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Jointed Goatgrass (*Aegilops cylindrica*) Ecology and Interference in Winter Wheat[1]

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Abstract. **Jointed goatgrass is a serious weed in winter wheat, and presently no herbicides are available for its selective control. This study examined the effect of time of emergence and removal on jointed goatgrass interference in winter wheat, as well as its rate of development and soil water extraction. The goal of this study was to suggest cultural practices that minimize jointed goatgrass interference in winter wheat. Jointed goatgrass development was identical to 'Vona' winter wheat in two crop seasons, even though precipitation differed drastically between seasons. Depth of soil water extraction of both species was also similar. Jointed goatgrass at 18 plants m^{-2} reduced grain yield 27 and 17% when emerging 0 and 42 d after Vona, respectively. The relationship between time of jointed goatgrass emergence after winter wheat and grain yield loss was Y = 30.6 – 0.29X (X = days, r = 0.72), indicating that plants emerging in late fall still caused yield loss. Removing jointed goatgrass by early March prevented winter wheat grain yield loss. The interference data suggests that producers assess infestation levels and plan control measures in early March. Nomenclature: Jointed goatgrass, *Aegilops cylindrica* Host. #[3] AEGCY; winter wheat, *Triticum aestivum* L. 'Vona'.**

Additional index words: **Development, soil water extraction, time of emergence, time of removal, community yield, AEGCY.**

INTRODUCTION

Jointed goatgrass infests 1 to 1.2 million hectares of winter wheat in the United States, and, along with downy brome (*Bromus tectorum* L.) and volunteer rye (*Secale cereale* L.), is extremely troublesome in the Great Plains (12, 23, 33). These species are well adapted to the winter wheat-fallow production system most commonly used in the Western United States and are estimated to cause $24 million loss annually in Colorado (17).

Jointed goatgrass is genetically related to winter wheat, with one chromosome genome derived from the same progenitor (21). Due to this genetic similarity, no herbicides are available that will control jointed goatgrass in winter wheat. Therefore, producers are seeking cultural alternatives to reduce jointed goatgrass impact on winter wheat production.

Cultural practices can enhance a crop's tolerance to weeds (31, 32). For example, downy brome interference in winter wheat has been reduced by altering time of N fertilizer application (4), planting tall cultivars (9), and delaying planting (32).

Developing effective integrated management systems for specific weed species requires knowledge about ecological characteristics such as peak growth periods and rooting depth (31). For example, differences in plant rooting depth in soil between species can be exploited to favor one species. Downy brome roots seldom penetrate deeper than 33 cm (18, 20, 28), whereas winter wheat roots can penetrate to 200 cm (10, 25). Applying N fertilizer in April of the fallow season results in N leaching below the rooting zone of downy brome, and consequently less downy brome growth in winter wheat (4).

Understanding jointed goatgrass interference characteristics in winter wheat and soil water extraction patterns will improve effectiveness of known cultural practices, but also may suggest new cultural practices that reduce its impact on winter wheat production. Presently, knowledge of jointed goatgrass ecology is limited (12).

This study was conducted to compare the phenological development and soil water extraction pattern of jointed goatgrass and winter wheat, determine the effect of duration of jointed goatgrass interference on winter wheat production, and suggest cultural practices that minimize jointed goatgrass interference in winter wheat.

MATERIALS AND METHODS

Site description. This study was conducted over two crop seasons between 1987 and 1989 at Akron, CO. The long-term yearly precipitation average is 419 mm. Average precipitation during the winter wheat growing season (September 15 to July 1) is 283 mm. Average air temperature for September to November is 9.9 C, for December to February –2.7 C, and for March to June 10.8 C. The soil was a Weld silt loam (fine, montmorillonitic, mesic Aridic Paleustoll), with 1.2% organic matter and a pH of 7.

General procedures. Vona winter wheat, an early-maturing, semidwarf variety, was planted at 45 kg ha^{-1} September 22, 1987, and September 19, 1988, with a hoe-drill at 30-cm row spacing. Ammonium nitrate was applied broadcast within 3 wk after planting at 45 kg N ha^{-1}, which is the prevalent rate used by producers in this area.

Jointed goatgrass cylinders[4] were collected from a local seed cleaning plant, planted in peat pellets[5,6], and incubated

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

[4]Cylinder refers to the dispersal unit where seeds are fused to the lemma and palea of the spikelet (12).

[5]American Clayworks and Supply Co., Denver, CO 80204.

[6]Trade and company names are included for the benefit of the reader and do not imply any endorsement by the USDA-ARS.

in a greenhouse until seedling emergence. To ensure uniform size, seedlings between 8 and 12 mm were transplanted equidistant between winter wheat rows and 15 cm apart. For all treatments described below, jointed goatgrass was established at 18 plants m^{-2}. Previous research showed that 10 jointed goatgrass plants m^{-2} caused approximately 30% yield loss in Oklahoma (16), while 50 to 80 plants m^{-2} caused 25 to 29% yield loss in Oregon (12).

The experimental design for all studies was a randomized complete block with four replications, and plot size was 2 by 2 m. Data were subjected to analyses of variance, and differences among means were determined at the 0.05 level of probability (27).

Time of emergence and plant development study. Jointed goatgrass in pellets was transplanted in winter wheat to simulate emergence 0, 14, 28, 42, and 160 d after Vona emergence. The rate of emergence of jointed goatgrass and winter wheat is identical, both emerging 7 to 8 d after planting. Planting jointed goatgrass in pellets began on the day of winter wheat planting and was repeated at the above sequence of days. Because emergence rate was similar at all planting times for jointed goatgrass, the date of transplant simulates time of emergence after winter wheat emergence. Also, using pellets insured a consistent rate of emergence for each designated treatment.

Jointed goatgrass emerges between late August and mid-November and in late February and early March (6). Therefore, the selected treatments represent the time of high probability for jointed goatgrass emergence.

After establishment, four random jointed goatgrass plants were marked in each replication for all treatments, and development was recorded weekly during the growing season based on the Zadoks-Chang-Konzak scale (8). This scale assigns a number for each development stage, with the entire life cycle defined between 0 and 100. The recorded stages analyzed were: initiation of tillering, jointing, heading, and anthesis. Four Vona plants from each replication of the control treatment (no jointed goatgrass within the plot) were also marked. This technique resulted in a total of 16 plants being evaluated, similar to the number of plants monitored to characterize the phenology of winter wheat (22).

To assess the effect of time of emergence on growth of jointed goatgrass, the 16 marked plants from each treatment were harvested 2 wk before winter wheat to determine biomass, tillers, and cylinders per plant. The remaining jointed goatgrass plants from the center 1 m^2 of each plot were harvested for biomass measurement.

At Vona maturity (July 8, 1988 and July 13, 1989), biomass and grain yield from the center 1 m^2 were measured. Yield components were determined by counting all tillers within the 1-m^2 quadrat, with the number of kernels per tiller and 1000-kernel weight measured from 20 tillers selected at random. Community biomass yields were determined from the jointed goatgrass and Vona biomass measurements.

Time of removal study. Jointed goatgrass was established in Vona in six plots. The pellets were planted on the day of Vona planting in the field and transplanted 10 d later. On March 1, April 1, May 1, June 1, and June 15, jointed goatgrass was removed by handweeding from designated plots. March 1 was approximately 160 d after winter wheat planting. The removal treatments followed the format used by Rydrych, who tested removal effects on downy brome interference in winter wheat (24). A full-season interference control and a weed-free control were included. At maturity, biomass and grain yield were measured from the center 1 m^2. Yield components were determined as described above in the time of emergence study.

Soil water extraction study. Jointed goatgrass and Vona were planted in pellets September 22, 1987 and September 19, 1988 and incubated in the greenhouse. After emergence, the seedlings were transplanted into separate plots in the field. A second treatment of jointed goatgrass also was established 21 d later. Plot size and plant density were as stated previously, with a row spacing of 30 cm.

Access tubes for measuring soil water content were placed in the center of each plot, as well as in a control plot with no plants. Soil water was measured weekly from February until winter wheat harvest with a neutron probe[7] at depths of 46, 76, 107, 137, and 168 cm. Rooting depth was inferred from changes in water content by soil depth. A change in water content of at least 3 mm per soil depth between successive measurement dates was assumed to have been due to root extraction, based on methodology devised by Bauer et al. (7).

RESULTS AND DISCUSSION

Seasonal precipitation. Precipitation was 13% above normal in the first season and 30% below normal in the second season. Despite the difference in precipitation, there was no crop season by treatment interaction for the plant parameters measured for each study. This indicates that jointed goatgrass and winter wheat responded similarly to different environments, as reported previously (15). Therefore, data shown below were averaged over crop seasons.

Plant development. Jointed goatgrass and Vona developed similarly when they emerged at the same time (Table 1). When emerging later than Vona, jointed goatgrass reached jointing, heading, and anthesis at a later calendar date but required fewer days to reach each development stage than Vona.

Jointed goatgrass tillered in the fall when emergence occurred before October 15. Plants emerging in late October (28-day treatment) or later did not tiller until March. Fall-emerging jointed goatgrass developed the majority of its tillers between March 20 and May 1 (data not shown). Plants emerging 160 d after Vona (March 1) begin tillering 55 d later (in late April).

Vona and jointed goatgrass emerging within 28 d of Vona began jointing in late April and heading in late May (Table 1). Peak growth and resource use by winter wheat occurs between jointing and heading (30). If cultural practices (such

[7]Model 3321. Troxler Electronic Lab., Research Triangle Park, NC 27709.

Table 1. Development of jointed goatgrass as affected by time of emergence. Vona winter wheat included for comparison. Data were averaged over years.

Species	Time of emergence[a]	Time to reach growth stage: Tillering	Jointing	Heading	Anthesis
		——— days after Vona emergence ———			
Vona	0	33	218	247	259
Jointed goatgrass	0	33	215	247	258
	14	69	220	252	259
	28	186	223	256	264
	42	208	235	257	268
	160	215	260	—[b]	—[b]
LSD (0.05)		6	5	3	2

[a]Time of emergence refers to days after Vona emergence.

[b]Jointed goatgrass planted 150 d after Vona reached the heading and anthesis growth stage only in the first study.

as altering planting date or variety) could induce winter wheat to joint earlier, it would capture resources such as N or soil water sooner, a situation which favors the early species over competitors (2).

Jointed goatgrass emerging with Vona began anthesis June 5, 258 d after emergence (Table 1). A delay in jointed goatgrass emergence delayed anthesis, but all fall-emerging plants reached anthesis within 10 d of Vona. In this study, the anthesis period ranged between June 5 and 15.

This flowering characteristic of jointed goatgrass can be used to guide producers' options in integrated management systems. For example, mowing winter wheat with infested jointed goatgrass is one cultural practice that producers can use to reduce the future weed seedbank in the soil. Development of seed viability is presently unknown for jointed goatgrass, but other grass species develop viability soon after anthesis (1, 5). For example, a small percentage of downy brome seeds was viable by late anthesis (29) and early milk (28), whereas 50% of longspine sandbur [*Cenchrus longispinus* (Hack.) Fern] seeds were viable by early milk stage (5).

Therefore, if producers cut their infested winter wheat for forage, mowing plants before anthesis (before June 5 in this study) should prevent viable seed production by jointed goatgrass. Also, producers can destroy a percentage of their crop for government program benefits, if crop removal occurs by June 10. Producers should consider destroying their crop earlier than the government target date if jointed goatgrass is present.

Jointed goatgrass also emerges in late February and early March (6), raising the question of whether these plants will flower and produce seed. Jointed goatgrass has a quantitative vernalization requirement for flowering, which means that cold temperatures hasten floral initiation but are not an absolute requirement (11). In this study, temperatures after jointed goatgrass establishment in March were cold enough to stimulate flowering and production of seeds before winter wheat harvest in 1 yr out of 2. When flowering did not occur, plants remained in a vegetative state until study termination in July.

Jointed goatgrass production. Simulation models can predict economic optimal thresholds over a long-term basis by using information on seed production per plant (19). For example, a model was developed to predict the effect of control levels on the long-term population dynamics of an annual weed (*Agrostemma githago* L.) in spring wheat, based on seed production of escaped plants (14). Knowledge about individual plant productivity would be valuable if a model was developed to predict population dynamics of jointed goatgrass in winter wheat.

Biomass, tiller, and cylinder production per plant were affected by time of emergence. If emerging with Vona, jointed goatgrass produced 23 tillers and 146 cylinders per plant, but only 11 tillers and 62 cylinders per plant if emergence was delayed 28 d (Table 2). Production decreased by 2.7 cylinders for each day delay in fall emergence ($Y = 140 - 2.7X$, $r = 0.76$, where Y = cylinders plant^{-1}, and X = days after Vona emergence).

Jointed goatgrass still contributed significantly to the weed seedbank when emerging in late fall or early spring; a plant emerging 42 d after winter wheat produced 32 cylinders, while a plant emerging in the spring, if vernalized, produced three cylinders (Table 2). In previous research (11, 12), jointed goatgrass cylinders contained an average of two seeds. Therefore, a plant emerging in the spring and flowering may contribute six seeds to the soil seedbank.

Time of jointed goatgrass emergence effect on winter wheat yields. Jointed goatgrass at 18 plants m^{-2} reduced

Table 2. Effect of emergence time on jointed goatgrass biomass, tiller, and cylinder production when growing in winter wheat. Data were averaged over years.

Time of emergence[a]	Biomass	Tillers	Cylinders
d	g plant^{-1}	—— no. per plant ——	
0	6.8	23	146
14	3.6	14	94
28	2.7	11	62
42	1.3	6	32
150	0.4	3	3
LSD (0.05)	1.3	4	27

[a]Time of emergence refers to days after Vona emergence.

Table 3. Vona production and yield components as affected by time of jointed goatgrass emergence. Data were averaged both years.

			Yield components			Community components	
Time of emergence[a]	Biomass	Grain	Tillers m^{-2}	Kernels $tiller^{-1}$	1000-kernel weight	Total biomass	Jointed goatgrass
d	g m^{-2}		no.		g	g m^{-2}	%
Control	538	172	388	28.1	22.3	538	0
0	395	126	305	25.9	22.3	552	30
14	423	134	337	26.7	22.8	507	18
28	424	133	327	27.8	22.3	469	9
42	449	142	339	26.7	22.1	474	5
160	498	161	365	27.5	23.1	518	4
LSD (0.05)	35	10	28	NS	NS	32	6

[a]Time of emergence refers to days after Vona emergence.

wheat grain yield 27% when it emerged with Vona and 22% when it emerged 14 d later (Table 3). The relationship between time of jointed goatgrass emergence in the fall and Vona grain yield loss was Y = 30.6 – 0.29X (r = 0.72, Y = grain yield, and X = days after Vona emergence), where each day of delay in jointed goatgrass emergence after Vona reduced grain yield loss by 0.3%. Jointed goatgrass emerging in the spring also was detrimental, reducing grain yields by 6% (Table 4).

Jointed goatgrass emerging in the fall interfered with Vona tiller formation to reduce yields but did not affect kernels per tiller nor kernel weight (Table 3).

If community biomass yields of treatments with jointed goatgrass increase over the control treatment, then the two species are competing for different resources or excess resources are available (2). When jointed goatgrass emerged within 2 wk of Vona (0- and 14-d treatments), community yields did not differ from the control, indicating that jointed goatgrass replaced Vona in the community (Table 3). Jointed goatgrass emerging 28 or 42 d after Vona, however, decreased community yield, suggesting that factors not measured in this study may have affected the community yield.

Time of removal study. Jointed goatgrass affected winter wheat growth early in the spring, since grain yield loss was 5% when jointed goatgrass was removed March 1 and 21% if removed April 1 (Table 4). The relationship between time of jointed goatgrass removal and grain yield loss suggests that jointed goatgrass control should occur in early March, as calculated yield loss exceeds 10% by March 18 (Figure 1).

As found in the time of emergence study, Vona yield reduction due to jointed goatgrass interference was caused by reduced number of tillers m^{-2} (Table 4). Kernels per tiller and kernel weight were not affected by jointed goatgrass.

Soil water extraction. Depth of soil water extraction by Vona and jointed goatgrass emerging together did not differ (Table 5). When emerging 21 d after Vona, jointed goatgrass extracted water at lower depths later, but final rooting depth (137 cm) did not differ between species. Similar results in the greenhouse have been reported with jointed goatgrass and white wheat of the Pacific Northwest, where rate of root growth was identical between the two species (13). These results suggest that N placement deep in the rooting profile may not favor winter wheat over jointed goatgrass, contrasting with results found with winter wheat and downy brome (4).

Management implications. *Time of assessing infestation.* The time of emergence and removal studies suggest assessing jointed goatgrass infestation in early March. March evaluation would occur after emergence of plants that cause grain yield loss but would precede the period when grain yield loss occurs in late March. If postemergence herbicides are

Table 4. Vona production and yield components as affected by time of jointed goatgrass removal. Data were averaged over years.

Time of removal	Biomass	Grain	Tillers m^{-2}	Kernels $tiller^{-1}$	1000-kernel weight
date	g m^{-2}		no.		g
Control	469	151	367	25.1	22.8
March 1	453	143	367	25.4	22.4
April 1	369	120	266	26.2	22.5
May 1	390	128	318	24.3	23.1
June 1	366	117	305	24.6	21.8
June 15	386	110	301	24.7	22.5
Harvest	383	118	316	26.4	22.5
LSD (0.05)	38	12	31	NS	NS

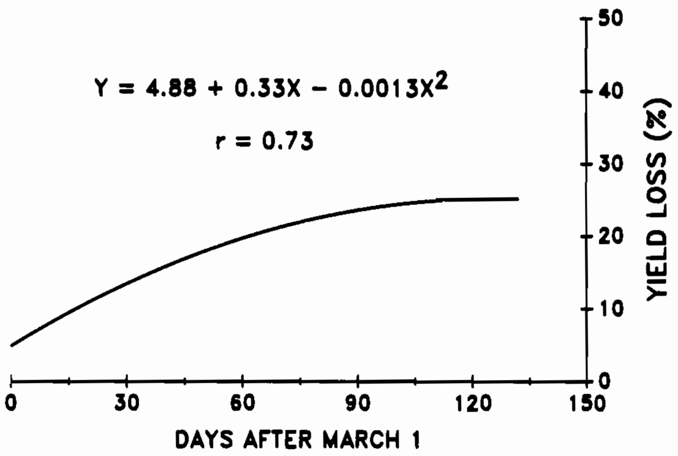

Figure 1. Effect of time of jointed goatgrass removal on winter wheat yield loss (%). Density of jointed goatgrass was 18 plants m^{-1}.

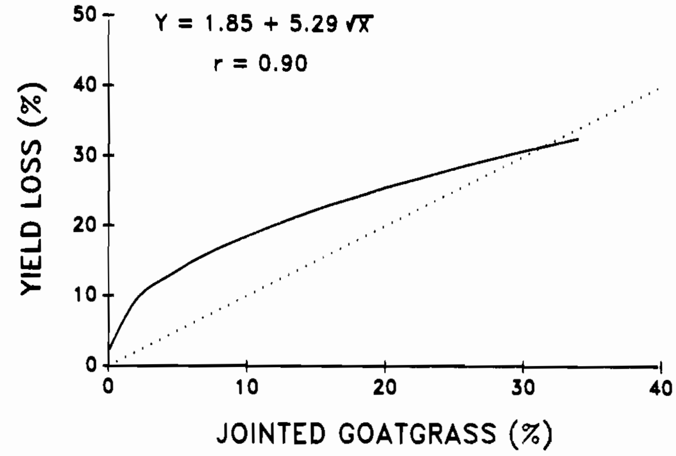

Figure 2. Relationship between jointed goatgrass component of community biomass (%) and Vona grain yield reduction (%). The dotted line represents a 1:1 relationship and is included for comparison.

developed for jointed goatgrass control in winter wheat, then application by early March would limit grain yield loss.

Assessing the infestation in early March also enables the producer to estimate the time of emergence of jointed goatgrass. For example, by March 1, plants emerging with winter wheat averaged three to six tillers, plants emerging 14 d later averaged one to three tillers, and plants emerging 28 d or later did not form tillers until late March (data not shown). Therefore, if jointed goatgrass has several tillers by early March, its emergence was early in the fall, and consequently greater winter wheat yield loss would occur.

Comparison with downy brome. Jointed goatgrass and downy brome occupy similar niches in winter wheat (12, 33). However, interference characteristics differ between these species. For example, jointed goatgrass interference in winter wheat is less affected by time of emergence than by downy brome. Jointed goatgrass reduced grain yield 17% when emerging 42 d after winter wheat, and 6% when emerging in early March (Table 4), contrasting with downy brome not affecting grain yields if emerging 21 d or later after winter wheat (26). Therefore, producers could assess their downy brome infestation and plan control measures in late fall rather than spring.

Table 5. Number of days after Vona emergence until soil water was extracted at specified depths as detected with the neutron probe. Data were averaged over years.

Species	Time of emergence[a]	Time to extract water to indicated soil depths (cm)			
		46	76	107	137
		days			
Vona	0	219	233	244	262
Jointed goatgrass	0	224	236	249	266
	21	243	252	258	274
LSD (0.05)		7	5	12	NS

[a]Time of emergence refers to days after Vona emergence.

Control measures for both species should occur by early March, however, since jointed goatgrass (Figure 1) and downy brome (24) began reducing winter wheat grain yield by this time.

Predicting yield loss. Aldrich suggested that canopy composition may be more accurate in predicting crop yield loss than weed density or area influenced (3). Using data collected from the time of emergence study, we fitted a curve[8] relating percent winter wheat yield loss to jointed goatgrass composition of community biomass (Figure 2) that showed a high correlation (r = 0.90).

The similarity of development between these species (Table 1) suggests that an earlier assessment may generate a similar relationship. If this earlier assessment of community biomass component-yield loss relationship is accurate and is consistent over several environments and winter wheat varieties, then measuring community composition in early March could predict potential yield loss and guide management decisions for jointed goatgrass-infested fields before yield losses occur.

[8]TableCurve. Jandel Scientific, San Rafael, CA 94901.

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