Crop Residue Reduces Jointed Goatgrass (*Aegilops cylindrica*) Seedling Growth[1]

RANDY L. ANDERSON[2]

Abstract. Producers need alternative methods to manage jointed goatgrass because there are no herbicides that selectively control jointed goatgrass in winter wheat. The effect of crop residue incorporated in soil on reducing seedling growth of jointed goatgrass was examined in the greenhouse. Residues of corn, proso millet, safflower, grain sorghum, and winter wheat reduced fresh weight of jointed goatgrass by 70 to 85%. Applying N fertilizer at 33 or 66 kg ha^{-1} diminished this effect, indicating that residue stimulated microbial immobilization of N. Ethiozin applied preemergence at 0.2 $\mu g\ g^{-1}$ soil reduced jointed goatgrass seedling growth by 50%, but combining crop residue with ethiozin did not synergistically improve control of jointed goatgrass. These results suggest that producers may favor winter wheat growth over jointed goatgrass by incorporating crop residue in soil with tillage before planting and by banding N with winter wheat seed at planting. **Nomenclature:** Ethiozin, 4-amino-6-(1,1-dimethyl-3-(ethylthio)-1,2,4-triazin-5(4*H*)-one; corn, *Zea mays* L.; jointed goatgrass, *Aegilops cylindrica* Host. #[3] AEGCY; proso millet, *Panicum miliaceum* L.; safflower, *Carthamus tinctorius* L.; grain sorghum, *Sorghum bicolor* L. Moench; winter wheat, *Triticum aestivum* L.

Additional index words: Allelopathy, ethiozin, integrated weed management, N immobilization, SMY-1500, AEGCY.

INTRODUCTION

Hectarage of jointed goatgrass-infested winter wheat is increasing in the western United States. One factor contributing to increased infestations is the difficulty of developing herbicides that control jointed goatgrass selectively in winter wheat because jointed goatgrass is genetically related to winter wheat (8, 16). Secondly, government programs require minimum levels of residue to remain on the soil surface, which increase winter annual grass populations (8, 26) due to microclimate amelioration (7). Consequently, producers require alternative control measures to reduce jointed goatgrass interference in winter wheat.

One alternative control measure could be allelopathy (21, 27), since allelopathy from crop plants contributes to integrated weed management strategies (15, 25). For example, fall-planted rye (*Secale cereale* L.) is used as a smother crop in the northern Corn Belt. Residues from rye killed in the spring reduce weed growth in summer (3, 4). Winter wheat residue also suppresses weeds in no-till soybeans [*Glycine max* (L.) Merr.] (25).

When conservation tillage systems such as stubble mulch were first introduced, winter wheat grain yields were reduced compared with conventional systems because crop residue stunted seedlings and subsequently reduced grain yields (5, 10, 17). This residue phytotoxicity was more prominent in areas of higher precipitation (> 500 mm) (10, 11).

Extensive research was conducted to determine the cause of this phytotoxicity. Greenhouse studies showed that sorghum, corn, and winter wheat residue inhibited winter wheat seedling growth (13), but this effect differed among species, as duration of residue toxicity was 4 to 5 wk for winter wheat, 8 to 12 wk for corn, and 12 to 16 wk for sorghum (14). Residue inhibition of seedling growth was enhanced if winter wheat residue was incorporated before planting, but drastically reduced if residue remained on the surface (6, 9, 10).

Crop residue toxicity to winter wheat seedlings was likely caused by either an allelopathic compound (5, 18) or N immobilization due to increased microbial populations (6, 9). The allelopathic compound was either a water-soluble compound leached from residue (13) or a compound produced during microbial decomposition of wheat residue (18). Other studies showed that microorganisms digesting residue immobilized N, but adding N

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[2]Res. Agron., Agric. Res. Serv. U.S. Dep. Agric., Akron, CO 80720.

[3]Letters following this symbol are a WSSA-approved computer code from Composite List of Weeds, Revised 1989. Available from WSSA, 309 W. Clark St., Champaign, IL 61820.

fertilizer to the soil (9, 19), or banding N with the seed (6) alleviated this effect.

Since winter wheat and jointed goatgrass occupy similar ecological niches, residue incorporation also may inhibit seedling growth of jointed goatgrass, and if so, aid in controlling this species.

Ethiozin[4] and metribuzin [4-amino-6-(1,1-dimethylethyl)-3-(methylthio)-1,2,4-triazin-5(4*H*)-one] are herbicides used in winter wheat, but do not control jointed goatgrass consistently (2, 8). If crop residue can be manipulated to reduce jointed goatgrass growth, then combining residue management with ethiozin or metribuzin application may enhance jointed goatgrass control by these herbicides.

Crop residues interact with herbicides and affect their performance. For example, residues intercept and retain herbicide spray, thereby reducing the quantity of herbicide reaching the soil surface, and consequently, being absorbed by plants (20, 28). Conversely, incorporating winter wheat residue into soil increased the availability of imazaquin [2-(4,5-dihydro-4-methyl-(1-methylethyl)-5-oxo-1*H*-imidazol-2-yl)-3-quinolinecarboxylic acid] in the soil solution and its bioactivity on plants (29). The effect of incorporated residue on ethiozin bioactivity in soil is presently unknown.

The objective of this study was to determine if crop residue incorporated into soil reduces jointed goatgrass seedling growth, and if this effect occurs, determine if residue enhances ethiozin performance on jointed goatgrass.

MATERIALS AND METHODS

In this greenhouse research conducted between Nov. 1 and April 1 over several years, day and night temperatures averaged 25 C and 16 C, respectively. Length of daylight during this period ranged from 10 to 12 h.

Two soils commonly used for winter wheat production in eastern Colorado were compared in this study: Valent sand (mixed, mesic Ustic Torripsamments) composed of 91% sand, 5% silt, and 4% clay, with 0.7% organic matter and a pH of 7.1; and Platner loam (fine, montmorillonitic, mesic Aridic Paleustoll) with 37% sand, 45% silt and 18% clay, 1.3% organic matter, and a pH of 6.6.

Two pot sizes were used: pots (with drainage holes) 15 cm in diam and 15 cm deep filled with 1300 g of soil or pots (without drainage holes) 9 cm in diam and 9 cm deep filled with 400 g of soil.

Jointed goatgrass seed was collected from a seed cleaning plant near Akron, CO.

General procedures. Methods common among studies are described below. Eight jointed goatgrass cylinders[5] were planted 25 mm deep in each pot. Soil water level was maintained at 80% field capacity by daily weighing and watering (unless noted otherwise). After initial watering, pots were capped with aluminum foil for 4 d, to allow seed to imbibe water.

Aboveground fresh weight of all seedlings was measured 21 d after emergence. Data are expressed as biomass reduction per plant compared with a control treatment included in each replication. Control seedlings were grown in soil without amendments. Each study had five replications and was repeated. Treatment means were tested by analysis of variance and means were separated with LSD at the 5% level of probability (24).

Crop residue study. Corn 'Pioneer Hybrid 3732', grain sorghum 'Pioneer Hybrid 8790', winter wheat 'Vona', proso millet 'Cope', and safflower 'Hartman' residues was collected immediately after harvest of each crop, ground through a 2-mm sieve, and stored in air-dry conditions until study initiation. Treatments were imposed by mixing the residues with sand in a soil blender[6]. Three residue levels for each crop were used, 0X, 1X (residue levels for average yields) and 1.5X (Table 1), based on yields and grain:residue ratios common for eastern Colorado (1, 12, 22, 23). Treatments were established in 400-g capacity pots.

In this study, Vona winter wheat seedlings also were evaluated for response to crop residue. The experimental design was a three-way factorial, with factors being crop residue, residue amount, and plant species (jointed goatgrass and winter wheat).

Crop residue and N study. Residue from corn and safflower at 0X, 1X, and 1.5X (rates listed in Table 1) was mixed with sand or loam in the soil blender. Nitrogen as ammonium nitrate was added to each residue treatment at 0, 33, or 66 kg ha^{-1}, and mixed with the blender. Treatments were established in 400-g pots. The experimental design was a four-way factorial, with factors being crop residue, residue level, N rate, and soil type.

[4]Ethiozin was developed under the code number SMY-1500, and is not currently registered for public use.

[5]Cylinder refers to the dispersal unit where seeds are fused to the lemma and palea of the spikelet (8).

[6]Patterson-Kelley Co., East Stroudsburg, PA 18301.

Table 1. Residue levels for corn, grain sorghum, winter wheat, proso millet, and safflower based on yields and grain:straw ratios common for dryland production in northeastern Colorado.

Crop	Dryland yield	Grain:straw ratio	Residue level 1X	Residue level 1.5X
	kg ha^{-1}		kg ha^{-1}	
Corn	2500	1:2	5000	7500
Grain sorghum	1900	1:2	3800	5700
Winter wheat	2700	1:1.7	4590	6890
Proso millet	1650	1:1.1	1820	2730
Safflower	1120	1:1	1120	1680

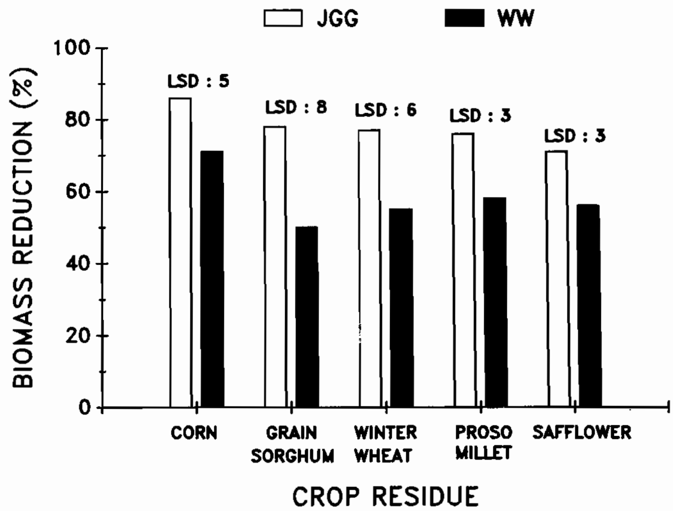

Figure 1. Effect of crop residue on seedling growth of jointed goatgrass and winter wheat in sand. Residue levels (kg ha^{-1}) for corn were 5000 and 7500; grain sorghum, 3800 and 5700; winter wheat, 4590 and 6890; proso millet, 1820 and 2730; and safflower, 1120 and 1680. Data were averaged over residue levels.

Ethiozin effect on jointed goatgrass. *Concentration.* The two soils were treated with ethiozin mixed in a soil blender to establish a concentration gradient of 0, 0.2, 0.4, 0.6, and 0.8 μg g^{-1}. Treatments were established in 400-g pots. The experimental design was a two-way factorial examining ethiozin concentration and soil type.

Growth stage. Ethiozin was applied to jointed goatgrass at four different growth stages: before seed germination, and at the seedling emergence, two-leaf, and four-leaf growth stages. Ethiozin was applied at 1.1 and 1.7 kg ha^{-1} (approximately 3 and 5 μg g^{-1}, respectively, for 25-mm soil depth) to the soil surface in 30 g of treated soil (mixed in the blender) to simulate a preemergence application. Jointed goatgrass was planted 25 mm deep into 1300-g pots filled with loam.

Water was applied (simulating a rainfall of 12 mm) to each pot at the initiation of study, and after each ethiozin application with the later growth stage treatments. After the initial watering, pots were subirrigated to maintain 80% field capacity three times a week. Aboveground fresh weight was measured 21 d after ethiozin application for each growth stage.

The experimental design was a randomized complete block. Data are expressed as fresh weight reduction as a percentage of a control (no ethiozin application) for each growth stage.

Residue by N rate by ethiozin concentration study. Corn residue at 0 and 5000 kg ha^{-1}, N at 0 and 33 kg ha^{-1}, and ethiozin at 0, 0.1, and 0.2 μg g^{-1} were blended with sand in the soil blender. Sand and ethiozin were mixed first, followed by residue, then N. Treatments were established in 400-g pots. The experimental design was a three-way factorial, with factors being residue level, N rate, and ethiozin concentration.

RESULTS AND DISCUSSION

Crop residue study. Incorporating crop residue into soil reduced jointed goatgrass seedling growth by 70 to 85% (Figure 1). Winter wheat seedling growth, however, was reduced less by residues than was jointed goatgrass. For example, grain sorghum residue reduced jointed goatgrass seedling growth 78%, but winter wheat seedling growth by only 50%. The other crop residues inhibited winter wheat growth approximately 20% less than jointed goatgrass growth.

Because residue level effects within any crop were not significant, data were averaged over residue levels in Figure 1. Residue effect on jointed goatgrass and winter wheat growth differed slightly among type of residue (inhibition differed ≤ 15% among residue types), but this effect may have been confounded by the difference in quantity of residue incorporated into the soil.

Also, residue did not decrease seedling emergence of either species, confirming previous research that these crop residues do not affect germination of winter wheat (13, 14). However, this germination effect may be related to type of residue, as rye residue inhibits germination of several weed species (4).

Crop residue and N rate study. Adding N to soil mixed with corn or safflower residue diminished the residue effect on jointed goatgrass growth (Figure 2).

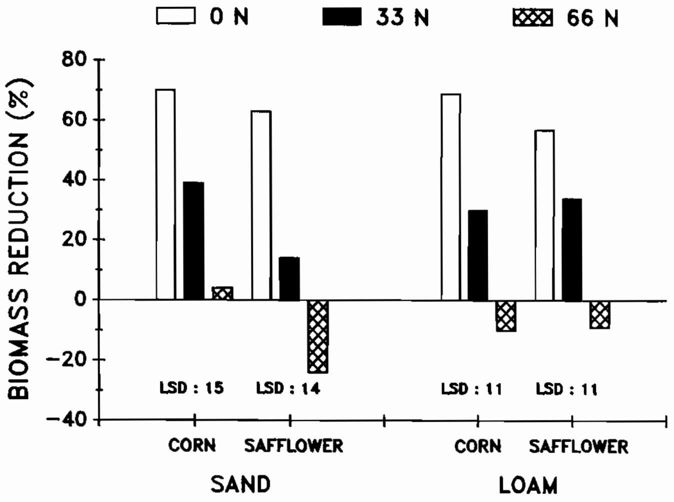

Figure 2. Nitrogen (kg ha^{-1}) and crop (corn and safflower) residue effect on seedling growth of jointed goatgrass in sand and loam. Residue levels (kg ha^{-1}) for corn were 5000 and 7500; and safflower, 1120 and 1680. Data were averaged over residue levels.

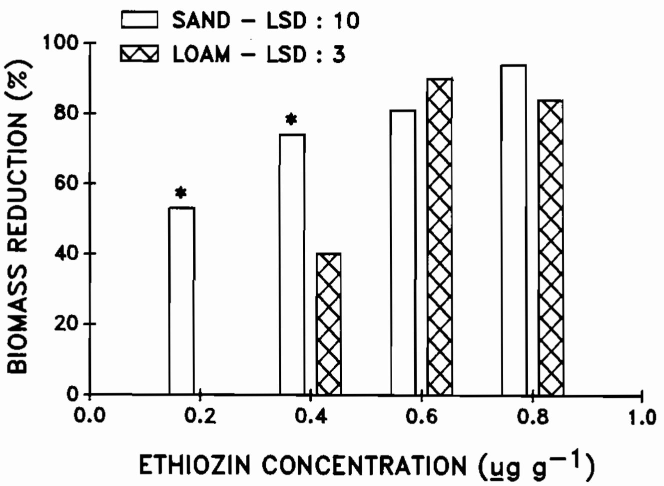

Figure 3. Jointed goatgrass response to ethiozin at various concentrations in sand and loam. Significant differences at $P \leq 0.05$ between soils within a concentration are designated with an *. The LSD values for the 0.2 and 0.4 $\mu g\ g^{-1}$ concentrations were 4 and 14, respectively.

Corn residue alone reduced seedling growth by approximately 70% in both soils, but adding N at 33 kg ha^{-1} reduced the residue effect to 40% for sand and 30% for loam. When N was increased to 66 kg ha^{-1}, growth was reduced only 5% in sand, whereas seedling growth was increased 10% in loam. Similar results also occurred when N was combined with safflower residue. A N by residue level interaction did not occur, therefore data were averaged over residue levels.

These data indicate that N immobilization by residue probably affected seedling growth, as reported elsewhere for other species (6, 9). Corn and safflower residues were examined in this study because these residues exerted the highest and lowest effect on jointed goatgrass seedling growth, respectively (Figure 1), yet the N effect was similar among these residues, further suggesting that N immobilization stunted growth. Nitrogen applied to soil without residue increased seedling growth by 5 and 15% at the 33 and 66 kg ha^{-1} rate, respectively, for both soils (data not presented).

Ethiozin effect on jointed goatgrass. *Concentration.* A soil by concentration interaction occurred with ethiozin bioactivity on jointed goatgrass (Figure 3). Ethiozin at 0.2 $\mu g\ g^{-1}$ reduced seedling fresh weight by 50% in sand, but did not affect seedling growth in loam. At 0.4 $\mu g\ g^{-1}$, biomass reduction by ethiozin in loam was still 35% less than in sand, indicating that jointed goatgrass was more susceptible to ethiozin in sand than in loam. This soil effect may have occurred due to ethiozin being absorbed by organic matter or clay particles in the loam, therefore reducing ethiozin availability for plant absorption.

Growth stage. Ethiozin applied before or at emergence reduced jointed goatgrass biomass > 80%, but when application was delayed until jointed goatgrass developed four leaves, biomass was reduced only 37% (Table 2). A growth stage by ethiozin rate interaction did not occur, as increasing ethiozin rate from 1.1 to 1.7 kg ha^{-1} did not alleviate this growth stage effect. Biomass reduction at the four-leaf stage with the higher rate of ethiozin was only 39%, similar to 34% with the 1.1 kg ha^{-1} rate (Table 2).

Crop residue by N rate by ethiozin concentration study. Because jointed goatgrass was more susceptible to ethiozin applied before or at emergence in sand,

Table 2. Effect of growth stage on the response of jointed goatgrass to ethiozin at 1.1 and 1.7 kg ha^{-1} in loam.

	Ethiozin (kg ha^{-1})		
Growth stage	1.1	1.7	Mean
	% biomass reduction		
Pre-germination	78	85	82
Emergence	80	91	86
Two-leaf	63	74	69
Four-leaf	34	39	37
LSD (0.05)			11
Mean (Ethiozin)	64	72	
LSD (0.05)	7		

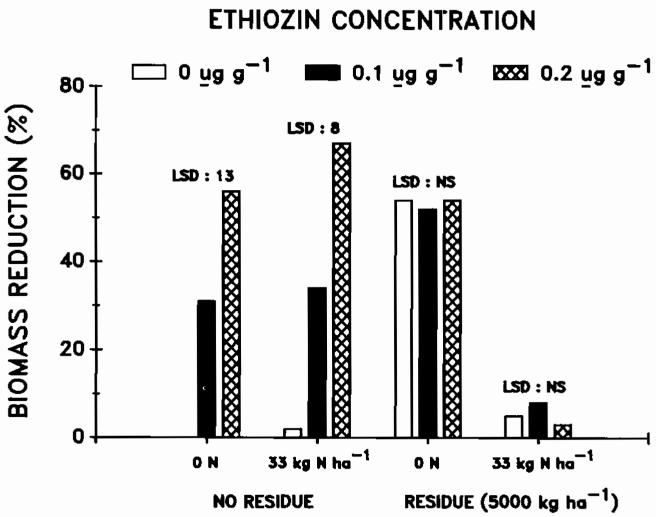

Figure 4. Effect of corn residue, N, and ethiozin concentration on seedling growth of jointed goatgrass in sand.

ethiozin at reduced concentrations was mixed with crop residue and N in sand to determine if combining ethiozin with residue would enhance jointed goatgrass control.

A significant residue by nitrogen by ethiozin interaction occurred. Therefore, data are shown for ethiozin rates within each N and residue level. Ethiozin at 0.1 and 0.2 $\mu g\ g^{-1}$ (without residue or N) reduced biomass by 31 and 57%, respectively (Figure 4). Adding N at 33 kg ha^{-1} did not alter ethiozin bioactivity on jointed goatgrass.

Adding residue to the soil, however, completely masked ethiozin bioactivity. For example, if no N was added, residue reduced seedling growth by approximately 55% for both ethiozin rates and the control. When N was added, residue plus ethiozin reduced biomass no more than 10%, regardless of ethiozin rate. This indicates that residue exerted the greatest effect on seedling growth, and that synergism between ethiozin and residue did not occur.

Management implications. Integrated weed management involves numerous optional control components, such as cultural, mechanical, biological, and chemical practices. Individual components may provide only partial control on their own, but combining several components may achieve effective control. Residue incorporation may have potential as a partial control measure for jointed goatgrass and merits further study in field environments.

Residue-induced stunting of winter wheat seedlings was affected by several factors: level of incorporation, length of decomposition, and timing of precipitation (5, 10, 17, 18). This present study suggests that incorporating crop residue into soil before planting in conjunction with banding N with winter wheat seed at planting would favor winter wheat over jointed goatgrass if environmental conditions are such that residue-induced inhibition occurs. Compliance for government programs may limit tillage options and level of residue incorporation, consequently altering the intensity of residue-induced stunting of jointed goatgrass in comparison with the greenhouse results.

Producers including this residue strategy in their production systems should consider applying the remainder of their crop's N needs at times other than at planting, as broadcasting N near planting would eliminate the residue effect on jointed goatgrass. Other possible options for N placement include deep banding, where the total N needs for winter wheat are satisfied with deep placement (> 20 cm), or spring applications.

One drawback with incorporating residue with a sweep plow would be enhanced emergence of seedlings caused by burying weed seed shallowly. If tillage occurred 2 wk before planting, producers would be able to control emerged seedlings with non-residual herbicides at planting, then rely on residue immobilization of N to inhibit the later-emerging plants.

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