Weed Control for Colorado Farmers and Wheat Producers

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For crop producers, weeds represent the most complex and expensive pest management challenge that must be addressed on an annual basis. Weeds frequently reduce crop yields by 20 to 50% due to their direct competition for water, nutrients, and sunlight that are then diverted from crop production. Weeds can harbor insect or disease pests or contribute to reduced land values due to a degraded ability to efficiently produce crops on some farms.

The weed pictures that accompany this article are numbered P1 to P65. Researchers have studied the impact of increasing weed densities on the yield reduction of winter wheat. Jointed goatgrass (P49), feral rye (P55), and downy brome (P58) show weed densities that can easily cause 50% or more wheat yield loss. The data in figure 1 show how feral rye and jointed goatgrass cause severe wheat yield losses even at low densities of less than 10 plants per square yard. Although downy brome is less competitive on a per plant basis, it often occurs at densities high enough to cause serious yield loss. In thick patches, densities of grass weeds can be over 100 plants per square yard at which levels all three grasses cause significant yield losses. In addition, both jointed goatgrass and feral rye (P65) cause dockage losses when they remain as a contaminant in harvested wheat, sometimes resulting in rejection of the wheat for export or milling purposes.

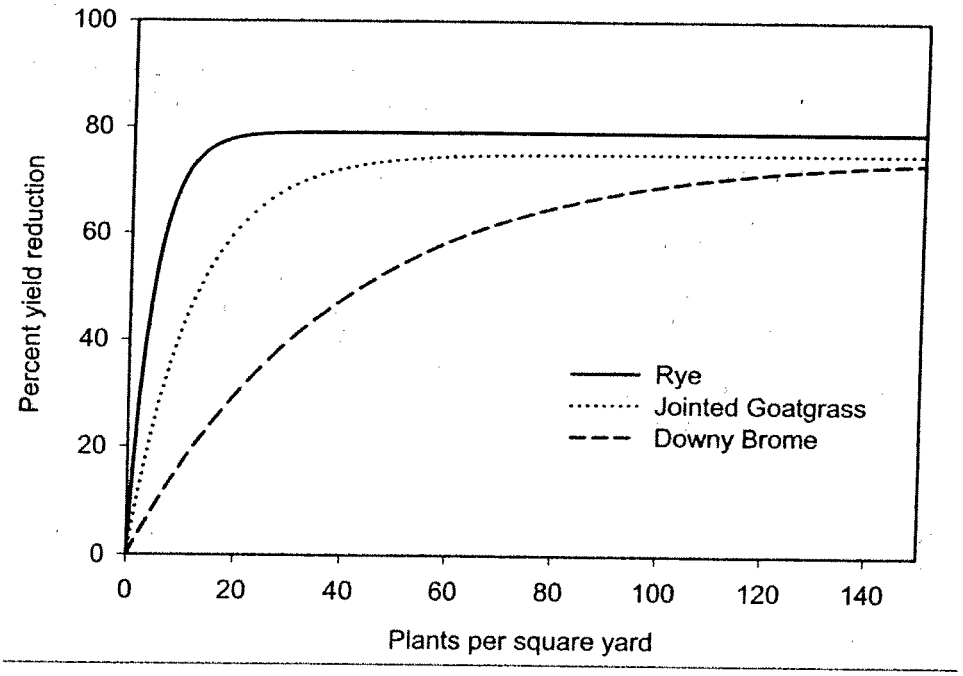

Figure 1. Winter wheat yield losses caused by increasing densities of feral rye, jointed goatgrass, and downy brome.

Weed Life Cycles

Weed control is complicated by the fact that there are many different weeds with different life cycles and different abilities to compete successfully in selected niches with desirable crops.

Perennial Weeds (P1-8) live for several years and can reproduce by seeds (P3) or by buds on underground rhizomes or roots (P7). They are often spread by tillage operations and often do well in dryland wheat or irrigated spring seeded crops such as corn, drybeans, or sugarbeets. Perennial weeds such as field bindweed and Canada thistle have an incredible ability to generate thousands of buds per year on underground roots or rhizomes (P7). This allows perennial weeds to spread either by seeds (P3) or by root material which contains live buds. It is often difficult to get enough herbicide to these deep buds in one season such that the total plant is killed.

Winter Annual Weeds (P9-12 and P48-65) germinate in the fall, lie dormant during the winter, and flower and produce seed the following summer. These weeds are often problems in winter wheat because they share the same life cycle as winter wheat. Winter annual grasses, whether weeds or crops, do not go "dormant" in the winter. They are in fact physiologically active, as they do respire and may photosynthesize if temperatures are warm enough. These weeds normally are not a problem in spring seeded crops. If these weeds produce significant fall growth, control can be practiced in the fall. Otherwise, these weeds are often sprayed in the spring before they "bolt" and produce seed heads.

Summer Annual Weeds (P13-47) germinate in the spring and flower and produce seed during a single growing season. These weeds can be problems in spring-seeded crops or in winter wheat. Weeds like kochia and Russian thistle quickly become serious weed problems in areas of winter kill or where thin wheat stands occur. Kochia seed, however, only lives for 2 or 3 years which forces the plant to produce lots of seed in good years. This high level of genetic turnover may help explain why kochia has become resistant to many commonly used herbicides.

Table 1. Selected examples of weeds with different life cycles.

Perennial Weeds	Winter Annual Weeds	Summer Annual Weeds
Field bindweed	Blue mustard	Kochia
Canada thistle	Prickly lettuce	Russian thistle
Silverleaf poverty weed	Jointed goatgrass	Pigweeds
Common milkweed	Feral rye	Foxtails
Leafy spurge	Downy brome	Barnyard grass

Efficient weed control depends on accurate weed identification in each field, and the knowledge of the life cycle of each weed. Such information facilitates targeting weed control to the time-frame when a weed is easiest to kill. Because perennial weeds can regrow from underground roots or rhizomes, they are seldom killed by a single herbicide or tillage treatment. One reason why perennial weeds are so difficult to control can be seen in P7 which shows the total growth of one Canada thistle plant after 1 year of growing in a 2 X 4 X 8 foot box filled with soil. The roots with buds on this growth from a single plant were over 1,500 feet long and had filled the entire soil profile. This picture shows the plant after washing all the soil from the roots. Field

bindweed exhibits a similar growth pattern over a single growing season. Thus perennial weed control requires a long-term management plan that may require repeat treatments for 3-5 years.

Winter annual grass weed seeds require a decent amount of fall moisture to germinate, or else they remain dormant until such moisture triggers germination. This presents a difficult situation for weeds such as feral rye where Beyond® gives best control when applied at the 1-3 leaf stage which occurs in the fall in normal years. Furthermore, when moisture is limited, not all rye seeds germinate at the same time. In drought years, producers may need to delay Beyond® treatments until the spring at which time there could be rye plants of different sizes in the same field. This scenario is due to the fact that Beyond has very little soil residual activity and thus must be applied to emerged and growing weeds.

Weed Seed Dormancy. Many weed seeds exhibit strong dormancy which means they will not germinate even in the presence of favorable moisture, temperature, and light conditions. Seed dormancy ensures that not all seeds germinate at one time, thus perpetuating the weed problem in subsequent years. Eliminating or minimizing weed seed production is one way to help reduce weed pressure in wheat fields.

Unique Characteristics of Jointed Goatgrass. Jointed goatgrass is an invasive weed that was brought to America in wheat seed from Russia, southern Europe, or western Asia in the early 1900's. It spread rapidly in wheat country from its introduction on the east coast and by 1917 was reported in the Pacific Northwest. Jointed goatgrass now infests over 5 million acres of wheat and is still spreading. It can infest rangeland and roadsides because of a unique cylinder which surrounds from 1 to 3 seeds (P65). A jointed goatgrass seed head is called a spike, which is analogous to a wheat spike. Each spike consists of 10 – 15 spikelets which break apart at maturity and often fall to the soil prior to wheat harvest. Jointed goatgrass seed can remain dormant up to 5 years, but in most years most of the seed will germinate under favorable conditions in the fall. The cylinder which surrounds the seed can act like a sponge, soaking up water in a rainstorm and providing enough moisture for jointed goatgrass to establish on the soil surface without being buried in the soil. A root system will emerge from the spikelet and establish a plant even though no tillage buries the seed; sometimes 2 plants will develop from 2 seeds that germinate inside a spikelet. This allows infestations to become severe in pastures, rangeland, and roadsides. In the seedling stage, fine hairs along the leaf margin (P60) distinguish jointed goatgrass from winter wheat. Many growers have resorted to diversified crop rotations utilizing spring crops such as corn, millet, sunflower, and sorghum to disrupt the life cycle of jointed goatgrass. Jointed goatgrass will almost always be a worse problem in a wheat-fallow system. An excellent review of the biology and ecology of jointed goatgrass can be found at www.jointedgoatgrass.org/Acrobat%20Files/Ecology.pdf.

A new research project at CSU is evaluating the viability of seed from jointed goatgrass X winter wheat hybrid plants (P64). In 2002 and 2003, a total of 6,700 hybrid spikelets have produced 41 plants. This is a viability rate of less than 1% (.61%) for hybrid spikelet seed that develop from these genetic crosses. Further research will help determine if the wheat or jointed goatgrass was the maternal parent for these plants.

Since 1994, CSU and wheat growers from Colorado have been actively involved in a National Jointed Goatgrass Research and Education initiative. This competitive research program has

funded a sustained scientific effort in 12 western states on this unique weed. A wealth of information from nearly 10 years of coordinated research on this unique weed can be found at http://www.jointedgoatgrass.org. Darrell Hanavan, executive director of the Colorado Wheat Administrative Committee (CWAC), is chairperson of this national research program.

Feral Rye is a weedy escape of rye that was grown during the dust bowl days for cattle feed and for making bread. Its appearance and growth habit is similar to cultivated rye, but the seed of feral rye has adapted to a weedy lifestyle. When feral rye seed shatters in the summer, usually prior to wheat harvest, more than 90% of the seed will germinate if moisture is present. However, approximately 1% of feral rye seeds are highly dormant and look like small shriveled prunes when dug from the soil. These highly dormant seeds will not germinate even if conditions are favorable. CSU research has shown that this highly resistant seed remains in the soil for as long as 5 years, and is most likely the source of those rogue rye plants that seem to appear from nowhere. Feral rye normally grows from 6" to 1' taller than wheat (P53, 54) and is visually the most noticeable of our winter annual grasses. At any given weed density, feral rye causes the most wheat yield reduction of the winter annual grasses.

Downy Brome and Cheatgrass are the most common grass weeds of wheat in Colorado when all infested acres are considered. Maverick herbicide from Monsanto will control these weeds in conventional wheat. Olympus is another herbicide under development by Bayer for control of these weeds in conventional wheat. These weeds are a serious problem in pastures, rangeland, and forest ecosystems where they help fuel serious forest fires.

Herbicide Resistance

Herbicide Resistant Weeds occur when weeds are no longer killed by an herbicide that is usually used to kill such weeds. A good example of this would be Atrazine resistant pigweed in corn (P29), or Glean and Ally resistant kochia (P13-16) in winter wheat. The weed that has developed the most resistance problems in Colorado is kochia with populations that are resistant or tolerant to triazine, sulfonylurea, 2,4-D, and dicamba herbicides. Researchers at the ARS and CSU are developing simple-to-use field kits to help growers test suspected herbicide resistant weed populations to ALS inhibitors, photosynthesis inhibitors and glyphosate.

Since Beyond® herbicide is in the ALS class of herbicides, it is possible that grass weeds can develop resistance to Beyond over time. In particular, there is concern that the hybrids which form naturally at very low levels between winter wheat and jointed goatgrass (P48, 61, 64) have the potential to move the Clearfield resistance gene from wheat to jointed goatgrass. These hybrids form because wheat (a hexaploid plant) and jointed goatgrass (a tetraploid plant) share the D genome in common. This common genome allows for low level hybridization which has been shown to be less than 1% in Colorado. Although gene flow from wheat to jointed goatgrass is expected to be very rare, controlled research has shown that such a scenario is possible. This is why it will be important to adhere to the BASF CLEARFIELD* Stewardship Guidelines which are intended to safeguard the long term utility of this new technology. Researchers are actively studying the level of gene flow between wheat and jointed goatgrass using unusual markers such as "hairy jointed goatgrass" (P63) which has very visible pubescence or "fuzz" on

the spikelets. Much of this basic research on jointed goatgrass and wheat has been supported by the very successful National Jointed Goatgrass Research Initiative which is chaired by Darrell Hanavan of CWAC.

CLEARFIELD* Wheat – A New Technology for Broad-Spectrum Selective Grass and Broadleaf Weed Control in Winter Wheat. Through a partnership between BASF Corporation and CSU, Clearfield winter wheat has been made available to Colorado wheat producers. Marketed by the Colorado Wheat Research Foundation under the variety named "Above", Clearfield wheat offers producers the first-ever opportunity to selectively control a broad range of weeds in winter wheat. Beyond® herbicide (imazamox) applied in growing Clearfield wheat selectively controls several grassy and broadleaf weeds while affording good crop safety in the wheat. Beyond has very little residual soil activity at the rates used in Clearfield wheat which mandates that weeds to be controlled with this technology must be up and growing at the time of herbicide application. Beyond herbicide applied in the fall to bare ground will not control weeds which come up at a later time. Thus the timing and stage of growth guidelines shown in Table 2 should be followed for best results. The questions to answer prior to a fall Beyond application are:

- Is feral (wild) rye present in the field?
- Have your grassy weeds germinated in the fall?
- Do you believe that MOST of your grassy weeds germinated in the fall?

When applied at the correct rate and at the proper weed growth stage, Beyond herbicide is very effective for the control of winter annual grass weeds (P56, 59, 60) and some broadleaf weeds such as members of the mustard family. Beyond is also very effective for cleaning conventional wheats out of Clearfield wheat fields since conventional wheat is killed by Beyond herbicide. To broaden the spectrum of total weed control, including the control of more broadleaf weeds, current research is evaluating the use of PGR herbicides such as MCPA to control weeds like kochia, Russian thistle, and pigweed.

Table 2. Winter annual grass control with Beyond herbicide.

Winter Annual Grass	Optimum Timing For Control	Optimum Stage of Weed Growth (Labeled stages)	Beyond Use Rate
Jointed goatgrass	Fall or Spring	3-4 leaf stage (1-5lf, 2 tiller)	4 oz
Brome or Cheat	Fall	2-3 leaf stage (1-5lf, 2 tiller)	4 oz
Feral Rye	Fall	2-3 leaf stage(1-4lf,1 tiller)	4-5 oz

These weeds begin to tiller at the 3-4 leaf growth stage.
Always add liquid nitrogen and NIS to Beyond spray solution; follow label recommendations.

History of Clearfield Wheat

The development of Clearfield wheat began in 1986 when researchers at American Cyanamid selected for tolerance to imidazolinone herbicides in mutagenized seed of Fidel wheat, a French winter wheat that was popular at the time. They were successful in finding a line, designated as FS 2, which was resistant to typical use rates of Beyond® herbicide (imazamox). FS 2 was not a genetically modified organism (GMO) because the tolerance trait was due to a mutation induced through the use of sodium azide and was not transferred in from another organism. However, the baking quality, winterhardiness, and heat and drought stress tolerance characteristics of FS 2 were unacceptable for successful production in the Great Plains.

In March 1997, CSU obtained wheat germplasm carrying the CLEARFIELD* trait from American Cyanamid. The germplasm, developed at Texas A&M University-Amarillo, consisted of three populations that carried the Clearfield gene yet were highly variable for other agronomic and quality characteristics. These populations were derived by "backcrossing" the Clearfield gene into the Texas A&M variety TAM 110 and two of it's unreleased sister selections. These populations were used for direct selection, which resulted in the eventual release of the Above and AP 502 CL varieties, and crossing with other wheat varieties to combine the Clearfield trait with important agronomic and quality traits. In Colorado, Above is marketed by the Colorado Wheat Research Foundation while AP502 CL is marketed in a variety of states by Agripro Wheat.

Breeding lines derived from the crosses made at CSU in 1997 continue to be evaluated and one line (designated CO00D007) is targeted for Foundation seed release in fall 2004. In CSU Dryland Variety Trials, CO00D007 has shown slightly higher yield and significantly improved milling and baking quality characteristics relative to Above.

Performance of Above Wheat In the CSU Dryland Variety Trials (UPVT, Table 3), Above has performed slightly less than Trego (a hard white wheat from Kansas) but equal to or better than all other varieties in these trials. A comparison of particular interest is that between Above and AP502 CL, Prairie Red (a Russian wheat aphid resistant version of TAM 107), and TAM 110, Above has shown a consistent 1-2 bushel yield advantage and at least comparable test weight.

Table 3. Yield and test weight of selected entries in CSU Dryland Variety Performance Trials (UVPT; 2000-2003).

Entry	Yield 2000 (8 locs)	Yield 2001 (8 locs)	Yield 2002 (4 locs)	Yield 2003 (6 locs)	Yield Average (25 locs)	Test Weight Average (25 locs)
Trego	41.3	47.8	34.3	52.9	45.3	59.8
Above	**39.7**	**41.9**	**34.5**	**52.8**	**43.0**	**57.3**
Alliance	40.2	44.0	32.5	50.5	43.0	57.4
Yuma	39.0	43.1	30.0	53.0	42.6	57.4
Akron	39.4	43.2	33.2	49.6	42.3	57.5
Avalanche	41.0	41.3	31.6	50.4	42.2	59.2
Prairie Red	38.9	40.7	34.6	50.2	41.6	57.3
Jagger	36.3	46.7	31.7	46.0	41.4	57.4
AP502 CL	38.8	39.5	32.7	48.9	40.7	56.7
TAM 110	39.6	37.9	32.2	50.0	40.7	57.0
Halt	35.4	42.9	34.7	46.7	40.4	57.0
Mean	**39.1**	**42.6**	**32.9**	**50.1**	**42.1**	**57.6**

Is This System Right For You?

Wheat producers contemplating the planting of a newly released wheat variety will want to know how well this variety has performed in variety trials and whether this variety/technology will make or save the producer money. There is information available (Table 3) to help producers make this decision. Colorado State University performs variety trials across the state of Colorado. This information is available at: www.colostate.edu/Depts/SoilCrop/extension/CropVar/

Above yield data are available for the 2003 commercial launch growing season but this variety has performed very well since its release in 2002. In summary, across locations, Above yielded 52.8 bu/A with an average test weight of 58.9 lb/bu. Of the 27 varieties tested, only two, Yuma (53.0 bu/A) and Trego (52.9 bu/A) yielded as well as or higher than Above. Fitting Above wheat into an integrated weed management program that might well include diverse crop rotations based on corn, sorghum, millet, or sunflower is one of the long-term objectives of current weed science research in Colorado. It is unwise to assume that a single new technology will be the silver bullet that forever eliminates weeds as a problem in wheat.

Launched in fall 2002, CLEARFIELD* wheat is tolerant to Beyond® herbicide which provides control of winter annual grasses and certain broadleaf weeds. By combining Clearfield wheat with Beyond® herbicide, wheat producers ensure that they can address most troublesome weed problems they may encounter in a given year. The collaborative efforts of CSU scientists, the Colorado Wheat Administrative Committee, the Colorado Wheat Research Foundation, and

BASF has helped educate Colorado wheat producers about the benefits and limitations of the Clearfield wheat program. As a result, Colorado has the highest adoption level of this new technology of all the Central Great Plains states. It is likely that Clearfield wheat is just the first of many exciting new winter wheat technologies that will be offered to Colorado wheat producers in the future.

The other factor that should be considered is the economics of the system. Producers are often hesitant to raise input costs, but the economics of the entire system should be considered. If factors such as dockage, yield loss to weeds, and foreign matter are taken into account, additional input costs may yield a high return on investment. Even though Above seed is slightly more expensive than conventional seed and Beyond® herbicide is more expensive than a conventional herbicide program, the producer who uses the Clearfield* system in a field infested with feral rye, jointed goatgrass or downy brome should see the substantial benefits of this system in his bottom line. BASF provides a calculator that can be used to determine whether or not a Clearfield system is beneficial to a producer. All a producer needs to do is plug in a few values like seed/herbicide cost, yield loss to weeds, dockage, foreign matter, and average wheat yield, and the calculator will provide the "Clearfield advantage" or how much the bottom line is influenced by using this system. An example of this calculator with hypothetical yield loss from weeds, dockage, etc. is included on the following page:

CLEARFIELD* Wheat ROI Calculator

Grower Break Even Analysis

Category	Conventional	CLEARFIELD*	Comments
Seed Cost ($/ac)	$ 6.50	$ 8.25	Avg. Central Plains price/acre
Herbicide Cost ($/ac)	$ 5.00	$ 20.00	Avg. Central Plains price/acre
Program Costs ($/ac)	$ 11.50	$ 28.25	Seed + herbicide cost ($/ac)
Less Certified Seed Bonus ($/ac)	$ -	$ 2.00	Valid on CLEARFIELD* seed + Beyond treated acres
Adjusted Program Costs ($/ac)	$ 11.50	$ 26.25	
Net Difference ($/ac)		$ 14.75	Difference in Conventional and CLEARFIELD* Program
Avg Net Price for Wheat ($/bu)	$ 3.88	$ 3.88	Net $/bu on grower basis
Break Even Point (bu/ac)		3.80	Net difference in program costs ($/ac) /Avg. Net Price ($/bu)
Average Wheat Yield (bu/ac)	40	40	
Production Break Even (%)		10%	Break even point (bu/ac)/Average wheat yield (bu/ac) Example assumes no yield loss if CL System is not used

CLEARFIELD* Wheat ROI Calculator

Production System Comparison Analysis

Category	Conventional	CLEARFIELD*	Comments
Avg Wheat Yield (bu/ac)	40	40	
Avg Net Price for Wheat ($/bu)	$ 3.88	$ 3.88	
Avg Gross Revenue ($/ac)	$ 155.20	$ 155.20	Yield x net price ($/bu)
Less Program Costs ($/ac)	$ 11.50	$ 26.25	Seed cost ($/ac) + herbicide cost ($/ac)
Net Gross Revenue ($/ac)	$ 143.70	$ 128.95	Net gross revenue = adj. gross revenue - program cost
Avg Yield Loss Due to Weeds (%)	15%	1%	See notes below
Avg Yield Loss Due to Weeds (bu/ac)	6	0.4	Avg yield x loss %
Avg. Yield Loss Due to Weeds ($/ac)	$ 23.28	$ 1.55	Avg yield x loss % x value of wheat $/bu
Net Gross Revenue ($/ac)	$ 120.42	$ 127.40	After weed losses
Dockage (%)	1.00	0.20	% Dockage assessed at elevator
Dockage Deduction ($/ac)	$ 4.76	$ -	$/ac loss based on elevator discounts
Foreign Matter (FM) (%)	1.00	0.20	% Foreign Matter assessed at elevator
Foreign Matter (FM) Deduction ($/ac)	$ 8.16	$ -	$/ac loss based on elevator discounts
Total Dockage and FM Deductions ($/ac)	$ 12.92	$ -	
Net Profit ($/ac)	$ 107.50	$ 127.40	
CLEARFIELD* Advantage ($/ac)		$ 19.90	CLEARFIELD* program - conventional program
CLEARFIELD* Wheat Acres		200	
CLEARFIELD* Advantage (total acres)		$ 3,979.60	

This **CLEARFIELD* Wheat Economic Calculator** is available through local BASF field representatives or online through the following link at the Colorado State Wheat Breeding and Genetics Program: http://wheat.colostate.edu/links.html

Additional Information on CLEARFIELD* Wheat, Beyond® Herbicide and Colorado Weeds

Clearfield* Wheat Economic Calculator
http://wheat.colostate.edu/links.html

Jointed Goatgrass Biology and Control (National Jointed Goatgrass Initiative)
http://www.jointedgoatgrass.org

Above Clearfield* Wheat Information
http://wheat.colostate.edu/above.html (variety description)
http://wheat.colostate.edu/form4.lasso (user-defined yield comparisons)
http://wheat.colostate.edu/vpt.html (variety trial information)

An excellent colored pocket guide to Colorado weed seedlings is available through:
http://www.colostate.edu/Orgs/VegNet/csuag/weedbook.html

IN CONCLUSION

- Keep fields free of weeds the year prior to planting wheat
- Plant clean, certified wheat seed so weed seeds are not planted with your wheat
- Learn to identify key weeds, their life cycles, and the best strategies for managing these weeds
- Don't let weeds rob precious moisture that could go to wheat production
- Practice good fallow weed control in wheat or other crop stubble
- Use the Clearfield wheat production system to control troublesome weeds such as jointed goatgrass, feral rye, downy brome, and selected broadleaf weeds

Excellent weed control recommendations for a number of key Colorado crops can be found in the weed control recommendation guide included in this handbook. Colorado producers must make sure that herbicide recommendations contained in this guide are labeled for use in the state of Colorado. For timely information on herbicides currently labeled in Colorado, contact your herbicide dealer, company sales reps, CSU extension personnel, or weed scientists at Colorado State University.

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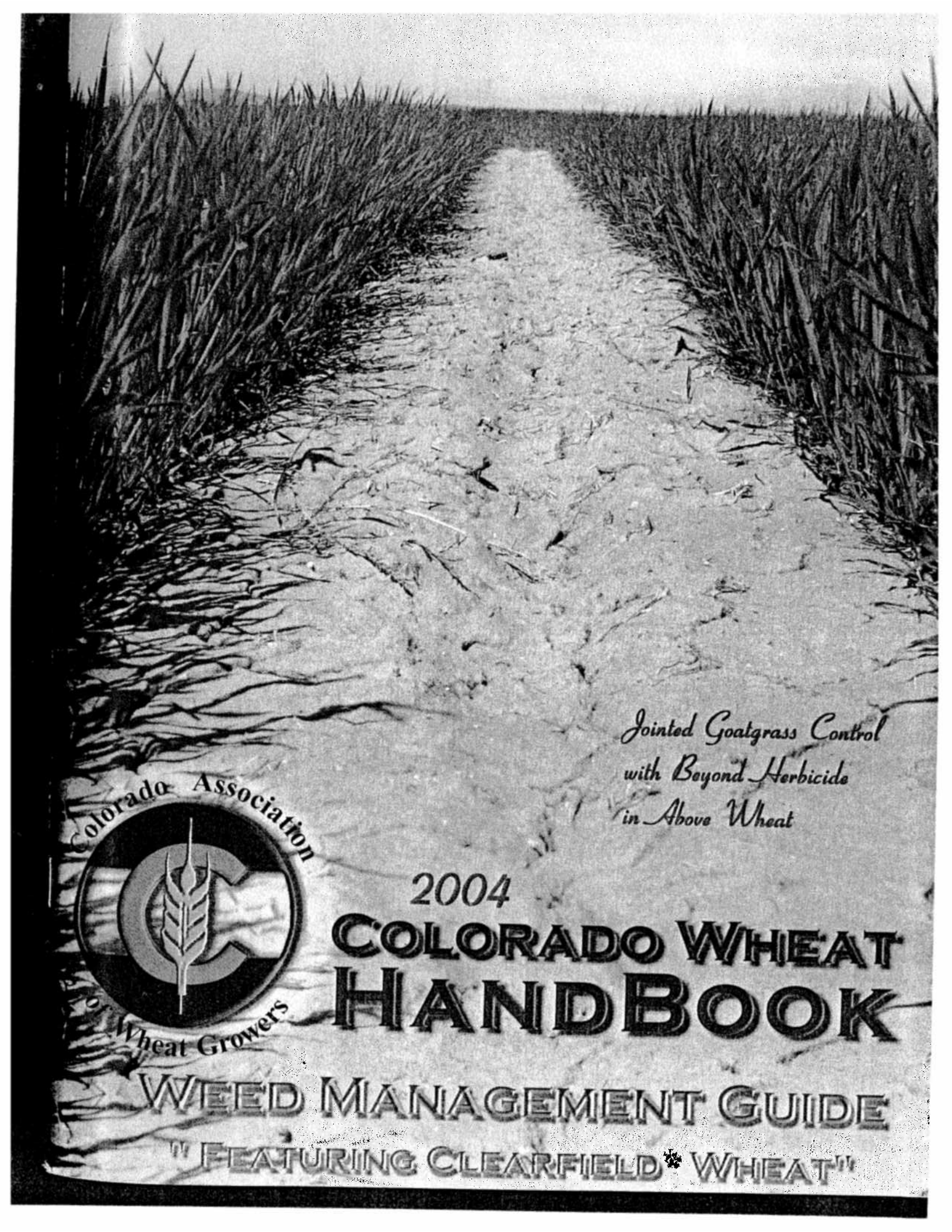

Jointed Goatgrass Control with Beyond Herbicide in Above Wheat

Colorado Association of Wheat Growers

2004

COLORADO WHEAT HANDBOOK

WEED MANAGEMENT GUIDE

"FEATURING CLEARFIELD® WHEAT"