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Cultural Systems Can Reduce Reproductive Potential of Winter Annual Grasses[1]

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Abstract: Feral rye and jointed goatgrass are winter annual grasses that infest winter wheat in the western United States. Currently, no herbicides are available that selectively control these weeds in wheat. Because of this constraint, producers need cultural practices that reduce the seed densities of these two grasses in the soil seedbank. This research shows that applying nitrogen 5 mo before wheat planting and increasing the seeding rate with a tall wheat cultivar reduces seed production per plant of either species by > 40%. However, tall wheat cultivars usually yield less grain than semidwarf cultivars. Producers can avoid this yield loss by combining narrow rows with time of N application and increased seeding rate of semidwarf cultivars. This combination reduces weed seed production similarly to cultural systems with tall cultivars.

Nomenclature: Jointed goatgrass, *Aegilops cylindrica* Host #[3] AEGCY; feral rye, *Secale* spp.; winter wheat, *Triticum aestivum* L. 'TAM 107' and 'Lamar.'

Additional index words: Cultural practices, seedbank management, systems approach, AEGCY.

INTRODUCTION

In the western United States, feral[4] rye and jointed goatgrass are difficult-to-control winter annual grasses in winter wheat (Wicks and Smika 1990). Yield loss due to these grasses can be high: five feral rye plants/m^2 reduce wheat yield 15%, while the same density of jointed goatgrass reduces yield 6% (Anderson 1994). These weeds also increase dockage and reduce grade when grain is sold (Donald and Ogg 1991).

Currently, there are few herbicides registered that selectively control these grasses in winter wheat (Holtzer et al. 1996). Thus, producers must employ cultural practices to minimize winter annual grass interference (Anderson 1994). Another complex of winter annual grasses, the brome species (*Bromus* spp.), infests winter wheat (Mack 1981; Wicks and Smika 1990). With few effective herbicides for in-crop control of the brome grasses (Peeper 1984), producers rely on cultural practices to minimize their impact on winter wheat (Koscelny et al. 1990; Wicks 1984). These practices include nitrogen (N) placement (Anderson 1991; Miller 1990), increased seeding rates (Koscelny et al. 1991), narrow row spacing (Solie et al. 1991), and tall winter wheat cultivars (Challaiah et al. 1986).

The knowledge gained in managing the brome grasses will be helpful in designing cultural strategies to manage jointed goatgrass and feral rye. For example, downy brome (*Bromus tectorum* L.) responds differently to cultural practices, with N management, either time of application or placement, and competitive canopies achieving the most consistent results (Anderson 1996a). In fact, producers can suffer economic losses if the cultural practice is ineffective (Ferreira et al. 1990; Justice at al. 1993). To aid producers in selecting effective cultural strategies, scientists have developed several decision aid models (Swinton and King 1994; Wiles et al. 1996), including a prototype model for jointed goatgrass (Maxwell et al. 1996).

Because winter annual grass seeds persist in the soil (Anderson 1994; Donald and Zimdahl 1987), any practice that minimizes the seedbank population favors winter wheat. Management strategies based on weed seedbank dynamics have been successful with other crops (Forcella et al. 1993) and are components of decision aid models (Wiles et al. 1996). If the effect of cultural practices on seed production of grasses infesting winter wheat were known, integrated systems based on seedbank management could be developed for jointed goatgrass and feral rye.

Seed production of weeds infesting crops can be minimized by nutrient (Wright and Wilson 1992) and crop canopy (Regnier and Bakelana 1995) management. Applying N during fallow, 5 mo before planting winter wheat, reduces downy brome seed production per plant by 10 to 20% (Anderson 1996b), and banding N below

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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.

[4] Feral is defined as: having escaped from domestication or cultivation and become wild.

the wheat seed at planting produces similar results (Miller 1990). Light competition, managed by crop canopy architecture, can reduce seed production per plant by 30% (McMasters et al. 1987). Furthermore, producers can increase the impact of cultural practices on weed seed production by combining several practices into one system (Holtzer et al. 1996).

Therefore, this research compared combinations of four cultural practices (N management, seeding rates, narrow row spacings, and cultivars) in winter wheat for their effect on growth and seed production of feral rye and jointed goatgrass.

MATERIALS AND METHODS

Site Description. Research was conducted during four crop seasons from 1992 to 1996 at Akron, CO. The long-term (88-yr) yearly precipitation is 419 mm, with 297 mm occurring during the winter wheat growing season (September 15 to July 1). Precipitation during the four crop seasons varied from 198 mm to 503 mm, averaging 308 mm. Average air temperature is 9.9 C for 5 September through November, −2.7 C for December through February, and 10.8 C for March through June. The soil was a Weld silt loam (Aridic Paleustoll) with 1.2% organic matter and pH 6.9.

Study 1. In two cropping seasons, 1992 to 1994, nine cultural systems were compared for their effect on winter annual grass seed production. Systems were comprised of combinations of three cultural practices: N management, winter wheat seeding rate, and cultivars.

Two levels of N management were compared: N (ammonium nitrate) applied broadcast at 66 kg/ha, 5 mo before planting (referred to as single application), or N applied broadcast at 50 kg/ha 5 mo before planting, plus 16 kg N/ha applied in a band with the wheat seed at planting (referred to as split application). Also compared were two seeding rates: 45 or 73 kg/ha; and two cultivars: TAM 107, a semidwarf cultivar, or Lamar, a tall cultivar. All possible combinations of these practices were evaluated, resulting in eight treatments. A ninth treatment, the conventional system for this region, also was included for comparison: TAM 107 planted at 45 kg/ha with 66 kg N/ha applied broadcast 2 wk before planting. All treatments were planted with a hoe drill in rows 30 cm apart. Plot size was 6 m by 7 m. Experimental design was a randomized complete block, with four replications.

Study 2. Three cultural systems were compared over two cropping seasons during 1994 to 1996: (1) the conventional system described above; (2) Lamar planted at 73 kg/ha with 66 kg N/ha applied broadcast 5 mo before planting; and (3) TAM 107 planted at 73 kg/ha in rows 18 cm apart. For system 3, N was applied broadcast at 50 kg/ha 5 mo before planting followed by 16 kg N/ha placed in a band on the soil surface, above the wheat row. Because TAM 107 seedlings were injured by N banded with the seed in study 1 (to be discussed later), N was placed on the soil surface to minimize injury (Tisdale and Nelson 1971). The conventional system and system 2 were planted in rows 30 cm apart. Plot size was 8 m by 16 m. Experimental design was a randomized complete block, with four replications.

Winter Annual Grass Establishment and Plant Measurements. Feral rye seed and jointed goatgrass spikelets[5] were collected from a local seed cleaning company, planted in peat pellets,[6] and incubated in a greenhouse until seedling emergence. To ensure uniform size, seedlings 8 to 12 mm tall were transplanted equidistant between wheat rows and 30 cm apart. For study 1, nine seedlings of each species were transplanted 1 wk after winter wheat emergence in a 2-m^2 site. For study 2, nine seedlings were transplanted 1 and 4 wk after winter wheat emergence, in a 4-m^2 site. The species were randomly mixed within each site.

To assess individual plant productivity, six plants of each weed species from each emergence date per plot were harvested 1 wk before maturity. The early harvest prevented seed loss due to shattering. For each treatment and weed species, tillers per plant, height of tallest tiller, aboveground biomass, reproductive ratio,[7] and seed or spikelet number per plant were determined.

At maturity, height of the tallest tiller per plant of winter wheat was measured at six locations in each plot. Winter wheat yield was determined using a plot combine, harvesting 15 m^2 of the remaining weed-free plot area. Grain yield is expressed on a 12% moisture content.

Data Analyses. For study 1, data were analyzed initially as a factorial, without including the conventional system data. The analysis indicated that a year effect did not occur; thus, data were pooled over years. However, a four-way interaction among weed species, cultivars, seeding rates, and N management occurred; therefore, each weed species was analyzed separately for each cul-

[5] Spikelet, the dispersal unit of jointed goatgrass, contains one to four seeds (Donald and Ogg 1991).

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

[7] Reproductive ratio is dry weight of inflorescence unit divided by dry weight of aboveground biomass.

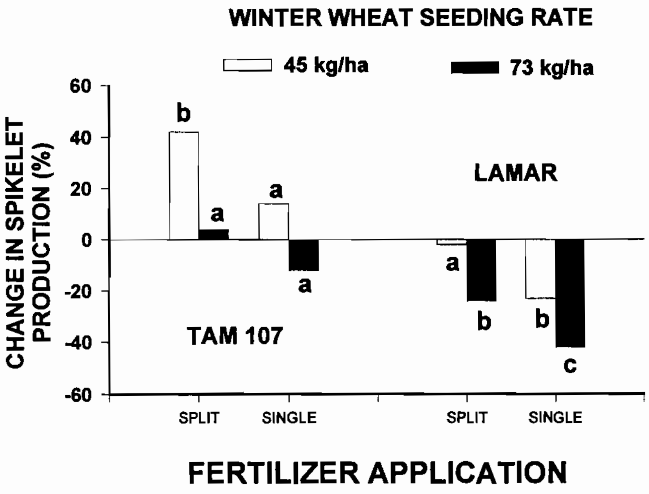

Figure 1. Spikelet production of jointed goatgrass as affected by cultural systems. Data are expressed as percent change in spikelet production compared to jointed goatgrass in the conventional system. Bars with identical letters do not differ as determined by Duncan's new multiple range test. The letter *a* signifies that the treatment did not differ from the conventional system.

Table 1. Jointed goatgrass response to cultural systems in winter wheat, study 1. The conventional system was included in the analysis of cultural systems for each cultivar.

Treatment			Individual plant basis			
Cultivar	Nitrogen application	Seeding rate	Tillers	Height	Biomass	Reproductive ratio
		kg/ha	No.	cm	g	%
TAM 107	Split	45	23	58	40	45
		73	18	57	29	48
	Single	45	19	58	26	47
		73	19	59	22	50
Conventional system[a]			19	59	25	49
LSD			NS	NS	10	NS
Lamar	Split	45	17	58	20	49
		73	13	55	17	45
	Single	45	15	57	20	45
		73	13	53	15	42
Conventional system[a]			19	59	25	49
LSD			5	NS	9	6

[a] Conventional system: TAM 107 planted at 45 kg/ha with 66 kg/ha of N applied broadcast 2 wk before planting.

tivar, with the conventional system included in both cultivar analyses for comparison.

For study 2, initial analysis indicated that a year effect did not occur; thus, data were pooled over years. However, a three-way interaction among systems, weed species, and emergence date occurred. Therefore, systems and emergence dates were analyzed within weed species.

For both studies, treatment mean differences were determined by LSD or Duncan's new multiple range test. Differences among means were determined at the 0.05 level of probability.

RESULTS AND DISCUSSION

Study 1. *Jointed goatgrass.* Averaged over two cropping seasons, jointed goatgrass produced 139 spikelets/plant in the conventional system (data not shown). Cultural systems with Lamar reduced spikelet production the most compared to the conventional system (Figure 1). For example, when Lamar was planted at 73 kg/ha with the single N application, spikelet production was reduced 42% compared to the conventional system. When Lamar was planted at 45 kg/ha with the single N application, spikelet production was reduced 23%.

None of the cultural systems with TAM 107 reduced jointed goatgrass spikelet production compared to the conventional system (Figure 1). Jointed goatgrass produced 42% more spikelets when TAM 107 was planted at 45 kg/ha and N banded with the seed, compared to the conventional system. TAM 107 seedlings in this treatment were stunted in the fall, probably because N banded with the seed injured the wheat (Mahler et al. 1989). Furthermore, both cropping seasons were drier than normal, which increases the risk of N injury to seedlings (Severson and Mahler 1988). The lack of early season growth with TAM 107 allowed jointed goatgrass to gain a competitive advantage. Apparently, Lamar was more tolerant to N banded with the seed, as no seedling injury was observed.

Other growth characteristics of jointed goatgrass were reduced most when Lamar was included in the treatment (Table 1). For example, planting Lamar at 73 kg/ha with the single N application reduced tillers/plant 32% and plant biomass 40%, compared to the conventional system (Table 1). Reduced growth of jointed goatgrass by cultural systems also may lead to less grain yield loss, as these parameters are correlated with jointed goatgrass-induced yield loss (Maxwell et al. 1996). Height of jointed goatgrass was not affected by cultural combination.

Feral rye. Averaged over two cropping seasons, feral rye produced 485 seeds/plant in the conventional system (data not shown). Cultural systems affected feral rye seed production similarly to jointed goatgrass: the greatest reduction occurred with Lamar systems (Figure 2). Planting Lamar at 73 kg/ha and applying N in a single application reduced seed production 45%. In contrast, none of the systems with TAM 107 reduced feral rye seed production. Banding N with TAM 107 seeds at either seeding rate increased the number of seeds per feral rye plant, again reflecting the loss of seedling vigor of TAM 107 due to N injury.

Planting Lamar at 73 kg/ha and applying N in a single

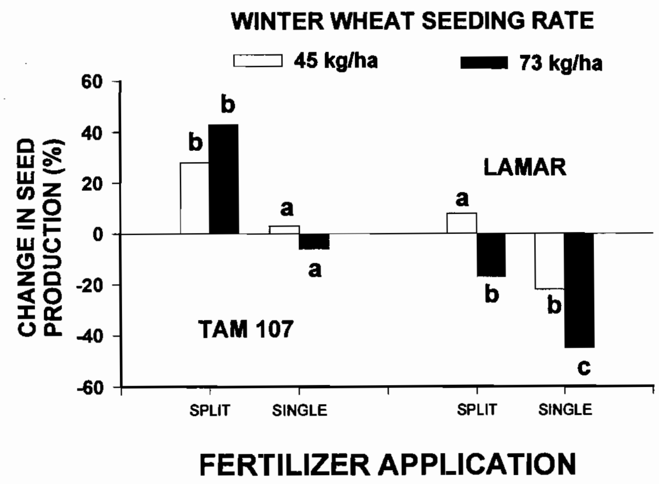

Figure 2. Seed production of feral rye as affected by cultural systems. Data are expressed as percent change in seed production compared to feral rye in the conventional system. Bars with identical letters do not differ as determined by Duncan's new multiple range test. The letter *a* signifies that the treatment did not differ from the conventional system.

Table 2. Feral rye response to cultural systems in winter wheat, study 1. The conventional system was included in the analysis of cultural systems for each cultivar.

Treatment			Individual plant basis			
Cultivar	Nitrogen application	Seeding rate	Tillers	Height	Biomass	Reproductive ratio
		kg/ha	No.	cm	g	%
TAM 107	Split	45	15	104	185	31
		73	16	107	167	30
	Single	45	16	104	129	28
		73	13	102	119	30
Conventional system[a]			14	97	122	31
LSD			NS	9	60	NS
Lamar	Split	45	14	105	137	32
		73	13	106	115	32
	Single	45	11	103	102	29
		73	9	100	66	29
Conventional system[a]			14	97	122	31
LSD			3	7	39	NS

[a] Conventional system: TAM 107 planted at 45 kg/ha with 66 kg/ha N applied broadcast 2 wk before planting.

application also reduced feral rye's tillers and biomass/plant (Table 2). Feral rye was taller than both Tam 107 and Lamar, whose average height was 77 and 89 cm, respectively (data not shown), whereas jointed goatgrass was shorter than either wheat cultivar (Table 1). Feral rye produced five times more biomass per plant than jointed goatgrass in the conventional system (Tables 1 and 2), which helps explain why feral rye reduces yield of winter wheat more than jointed goatgrass on a per-plant basis (Anderson 1994).

We were surprised that banding N with wheat seeds did not favor winter wheat over the grass weeds, even with Lamar, which did not show seedling injury. This contrasts with results from Wyoming, where deep banding of N reduced downy brome growth by 50% (Miller 1990). However, in the Pacific Northwest, deep banding of N below winter wheat seeds did not reduce the growth of either jointed goatgrass or downy brome (Cochran et al. 1990). These conflicting results suggest that weed response to N banding at planting may be interacting with other environmental or soil factors.

Winter wheat grain yield. Tall cultivars, such as Lamar, usually yield less grain than semidwarf cultivars (Anderson 1994). In this study, Lamar yielded 14% less grain than TAM 107, when averaged over N management and seeding rate treatments (Table 3). The only cultural system effect on yield within cultivars occurred with TAM 107, where the seeding rate of 73 kg/ha with the single N application yielded 360 kg/ha more grain than when the split N application was combined with the 45 kg/ha seeding rate. This yield decline of 12% reflects seedling injury due to banding N with the seed of TAM 107.

Study 2. Some producers may hesitate to grow tall cultivars because of their lower yield potential. Therefore, we evaluated a cultural system for TAM 107 that included narrow row spacing to determine if winter annual grass growth could be reduced without sacrificing grain yield.

Cultural system 2, Lamar planted at 73 kg/ha with a single N application, reduced spikelet and seed production of jointed goatgrass and feral rye, respectively, by > 40% (Figure 3), similar to results in study 1. System 3, where TAM 107 was planted at 73 kg/ha in narrow rows, also reduced seed production by similar levels (Figure 3). Thus, cultural systems with TAM 107 can be developed that will reduce seed production of winter annual grasses.

The only difference in system effect among weed emergence times occurred with feral rye. Seed produc-

Table 3. Winter wheat grain yield as affected by cultural systems, study 1.

Treatment		Variety	
Nitrogen application	Seeding rate	TAM 107	Lamar
	kg/ha	kg/ha	
Split	45	2,580	2,450
	73	2,850	2,300
Single	45	2,870	2,530
	73	2,940	2,350
Conventional system[a]		2,690	
LSD		300	

[a] Conventional system: TAM 107 planted at 45 kg/ha with 66 kg/ha of N applied broadcast 2 wk before planting.

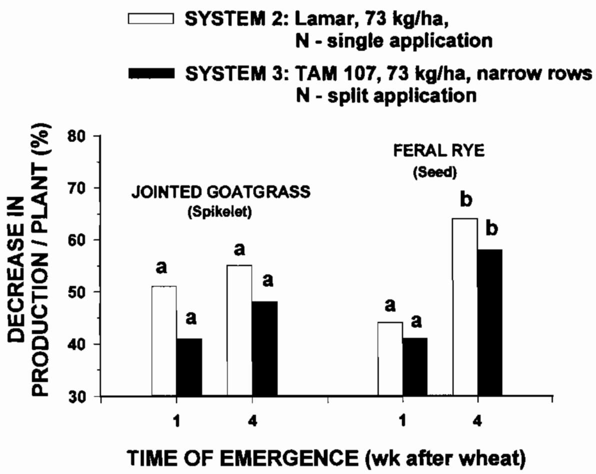

Figure 3. Effect of cultural systems on spikelet and seed production of jointed goatgrass and feral rye, respectively. Data are expressed as percent decrease in production compared to the conventional system. Bars with identical letters within each weed species do not differ as determined by Duncan's new multiple range test. All treatments differed significantly from the conventional system.

tion of plants as emerging 4 wk after winter wheat was reduced 20% more than when emerging 1 wk after wheat, when compared to the conventional system (Figure 3). This suggests that feral rye is not as competitive as jointed goatgrass when emerging later in the growing season.

Seed production by individual plants ranged widely over the four growing seasons. For example, seed produced by feral rye in the conventional system ranged from 455 to 945 seeds/plant (data not shown), due to differences in growing season precipitation. Regardless of this range in plant productivity and precipitation, planting Lamar at 73 kg/ha with a single N application performed similarly over all seasons, reducing seed production 40 to 45%.

Grain yield varied among growing seasons. In 1995, frost during flowering injured TAM 107 and reduced yield. Lamar, a later maturing cultivar, was not injured by frost and yielded 2,870 kg/ha (data not shown). TAM 107 yielded 26% less than Lamar. In 1995–1996, a growing season with above normal precipitation, grain yield did not differ among cultural systems, averaging 5,190 kg/ha (data not shown).

Management Implications. The prevalent crop rotation in the drier parts of the Central Great Plains is winter wheat–fallow. To reduce weed densities in future wheat crops, producers either plow, burn, or mow severely infested fields (Donald and Ogg 1991). However, these practices have serious environmental and economic consequences. Cultural systems in winter wheat offer producers a management strategy that reduces seed entry into the seedbank by almost half. By combining this strategy with other cultural practices such as delayed planting (Anderson 1994) or N management (Miller 1990), producers in a winter wheat–fallow rotation can minimize the economic impact of these winter annual grasses.

In addition, another successful strategy for winter annual grass management is to include summer annual crops in the rotation, to hasten the depletion of the soil seedbank (Anderson 1994; Lyon and Baltensperger 1995). Cultural systems in winter wheat will enhance this rotation effect by minimizing the initial seedbank density. A further benefit of more competitive winter wheat is reduced seed production of other weeds present in wheat, thus reducing weed populations in summer annual crops that follow winter wheat (Wicks et al. 1989).

Producers' concerns about less grain yield with tall varieties can be alleviated by combining narrow rows, N management, and increased seeding rate with semidwarf cultivars. Grain yields are maintained, yet weed seed production is still reduced.

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