CoAXium® wheat varieties are not Genetically Modified Organisms (GMOs).

In planning a jointed goatgrass control program using Clearfield® or CoAXium® wheat, careful attention should be paid to variety selection. Growers should review university variety trials and determine if there is a potential forage or grain yield penalty associated with growing a Clearfield® or CoAXium® variety. Most new Clearfield® varieties for this region are much better adapted and have higher yields than did earlier varieties. In contrast, several CoAXium® wheat varieties have been released in recent years and growers should consult with their local county extension agent or university agronomist for selection of the best suited variety for their region.

Producers using Clearfield® or CoAXium® wheat varieties should also implement as many other jointed goatgrass control practices as practical. Using crop rotation or moldboard plowing before planting Clearfield® or CoAXium® wheat on fields with a critical population will

significantly reduce the number of jointed goatgrass plants that the herbicide must control in the wheat. Although imazamox has been shown to provide 90% or better control of jointed goatgrass, final results will be better if there are fewer plants to control at the time of imazamox application.

Producers purchasing Clearfield® or CoAXium® wheat seed must sign a contract agreeing to comply with the **Clearfield® or CoAXium® Stewardship Program**. Further details about Clearfield® or CoAXium® wheat, the stewardship program, and information on applying imazamox and quizalofop-p-ethyl herbicides, are discussed in the next section of this bulletin.

## Management in the Growing Wheat

### Identify Infested Areas

Management of jointed goatgrass in the growing wheat crop begins with identifying infestations (see Identification and Biology section). Check for and identify plants growing between the wheat rows (Figure 8). Refer back to Figures 1 and 2 for help in determining whether small plants are jointed goatgrass or volunteer wheat.

### Border Sanitation

Field border sanitation is a very important background control practice. Pay particular attention to field edges, around oil wells, and along well access roads. Contamination of fields often begins from around power poles and road signs. Prevent the spread of jointed goatgrass from these areas by spot spraying seedlings with glyphosate or otherwise destroying them. Jointed goatgrass plants with fully emerged heads may have to be physically removed to ensure that no viable seed is produced. If physical removal is impractical, it is still better to spray these headed plants with glyphosate rather than to do nothing, since production of viable seeds may still be reduced if anthesis has not progressed too far.

### Graze-out + Glyphosate

The final intensive reclamation practice, graze-out + glyphosate herbicide, is done by aggressive grazing, and then removing the cattle early enough in the spring to allow the complete control of any remaining wheat and weeds with a herbicide application.

Two years of graze-out + glyphosate may be required to deplete the soil seed bank and recover from a critical infestation. Just as with crop rotation, it is essential to prevent seed production by destroying all jointed goatgrass before emergence of the first heads.

Graze-out without the use of glyphosate is often not successful because graze-out followed by tillage typically does not achieve complete weed control. Conditions after grazing typically leave a field compacted and covered with hoof prints. The first field operation, which is done in the spring rather than after harvest, is commonly done with



Figure 8. Jointed goatgrass growing between wheat rows.

a disk, chisel, or field cultivator in an attempt to loosen the soil and remove the hoof prints while killing weeds. However, this practice has only limited success because the compacted soil leaves a number of plants attached to large clods. And because conditions in the spring are normally cool and damp, these clods keep many jointed goatgrass and other grass weeds alive long enough to produce seed.

Therefore, producers using graze-out should apply glyphosate herbicide for initial weed control after cattle are removed. Although moldboard plowing might also provide adequate control (unless the soil turns up too cloddy), spraying with glyphosate will cover acres faster, and use less fuel. Under typical spring conditions (adequate moisture and moderate temperatures), the use of glyphosate will provide complete grass weed control where disking, chiseling, or field cultivating will often fail. Note: this does not contradict what we said earlier about avoiding no-till in situations with a critical infestation. That recommendation applied to weed control during the summer after wheat harvest, not to weed control in the cool, damp conditions of spring. Weed control after graze-out is under different conditions than weed control after harvest. The spring season goal is to prevent seed production, not to achieve seed-soil contact. If any seeds were on the soil surface prior to planting the wheat crop for graze-out + glyphosate, cattle walking on the field will have provided sufficient seed-soil contact for eventual germination (and subsequent destruction).

Spring conditions generally provide an excellent environment for weed control with glyphosate since cool temperatures and adequate moisture promote active plant growth. These same spring conditions often make spring tillage (other than moldboard plowing) ineffective at controlling weeds. For these reasons, glyphosate does a better job of controlling weeds in spring than it may in late summer when weeds may be subject to temperature or drought stress. Note, however, glyphosate has no residual soil activity. Seeds in the soil that have not germinated will



still remain part of the soil seed bank and may produce jointed goatgrass plants that will have to be controlled later. This is another reason that a multi-practice approach is important.

Finally, use of glyphosate for the first operation does not mean that a producer must continue weed control with herbicide until seeding. Glyphosate use can continue if desired, or a producer can use tillage for weed control and seedbed preparation. The decision should be based on cost, erosion concerns, and which system will provide the best seedbed.

For further information on the use of glyphosate see the Appendix A to this bulletin, or talk to your chemical supplier. **ALWAYS REMEMBER TO READ AND FOLLOW THE LABEL DIRECTIONS WHEN USING HERBICIDES!**

### ***Grazing Wheat Intended for Harvest***

Grazing wheat, which will not be destroyed as done for Graze-out + Glyphosate, may increase problems with jointed goatgrass and other grass weeds. Early planting for increased forage production eliminates opportunities to kill a late summer flush of weeds before seeding. Canopy reduction from grazing will reduce the ability of wheat to suppress weeds. Also, cattle may selectively graze wheat and ignore jointed goatgrass, further reducing the competitiveness of the wheat. Producers need to consider these effects and implement appropriate management practices to help compensate for them. Appropriate practices would include consistent use of as many background control practices as possible, careful monitoring of fields for increasing weed populations, and periodic use of intensive reclamation practices to prevent the development of critical infestations. Producers grazing Clearfield® or CoAXium® wheat that will be sprayed with Beyond® or Aggressor® herbicides should check the respective product label for grazing restrictions.

### ***Top-Dressing Nitrogen***

As discussed earlier, top-dressing nitrogen fertilizer onto growing wheat is not recommended when wheat is heavily infested with jointed goatgrass or other grass weeds. Refer to the section “Nitrogen Fertilization” (page 8) for the exception to this guideline: the use of UAN nitrogen solution diluted with water as the carrier solution when spraying Beyond® herbicide.

### ***Patch Control***

For fields that cannot be sprayed with imazamox herbicide (or for fields of Clearfield® wheat that will not be sprayed) small patches of wheat that are densely infested with jointed goatgrass should be destroyed by tillage or by spraying with glyphosate. This is especially true if the field is otherwise not infested or has only a low background population of jointed goatgrass. It is important to spray these patches no later than emergence of the first jointed goatgrass heads. Ideally, they should be sprayed before any jointed goatgrass heads

emerge. Tillage to kill these patches should be performed before any heads emerge. It is better to lose a small amount of wheat by destroying an infested patch or field edge than to allow jointed goatgrass to spread and become a critical infestation over an entire field. Remember, a combine can do an excellent job of spreading weed seeds further into a field.

### ***Crop Destruction***

In some years, drought or other natural disasters may severely damage a wheat crop by early spring. If this crop was infested with jointed goatgrass or other winter annual weeds, even at only a low or moderate level, destroying the entire field or fields may be advisable. Interrupting the normal life cycle of winter annual grass weeds by destroying them in a spring when they otherwise would head out and produce seed is a very effective control practice.

### ***Haying***

It is not advisable to try to control jointed goatgrass by haying an infested field. Haying of wheat would likely be done after jointed goatgrass had already produced seed, and typically, not all of this seed is removed from the field with the hay. In addition, cutting jointed goatgrass will not kill all plants, and some may produce new tillers with additional seed. Also, feeding infested hay to cattle can spread jointed goatgrass through viable seed in the manure.

### ***Imazamox Use on Clearfield® Wheat***

Fields planted to a Clearfield® wheat variety have an additional management practice available for control or suppression of jointed goatgrass and many other grass weeds. This practice is the in-crop application of Beyond®, which is an herbicide containing imazamox.

**HERBICIDES SHOULD BE APPLIED ACCORDING TO LABEL DIRECTIONS. ALWAYS READ AND FOLLOW LABEL DIRECTIONS CAREFULLY!**

In field research studies, Beyond® has provided good (90% or better) control of jointed goatgrass when weeds were treated with 4 ounces of product per acre in the fall or early spring. Imazamox (the active ingredient in Beyond®) has been much more consistent and effective for jointed goatgrass control than for volunteer rye (feral rye) control. Volunteer rye in Oklahoma has been variable in response to imazamox.

Although imazamox herbicides typically provide good control of jointed goatgrass, environmental conditions such as drought or cold temperatures may reduce their effectiveness. Also, imazamox may provide very little residual control. This further demonstrates the need for producers to use a multi-practice approach in managing problem weeds.

Among weed scientists, the biggest concern about Clearfield® wheat is the potential for development of herbicide-resistant weeds. Because imazamox provides



good control of jointed goatgrass and several other grass weeds, it will exert a tremendous selection pressure for resistance. Imazamox belongs to a class of herbicides known as ALS-inhibitors. Other herbicides in this class have a history of quickly selecting for weeds that are herbicide resistant. Examples include ALS-resistant kochia, ALS-resistant prickly lettuce, and ALS-resistant Italian ryegrass.

To delay the onset of herbicide resistance, fields treated with imazamox herbicide should not be treated with another ALS-inhibitor in the same year. Growers should rotate Clearfield® wheat with CoAXium® wheat to reduce the selection pressure on ALS inhibitors for development of ALS-resistant jointed goatgrass or other grass and broadleaf weeds. Because many wheat herbicides are ALS-inhibitors, producers will need to be careful in choosing additional treatments. If additional weed control is needed, such as controlling warm season broadleaf weeds like kochia or pigweed, herbicides with a different site of action should be used. Products containing 2,4-D or dicamba are examples of herbicides with a different site of action. Consult herbicide labels or university weed control guides for further information.

The multi-year seed life of jointed goatgrass may require that imazamox be used two years in a row if other intensive reclamation practices are not also used. To help prevent the onset of imazamox-resistant jointed goatgrass, producers who have used imazamox for two consecutive years should not use it again in the same field for at least two more years. If the jointed goatgrass population is still unacceptable after two years of imazamox, other intensive reclamation practices (such as rotating with CoAXium® wheat) should be used.

Herbicide resistance can also occur through pollen transfer, as wheat and jointed goatgrass share a common ancestor. Imazamox-resistant jointed goatgrass × wheat hybrids that carry the resistance gene from a Clearfield® wheat variety have been identified in a commercial wheat field. This indicates it is likely that resistance to imazamox could be transferred from wheat to jointed goatgrass.

### ***Quizalofop-p-ethyl Use on CoAXium® Wheat***

The CoAXium® wheat production system combines the use of Aggressor® (quizalofop-p-ethyl, Group 1) herbicide with wheat varieties containing genes that confer tolerance to this herbicide – AXigen® trait. Three CoAXium® hard red winter wheat varieties (LCS Fusion AX, Crescent AX, and Incline AX) that contain the AXigen® trait are now commercially available for use.

Aggressor® herbicide has good foliar activity on grassy weeds, so the field planted with CoAXium® wheat production system can provide an additional opportunity for post-emergence control of winter annual grass weed species, including jointed goatgrass and other grass weed species. A single post-emergence application of Aggressor® herbicide at a rate of 8-12 fluid ounces per acre will provide

good control of jointed goatgrass (85% or better) when applied to CoAXium® wheat during the fall or spring when jointed goatgrass and other susceptible grass weeds are actively growing. Sequential applications (fall followed by spring) of Aggressor® can be made to CoAXium® wheat but should not exceed a total of 16 fluid ounces per acre per crop year. Aggressor® treatments should include either non-ionic surfactant (NIS) at 0.25% v/v or crop oil concentrate (COC)/methylated seed oil (MSO) at 1% v/v.

Group 1 herbicides like quizalofop-p-ethyl have a history of quickly selecting for resistant weed biotypes, for example, Italian ryegrass and downy brome. Therefore, as previously discussed for imazamox use in Clearfield® wheat, producers should not use other group 1 herbicides in the same year and they should be careful about their use of other group 1 herbicides throughout the crop rotation in that field.

Producers should not let the potential for the development of herbicide-resistant weeds discourage them from growing Clearfield® or CoAXium® wheat and using imazamox or quizalofop-p-ethyl herbicide, respectively. They should simply use good stewardship practices to help protect these technologies. Producers planting Clearfield® or CoAXium® wheat are required to comply with the respective stewardship program, and must enter a contractual agreement regarding the stewardship program to purchase wheat seed. The programs require producers to plant certified seed and stipulates that producers cannot save any grain from a crop of Clearfield® or CoAXium® to be used as seed for a subsequent crop, even a crop on their own farm. In addition, if Beyond® or Aggressor® herbicides are applied, the programs require they be used in accordance with the respective product label, including stated label rate and timing. The programs also have a number of recommendations, including frequency of use, crop rotation, and addition of herbicides with different modes of action. **Producers using Clearfield® or CoAXium® wheat should consult with their chemical dealer or seed supplier for full details on all requirements and recommendations of the stewardship programs.**

Scientists working as part of the National Jointed Goatgrass Research Program investigated herbicide resistance related to jointed goatgrass. They suggest ways to prevent and manage herbicide resistance in jointed goatgrass in “Strategies to Minimize the Risk of Herbicide-Resistant Jointed Goatgrass” (Washington State University, EM024E). This bulletin is available at [www.jointedgoatgrass.wsu.edu](http://www.jointedgoatgrass.wsu.edu) or from university Extension specialists.

### **Summary**

Throughout this bulletin, the use of a multi-tactic approach to control jointed goatgrass has been emphasized. The large year-to-year variations in precipitation and growing conditions in the western part of the Central Great Plains will greatly influence the effectiveness of any one practice in a given year. This

makes the use of multiple practices particularly important.

A producer who relies on only one practice, or on practices implemented at only one part of the cropping cycle, will not be successful at long-term control of jointed goatgrass or other winter annual grass weeds. A multi-tactic approach can effectively control jointed goatgrass and other winter annual grasses for dryland wheat producers. With this approach, producers can limit the negative economic and environmental impacts of these weeds.

The practices discussed in this bulletin are documented by multiple years of research in Kansas, Nebraska, Colorado, and Wyoming. Detailed research reports can be found at [www.jointedgoatgrass.wsu.edu](http://www.jointedgoatgrass.wsu.edu)

## **Appendix A. Glyphosate Use (After Graze-**

## out and During Other Applications)

Spring, when wheat and weeds need to be completely destroyed after graze-out, is an excellent time to replace multiple tillage operations with a single application of glyphosate. Often in the spring, complete wheat and grass weed control with tillage is difficult—it is very common to disk a field and then have cool, damp conditions where plants re-grow and produce seed. Glyphosate provides excellent control of susceptible grass species under typical spring conditions of adequate moisture and moderate temperatures. In addition, if weed species other than grass weeds are present, these species can be controlled using tank mixes containing herbicides such as 2,4-D and/or dicamba.

Note: a system that begins with a spray application of glyphosate doesn't require a producer to do all subsequent weed control with herbicides. If a producer prefers to use tillage for summer weed control (when weed species, and temperature and moisture conditions may not be as favorable for the use of glyphosate) that option is available. Simply begin tillage when appropriate and continue to use tillage as required until fall seeding. Tillage will also provide a layer of loose soil above the soil moisture line, which will insulate against seed zone moisture loss in the event of a late summer drought.

If glyphosate is used later in the summer, weeds may be under stress and more difficult to control. Try to spray weeds when stress can be minimized. Avoid spraying when temperatures exceed 90° F. If weeds are under drought stress, try to wait for rain and then spray about 5 days later. Weeds that were cut off with the combine at harvest should be given a chance to begin re-growth before spraying. But do not wait too long, as large weeds are more difficult to control.

When using glyphosate, it is always advisable to add spray-grade ammonium sulfate (AMS) as an adjuvant in the **spray solution** at a rate of 8.5 to 17 lb per 100 gallons of spray solution. Spray solution is the total tank mixture being applied through the sprayer: herbicides, plus any surfactants or other adjuvants, water, or water mixed with liquid fertilizer. It is especially important to use a 8.5 to 17 lb rate of AMS when spraying weeds under stress conditions such as drought. If liquid AMS is used, it is still important to use enough of the product to obtain the equivalent of 8.5 to 17 lbs of dry AMS per 100 gallons of spray solution. This may require 2.5 to 5 gallons of liquid AMS per 100 gallons of spray solution. Check the label of the liquid AMS product. When filling the sprayer, add AMS to the water before adding glyphosate, in order to allow the AMS to react with and neutralize any elements such as calcium or magnesium in the water. If these elements are not neutralized, they can "tie up" some of the glyphosate and reduce effectiveness of the spray.

Producers should also consider the amount of **nonionic**

**surfactant (NIS)** in their spray solution. Some glyphosate products provide a "partial load" of NIS, while other products provide no NIS. Both of these generally require the addition of NIS to the tank mixture, typically at a rate of 2 quarts NIS per 100 gallons of spray solution. Some glyphosate products are advertised as "fully loaded" and producers often assume that these products will provide adequate NIS. Remember however, the amount of NIS needed is determined by the total volume of spray solution (including water), while the amount of NIS provided by a "fully loaded" product is determined by how much glyphosate product is being added to the **total volume** of spray solution. **At glyphosate rates lower than the full labeled rate, especially with higher water volumes, "fully loaded" glyphosate products may not be providing enough NIS for the total volume of spray solution.** Check the label on all glyphosate products to see if additional surfactant is recommended or allowed. Chemical suppliers and university Extension specialists can provide further information on surfactant use.

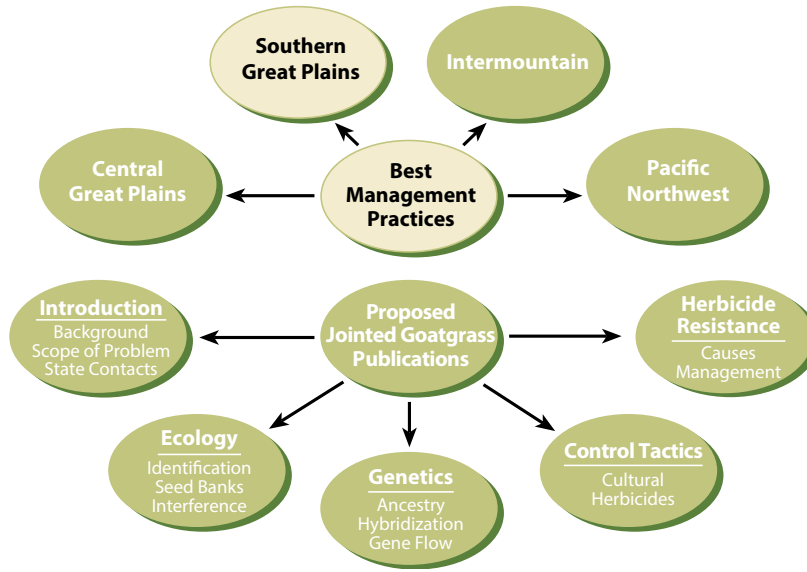
Spray coverage during glyphosate application is very important, especially if weed stands are very dense. To kill all plants, an adequate amount of herbicide must be deposited on every plant. Spray volume per acre must be great enough for adequate coverage; refer to the herbicide label for application information. Spray volume should not be excessive, however, as the droplets hitting the plants will have too dilute a chemical concentration. Too dilute a concentration will reduce the effectiveness of glyphosate.

To ensure coverage in the sprayer wheel tracks, increase the size of tips that spray the tracked area to provide a rate 25% to 50% greater than the rate provided by other tips on the boom. Do not increase tip size so much that more than the maximum labeled rate of herbicide will be applied.

On sprayers equipped with windscreens, the tips are typically angled forward to spray midway between the windscreens. On sprayers without windscreens, the tips should be angled 10° to 25° past a straight-down position and towards the rear of the sprayer.

Remember also, when setting boom height, measure the distance between the spray tip and the target plants at the same angle of orientation as the spray tip. When spraying rough ground, extra boom height may be necessary to maintain adequate spray pattern overlap. This is because bouncing of the boom may place it below the necessary distance to the target plants.

Finally, don't expect optimum performance from an application of glyphosate if the field has been tilled. Excessive dust can reduce herbicide performance. A rough soil surface can also cause boom bounce, making coverage uneven.



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- 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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