INTEGRATED MANAGEMENT OF DOWNY BROME IN WINTER WHEAT

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Introduction

Downy brome (*Bromus tectorum L.*), also known as cheatgrass, was introduced into North America from the Mediterranean area of Europe. It was first identified in the eastern United States in 1861, and by 1914 this invasive grass weed had spread throughout the continent. Downy brome is adapted to climates with annual precipitation ranging from 6 to 22 inches. It can colonize both disturbed and undisturbed sites with a wide range of soil conditions.

Downy brome is a major weed management problem in winter wheat (Figure 1). Downy brome is very competitive with crops. For example, in eastern Washington, 54 downy brome plants per square foot reduced winter wheat yield by 92 percent (Rydrych and Muzik 1968). Downy brome is especially troublesome in low precipitation crop production areas where crop rotations are mostly limited to winter wheat followed by a year of fallow.

Downy brome is best controlled in wheat using integrated weed management (IWM) strategies. This approach, discussed in this publication, involves implementing a combination of management tools to reduce a weed population to an acceptable level while preserving the quality of natural resources.

Identification

Downy brome is a winter annual grass species that ranges from 12 to 24 inches in height at maturity. The seed head is 2–6 inches long, with 5–8 spikelet flowers (Figure 2). Magnification reveals greater detail of the ½ inch long seeds and their ½–¾ inch long awns (Figure 3) as well as the fine hairs on the leaf sheaths and blades (Figure 4).

Figure 1. Downy brome infestation in a winter wheat—fallow crop rotation. Photo by Drew Lyon.

Figure 2. Mature downy brome plant showing slender, erect culms (tillers) supporting dense, slender, drooping panicles (seed heads) with spikelets of flowers. Photo by Larry Burrill, formerly with Oregon State University.

Figure 3. Downy brome seeds with sharp-tipped, narrow awns. Photo courtesy of Steve Hurst, USDA-NRCS, Bugwood.org.

Figure 4. A downy brome leaf blade with sheath and ligule. The outgrowth from the top of the leaf sheath is membranous with frayed margins; it has no auricles (small ear-like projection from the base of many grass leaves). Photo by Don Morishita, formerly with University of Idaho.

Biology

The winter annual life cycle of downy brome requires vernalization (exposure of young plants to cold temperatures) to promote flowering. The amount of time required for vernalization to occur differs among downy brome populations (Lawrence et al. 2018). Downy brome seed germination typically occurs in autumn shortly after the onset of rains when the soil temperature is about 70°F. Seeds can continue to germinate at soil temperatures between 35° and 40°F if soil moisture is adequate. Plant emergence may not be evident until late winter or early spring. Established plants overwinter in the vegetative stage, resume rapid growth in the early spring, and mature in May or June (4–6 weeks before winter wheat). Downy brome seedlings can also be produced from seeds germinating in the spring, although seed production is much more prolific from autumn-germinating plants. Newly mature downy brome seed requires a short after-ripening period for optimum germination. After-ripening, a process that many grass seeds must undergo after maturity before they can germinate, prevents seed from germinating prematurely under moist soil conditions.

Beyond this initial after-ripening period, little seed dormancy remains and germination occurs when favorable temperature and soil moisture conditions exist. Germination often exceeds 95 percent for seeds buried within 2 inches of the soil surface. Seeds buried below 4 inches may germinate but will rarely emerge above the soil surface. Seeds in aboveground crop or weed residue will survive longer than those seeds in direct contact with the soil. The majority of downy brome seeds remain viable in the soil for 2–3 years.

Downy brome exhibits rapid growth and development, making it highly competitive with winter wheat, particularly when the timing of emergence for the two is similar. The primary root system, which develops from the seed, grows throughout the fall and winter at soil temperatures just above freezing. Secondary or adventitious roots emerging from the plant crown are usually initiated in the fall or winter and become well developed before winter wheat resumes growth in the spring. The finely divided fibrous root system is highly efficient in exploiting soil moisture and nutrients. While some roots can reach 4 feet deep, more than 90 percent of the root mass is contained in the top 15 inches of soil.

By the time winter wheat begins rapid spring growth, downy brome plants are often tillering or jointing. Heading usually occurs 4 weeks earlier than winter wheat. Seeds mature by late spring and seed shatter often begins before wheat harvest. In research conducted in northeast Oregon, downy brome growing in winter wheat produced between 140 and 1,350 seeds per plant, with an average of about 425 seeds per plant (Judit Barroso, unpublished data). Under ideal environmental conditions—represented by a dense infestation—downy brome can produce over 500 pounds of seed per acre, resulting in the potential for 125 million plants per acre.

Management

Using IWM strategies for downy brome in winter wheat is based on preventing the weed from becoming established in new areas, limiting seed production, growing a competitive crop, and keeping weeds off-balance by changing management practices.

All the practices discussed here can be effective against downy brome, provided the associated cautions are taken. Unless using narrow-windrow burning as part of a harvest weed control system (HWSC, discussed below in the subsection Harvest Weed Seed Control), field burning is not considered part of IWM for downy brome because the many undesirable consequences of burning crop residue far outweigh the questionable benefits.

Elimination of Seed Sources

Because downy brome is a prolific seed producer and a successful invasive weed, eliminating seed sources can be an effective preventive control strategy. However, this often requires sustained effort over time. Apply a combination of the following methods that fit best:

- Plant crops using clean, certified seed.
- Seed perennial, cool-season grasses in non-crop areas and field borders. Vigorous stands of grasses or grass–legume combinations are highly competitive with downy brome and other annual weeds. (See the sidebar on grass options for suggestions.)
- Destroy downy brome seedlings in cultivated fields before they produce seed.
- Control small patches or area infestations before they spread.
- Where perennial grass borders are not feasible, consider (a) using herbicides or tillage to kill downy brome and (b) cropping field borders.
- Use herbicides that do not kill established perennial grasses around field borders.
- Mow small infestations close to the ground in pastures, roadsides, and waste areas where cultivation or herbicides are not feasible. Plan to complete mowing before viable downy brome seeds are produced. More than one mowing may be necessary to prevent tillers from producing seed.

Perennial, cool-season grass species options for non-crop areas and field borders to prevent downy brome infestation.

Precipitation zone (inches/year)	Grass cultivar
High (20+)	'Durar' hard fescue 'Rush' intermediate wheatgrass 'Alkar' tall wheatgrass
Intermediate (15–20)	'Durar' hard fescue 'Nordan' crested wheatgrass 'Bannock' thickspike wheatgrass
Low (less than 15)	'Covar' sheep fescue 'Sodar' streambank wheatgrass 'Vavilov II' Siberian wheatgrass

Crop Diversity

Crop rotation is one of the most effective control measures for downy brome because of the relatively short life span (2–3 years) of the seed in soil. The highest rate of success is associated with lengthening the period between winter wheat crops by including 2 or more years of various combinations of spring-planted crops with or without fallow.

Broadleaf crops, such as dry pea, chickpea, lentil, and canola, are good choices for rotation with winter wheat because they allow the use of herbicides that are not commonly used in wheat or are not registered for use in wheat. See labels for specific application instructions and plant-back restrictions. Examples of such herbicides include Group 1 herbicides (ACCase inhibitors), such as sethoxydim (Poast), clethodim (Select Max), or quizalofop (Aggressor, Assure II, Targa); Group 3 herbicides (microtubule assembly inhibitors), such as ethalfluralin (Sonalan HFP), pendimethalin (Prowl H2O), and trifluralin (Treflan HFP); and Group 15 herbicides (inhibitors of very-long-chain fatty acid synthesis), such as dimethenamid (Outlook) and S-metolachlor (Dual Magnum), to manage seedling downy brome. In lower precipitation areas, possible crop rotations are (1) winter wheat–summer fallow–winter canola or spring wheat–summer fallow, (2) winter wheat–spring barley or spring canola–summer fallow, and (3) winter wheat–spring barley or spring canola–spring wheat–summer fallow. With recent genetic improvements for cold tolerance and food quality, autumn-sown pea is another broadleaf crop rotation option for use in the traditional winter wheat–fallow region.

In higher precipitation areas with annual cropping, rotations including two years of spring crops such as barley, canola, chickpea, lentils, or dry pea between winter wheat crops can effectively reduce downy brome populations. These types of rotations allow for fall or spring control of germinating downy brome over two or more years. This can prevent new seed production and deplete the downy brome seed reserve in the soil.

The later in the spring these crops can be planted, the more effective they will be for allowing management to control downy brome. Later planting allows more time for downy brome to emerge in the spring and a higher percentage of weed seedlings to be killed with nonselective herbicides or tillage before planting. In addition, late-emerging downy brome may not be exposed to enough cold to vernalize (that is, become reproductive) and produce seed.

A significant disadvantage of delayed spring planting is potentially lower crop yield. Delayed planting tends to have a greater negative effect on yields for spring wheat than spring barley, which may make barley a better choice for use in crop rotations to control downy brome. However, there are fewer herbicide options for controlling downy brome in barley than in spring wheat. Chickpeas and other commonly grown pulse crops (for example, dry pea and lentil) may be some of the best alternatives because they are generally planted later than both of these spring small grains and allow selective Group 1 grass herbicides to be used.

The key aspect of crop rotation for control of downy brome is to prevent any new seed production for at least two years between winter wheat crops. During this time, the seed bank will decline significantly as the result of germination, predation, and other forms of seed mortality.

Fallow Management

Unless implementing harvest weed seed control systems (discussed below), the germination and subsequent control of downy brome seedlings are critical to good fallow management. This approach begins with even distribution of the wheat crop residues during crop harvest. Downy brome seed will be spread with the chaff and finer residue particles, allowing for seed-to-soil contact to encourage germination. Straw choppers on combines help spread the straw and make it easier to get good seed-to-soil contact later. Since rotary combines break up the straw, choppers are not usually needed.

After the crop residues have been adequately distributed, consider non-inversion tillage to “plant” downy brome seed for optimum germination during the fallow period. This is most useful in winter wheat–fallow rotations where there is only one year between winter wheat crops to deplete the soil seed bank. Research conducted in eastern Washington in a winter wheat–fallow rotation found that using a sweep plow or disc after wheat harvest resulted in fewer downy brome plants in the following winter wheat crop than using a skew treader or no tillage after harvest (Young et al. 2014) (Table 1).

Use non-inversion tillage or a non-selective herbicide such as glyphosate in the fall following downy brome emergence to control seedlings. Herbicides are more effective than tillage when soil is moist and plants are actively growing. Unlike tillage, herbicides do not destroy additional crop residues. For tillage to work well for controlling seedlings, the soil must be dry and the air temperature must be warm enough (above 80°F) to desiccate plants within about 30 minutes.

Table 1. Downy brome densities in winter wheat following five postharvest tillage treatments (amended from Young et al. 2014).

Treatment	Depth of tillage (inches)	Average number of plants/ft²
No-till	---	17a*
Skew treader	1–2	14a
Harrow	1	13ab
Sweep plow	4–5	10b
Disk	3–4	10b

*Treatment averages followed by the same letter are not significantly different from each other at the 95% confidence level.

During the spring of the fallow year, it is important not to allow any new downy brome seed production to occur. This can be difficult, particularly with prolonged wet conditions, because of the rapid development of downy brome from heading through seed set. Pollination occurs very quickly after heading and is difficult to recognize. Once pollination has occurred, at least some viable seed will be produced even if the plant is subsequently killed by tillage or herbicides. Research conducted in Oregon and Washington found that downy brome typically produces viable seed when approximately 1,800 growing degree days (GDD; 32°F base temperature) have accumulated from January 1 (Ball et al. 2004). Table 2 provides some average dates for attaining 1,800 GDD at locations across the inland Pacific Northwest.

Table 2. Average dates when 1,800 growing degree days have accumulated at several locations in Washington, Oregon, and Idaho.

Location	Date*
Washington	
Walla Walla	May 16
Lind	June 6
Pullman	June 18
Davenport	June 25
Oregon	
Corvallis	May 11
Pendleton	May 18
Moro	June 8
La Grande	June 13
Idaho	
Lewiston	May 19
Twin Falls	June 13
Pocatello	June 18
Idaho Falls	June 22

*Downy brome plants must be killed prior to these dates to ensure no new seed is produced.

Plowing

If soil erosion and conservation compliance are not management considerations, a moldboard plow may be used to bury downy brome seeds at least 4 inches deep. This can provide 95 percent control of downy brome. Subsequent plowing should be avoided for at least four years to prevent viable seed from returning to the soil surface. Plowing should be restricted to areas with the greatest downy brome infestations to limit negative effects on soil health, including erosion.

Fertilizer

Downy brome responds dramatically to nitrogen fertilization of winter wheat. Surface-applied nitrogen, either as commercial fertilizer or manure, has been shown to triple downy brome height and seed yield (Morrow and Stahlman 1984). Test soil and apply only the recommended amount of nitrogen fertilizer. Over-application can result in crop yield reduction due to downy brome competition.

Deep banding of nitrogen fertilizer improves winter wheat yield and crop competitiveness over downy brome compared to a surface broadcast application.

Deep band nitrogen fertilizer early in the fallow season rather than at or just prior to planting. Do not spring topdress nitrogen fertilizer in winter wheat fields with downy brome infestations, as the crop rarely benefits and this practice increases the seed production and water use of downy brome.

If phosphorus fertilizer is needed, a deep band or starter placement can stimulate wheat root growth and increase crop competitiveness with downy brome. However, there is often less crop response to phosphorus fertilizer in early seeded fields.

Timing and Winter Wheat Seeding

Seeding winter wheat at the optimum date for the area is important to control downy brome. Most downy brome will emerge from seed within the top ½ inch of the surface but will not germinate until moisture is sufficient. Seeding through a dry mulch layer into a moist seed zone with a deep furrow drill will allow wheat to emerge before downy brome and improve its competitive advantage. Research has shown that wheat emerging three weeks prior to downy brome will prevent significant yield losses from light to moderate infestations of about ten plants per square foot or less (Stahlman and Miller 1990). Yield loss increases dramatically when downy brome emerges within seven to ten days of wheat. Early winter wheat emergence also allows the differential growth between wheat and downy brome that improves the efficacy and crop safety of postemergence herbicides.

If sufficient rain (generally considered to be more than a tenth of an inch) occurs just before the anticipated winter wheat planting, the best strategy to control downy brome is to delay seeding until the weed has emerged and either been killed by tillage or sprayed with a nonselective herbicide. However, delaying seeding beyond the optimum seeding date may reduce fall crop growth, competitiveness with downy brome, and crop yield. If rain shortly after planting results in soil crusting and the need to replant, wait until downy brome has emerged so that it can be killed with herbicides or tillage prior to replanting winter wheat. With later seeding in moist conditions, winter wheat and downy brome will emerge at the same time, resulting in greater weed competition and reduced efficacy or increased crop injury from postemergence herbicides.

If downy brome infestation is severe, consider substituting a spring crop in place of winter wheat in the rotation. (See Crop Diversity section above.)

Herbicides

Several herbicides are labeled for selective control or suppression of downy brome in winter wheat. Some of the most effective of these have been Group 2 (ALS inhibitors) herbicides, such as sulfosulfuron (Outrider), mesosulfuron (Osprey, Osprey Xtra), propoxycarbazone (Olympus), and pyroxsulam (PowerFlex HL). These pose little risk for injuring winter wheat and have provided excellent control of downy brome when applied in the fall; however, they are more inconsistent when applied in the spring. Downy brome biotypes resistant to these Group 2 herbicides are now commonly found throughout the region.

Imazamox (Beyond) is another Group 2 herbicide that has provided excellent control of downy brome when properly applied, but it is specific to Clearfield wheat varieties that contain the gene or genes that confer tolerance to imazamox. Tolerance means that the winter wheat variety with the gene(s) is able to withstand a recommended rate of Beyond with minimal risk of crop injury. Wheat varieties that do not contain this gene are either killed or seriously injured by Beyond. Unfortunately, downy brome biotypes resistant to imazamox are also commonly found throughout the region.

In response to widespread resistance to the Group 2 herbicides, some growers have turned to the CoAXium wheat production system, introduced in 2018, to help them manage downy brome in wheat. This system combines the use of quizalofop (Aggressor), an ACCase-inhibiting herbicide (Group 1), with wheat cultivars containing a gene, commercialized as the AXigen trait, which confers tolerance to this herbicide. At the time of writing, there were no commercially available wheat cultivars with the AXigen trait that were bred for adaptation to the PNW, although breeding efforts were underway and adapted cultivars were expected by 2022 or 2023.

The CoAXium wheat production system has provided excellent control of downy brome in research studies conducted in eastern Washington, Idaho, and Oregon. However, the development of herbicide resistance is of great concern with Group 1 herbicides. In fact, a downy brome biotype resistant to quizalofop, the active ingredient in Aggressor and Assure II herbicides, was identified in northeast Oregon in 2005 (Ball et al. 2007). Careful stewardship of the CoAXium wheat production system is critical if this technology is to last more than just a few years. Do not use CoAXium wheat more than two out of six years. Consider diversified crop rotations where winter wheat is grown only once every three or four years. Avoid the use of quizalofop (Assure II) in broadleaf crops grown in rotation with CoAXium wheat. Consider rotating the use of the CoAXium wheat production system with the Clearfield wheat production system, where imazamox is effective. Always rogue and remove downy brome plants that survive herbicide treatments.

Herbicides with other mechanisms of action should be rotated with Group 1 and Group 2 herbicides. Axiom provides good control of downy brome that has not yet emerged. It contains two active ingredients, flufenacet (Group 15) and metribuzin (Group 5). Zidua and Anthem Flex both contain pyroxasulfone (Group 15) and provide control of downy brome similar to Axiom. Anthem Flex also contains carfentrazone (Group 14), which can provide effective burndown of some small broadleaf weeds. Crop injury is a potential concern with these herbicides, so it is critical to consult the labels for planting and application restrictions.

Other herbicides labeled for use in winter wheat, such as triallate (Avadex, Far-Go; Group 8), metribuzin, metribuzin + Finesse (Groups 5 and 2), and Treflan HFP (Group 3), can be used to suppress downy brome but generally do not provide the same level of control as the previously mentioned products.

Growers have long relied on glyphosate for the control of downy brome in fallow and non-crop phases of the rotation. However, several downy brome populations resistant to glyphosate were confirmed in eastern Washington in 2019. The resistant biotypes had a very high level of resistance to glyphosate. This may fundamentally alter downy brome management in fallow. Growers should no longer rely solely on glyphosate and should mix and rotate with other effective herbicides for downy brome control in fallow. Growers should consider the use of soil-applied herbicides as well, for example, flumioxazin + pyroxasulfone (Fierce).

For current herbicide control strategies for downy brome, refer to the *Pacific Northwest Weed Management Handbook* (Peachey 2020, updated annually) and contact local county Extension educators or agricultural professionals. As with all crop protection chemicals, read and follow label directions and understand their proper use.

Harvest Weed Seed Control

Harvest weed seed control (HWSC) is an innovative, non-chemical approach developed in Australia to assist with the management of herbicide-resistant weeds (Lyon et al. 2019). This system focuses on the management of chaff material in which most weed seed resides. Research conducted in northeast Oregon and southeast Washington found that, on average, 49% of downy brome seed was retained in the panicle at harvest time (San Martin et al., unpublished data). However, seed retention varied widely, from a low of 5% to a high of 80%. Seed retention tended to be greater at wetter sites or in wetter years than at drier sites or in drier years. This high variability of seed retention at harvest makes downy brome an intermediate candidate species for using HWSC as part of an integrated weed management program. To learn more about HWSC and its application in the PNW, see PNW730 *Harvest Weed Seed Control: Applications for PNW Wheat Production Systems* (Lyon et al. 2019).

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