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Seedling Emergence of Winter Annual Grasses as Affected by Limited Tillage and Crop Canopy[1]

R. L. ANDERSON[2]

Abstract: Jointed goatgrass and downy brome continue to plague winter wheat producers in the western United States. Because there are no effective herbicides for in-crop control of these weeds, producers are seeking cultural practices that stimulate seed germination and deplete the soil seed bank. We determined the effect of limited tillage and crop canopy on seedling emergence of these grasses. One tillage operation with a sweep plow increased jointed goatgrass seedling emergence 74% in the first year but did not affect emergence in later years. Downy brome emergence was not affected by tillage. Jointed goatgrass seedlings emerged over 5 yr, whereas downy brome did not emerge after 3 yr. Seedling emergence of both species was two times greater in corn and barley than in proso millet. Producers will accrue more benefit for seedbank management with cultural strategies such as alternative rotations and competitive wheat canopies than with limited tillage using a sweep plow.

Nomenclature: Downy brome, *Bromus tectorum* L. #[3] BROTE; jointed goatgrass, *Aegilops cylindrica* Host # AEGCY.; barley, *Hordeum vulgare* L.; corn, *Zea mays* L.; proso millet, *Panicum miliaceum* L.; winter wheat, *Triticum aestivum* L.

Additional index words: Rotation, seedbank depletion, seed survival.

INTRODUCTION

Since the 1930s, the prevalent cropping system in the semiarid central Great Plains has been winter wheat–fallow (Hinze and Smika 1983). Fallow in the rotation stabilizes yield and minimizes crop failure due to erratic precipitation. A negative consequence of this cropping system is that jointed goatgrass and downy brome are not controlled and now infest extensive hectarage (Donald and Ogg 1991; Wicks and Smika 1990). Because these weeds are not effectively controlled by herbicides in winter wheat (Holtzer et al. 1996), producers rely on cultural practices to manage these winter annual grasses (Anderson 1994).

One cultural practice is to insert summer annual crops in the rotation to lengthen time between wheat crops and favor natural decline of the soil seed bank (Lyon and Baltensperger 1995). Yet producers are hesitant to change from winter wheat–fallow because of possible summer crop failure. However, controlling weeds during noncrop periods with herbicides rather than tillage leaves more crop residue on the soil surface. Crop residue increases precipitation storage in soil (Smika 1990) and minimizes the probability of drought-induced crop failure. With no-till systems, more intensive cropping improves economic return, as a winter wheat–corn–fallow rotation produces 70% more grain and 40% more profit than winter wheat–fallow per rotation cycle (Peterson et al. 1993).

A limitation to crop rotation as a control strategy is survival of jointed goatgrass seeds for 3 to 5 yr (Donald and Zimdahl 1987). Because winter wheat is the most profitable and consistent crop in this region, producers are reluctant to use rotations that do not include wheat for three or more years. Thus, producers are seeking additional control strategies to supplement rotations in depleting the soil seed bank.

One possible strategy is tillage, which stimulates weed seeds to germinate (Froud-Williams et al. 1984). Roberts and Feast (1973) found that seedbank decline of several weed species was two to three times greater in cultivated soil compared to undisturbed soil, and jointed goatgrass responds similarly (Donald 1991). However, not all weed species respond to tillage similarly: tillage did not affect seed survival of six weeds in Mississippi (Egley and Williams 1990). Wild oat (*Avena fatua* L.) emergence was not influenced by tillage (Thurston 1961), whereas

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[2] Research Agronomist, Central Great Plains Research Station, Akron, CO 80720.

[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds,* Revised 1989. Available from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

tillage decreased barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] emergence (Ogg and Dawson 1984).

A possible drawback with tillage is that burial of weed seeds in soil extends their longevity (Aldrich 1984). Wild oat seeds persisted longer when buried 12 cm deep compared to seeds on the soil surface (Miller and Nalewaja 1990), whereas jointed goatgrass seeds persisted longer when buried 15 or 30 cm in soil compared to 5 cm (Donald and Zimdahl 1987).

Another concern is that tillage buries crop residue. One pass with a tandem disk harrow buries 75% of the surface residue (Good and Smika 1978). This loss of crop residue from the soil surface decreases precipitation infiltration and storage in soil (Peterson et al. 1993), subsequently reducing crop yield (Wicks et al. 1994). For example, corn yield is decreased 40% in a tilled, low residue system compared to a no-till system in the central Great Plains (Anderson 1990).

Roberts and Dawkins (1967) found that the impact of tillage on seedling emergence occurs mainly with the first operation. Thus, limited tillage may enhance seedling emergence from the seed bank, yet minimize residue burial and subsequent loss of crop yield. Zorner et al. (1984) suggested that shallow tillage would decrease kochia (*Kochia scoparia* L.) seed persistence in soil, whereas shallow tillage increased ripgut brome (*Bromus rigidus* L.) seedling emergence and subsequent seedbank decline (Gleichsner and Appleby 1989).

The sweep plow, which consists of V-shaped blades that sever weed roots with low soil disturbance, is commonly used by Great Plains producers because it only buries 10% of the residue with each operation (Good and Smika 1978). The sweep plow tills 8 to 10 cm deep and buries weed seeds shallowly, which may enhance germination and emergence. Field observations support this hypothesis, as sweep plowing wheat stubble stimulates extensive volunteer wheat emergence, compared to no-till fields.

Another possible strategy to enhance seedbank depletion is choice of crop that follows winter wheat, because crop canopy affects weed emergence (Dotzenko et al. 1969). For example, wild oat emergence during the growing season was less in barley than in spring wheat (Thurston 1962), whereas volunteer wheat emergence during September and October was three times greater in corn than in proso millet (Anderson and Nielsen 1996).

With the goal of improving the rotation effect on seedbank management, we evaluated two cultural strategies, limited tillage (one pass with the sweep plow) and choice of summer annual crop canopy, for impact on seedling emergence and seed survival of jointed goatgrass and downy brome.

Table 1. Cultural practices for establishing corn, barley, and proso millet in wheat stubble.

Culture data	Corn	Barley	Proso millet
Variety	P-3272[a]	Steptoe	Sunup
Planting date range	May 1–7	March 15–30	June 5–12
Seedling rate (plants/ha)	37,000	1.0 million	1.7 million
Row spacing (cm)	76	18	18
N fertilizer (kg/ha)	56	56	33
Harvest date range	October 15–25	July 1–10	September 5–15

[a] P represents Pioneer seeds.

MATERIALS AND METHODS

Site Description. This research was conducted during a 5-yr period, 1990 to 1995, at Akron, CO. Long-term (90-yr) yearly precipitation is 419 mm, with 297 mm occurring during the winter wheat growing season (September 15 to July 1). Yearly precipitation during this study varied from 325 to 530 mm, averaging 428 mm. Average air temperature is 9.9 C for September through November, −2.7 C for December through February, and 10.8 C for March through June. Soil was a Weld silt loam (Aridic Paleustoll) with 1.2% organic matter.

Seedling Emergence by Tillage Study. In August 1990, 24 1-m^2 sites were marked in wheat stubble, and 200 seeds of downy brome and 100 spikelets[4] of jointed goatgrass were placed on the soil surface. One-half of the sites were tilled with one pass of the sweep plow at a depth of 8–10 cm. Tractor speed was 8 km/hr. After one tillage pass, all sites were maintained no-till for the duration of the study. Plot size was 5 by 8 m, with the 1-m^2 site placed in the center of each plot. Experimental design was a randomized complete block with two treatments and 12 replications. Weeds were controlled using glyphosate [*N*-(phosphonomethyl)glycine] as needed.

The site was located in a field with no previous history of downy brome or jointed goatgrass. The field was planted to corn, barley, and proso millet in 1991, 1992, and 1993, respectively (Table 1 lists cultural data for each crop). Planting equipment included disk openers, which provided minimal soil disturbance, and 6-cm-wide press wheels. Atrazine [6-chloro-*N*-ethyl-*N*′-(1-methylethyl)-1,3,5-triazine-2,4-diamine] at 0.6 kg/ha was applied preemergence in corn. In September of 1994, winter wheat was planted with a hoe drill, which tills one third of the soil surface area during planting.

Seedling emergence by species was recorded weekly for each site from establishment in 1990 until July of 1995. Seedlings were pulled and removed after counting. After winter wheat harvest in 1995, five soil cores, 3 cm

[4] Jointed goatgrass spikelets, on the average, contain two seeds (Donald and Zimdahl, 1987).

diam and 10 cm deep, were collected from each site. The samples were washed through a sieve with 1.4 mm openings, and number of seeds was recorded.

Seedlings were summarized by year (September 15 to September 15) and compared between tillage treatments in each year with the Student's t test at the 5% level of probability. Emergence pattern for jointed goatgrass was developed by converting seedling emergence per week into a percentage of total emergence for each year, averaged over tillage treatments. Data over 5 yr were averaged by weekly intervals with one standard deviation derived from yearly averages for each week. An emergence pattern was not developed for downy brome because more than 90% of the total seedlings emerged in the first fall (discussed later).

Crop Canopy Effect on Fall Emergence. In a second study, corn, barley, and proso millet were planted no-till into wheat stubble using prevalent cultural practices for this region (Table 1). To quantify the canopy effect, 50 downy brome seeds or 25 spikelets of jointed goatgrass were planted 2 cm deep in 1-m rows, parallel to and equidistant between crop rows, at three locations in each plot. Simulated rainfall of 2.5 mm was applied to each 1-m row after planting to initiate fall germination of winter annual grasses (Anderson 1989; Anderson and Nielsen 1996). Planting occurred every 2 wk beginning on September 1 and continued through October, resulting in four planting dates per year. Number of seedlings was recorded 21 d after planting. The study was conducted in 1991, 1992, and 1993.

Experimental design was a randomized complete block with four replications. Plot size was 5 by 8 m. Data were analyzed as a three-way factorial, with crop canopy, planting date, and year as the main factors. The three subsamples in each plot were averaged. Analysis of variance indicated that no interactions occurred among factors; therefore, data were averaged over years and planting date. Means within species were separated with the Duncan's New Multiple Range Test at the 5% level of probability. Downy brome and jointed goatgrass data were analyzed separately because of their different dispersal units.

RESULTS AND DISCUSSION

Tillage Effect on Seedling Emergence and Seed Survival. Tilling with the sweep plow increased jointed goatgrass seedling emergence 74% in the first year compared to no-till (Table 2). However, seedling emergence did not differ between these practices for the next 4 yr.

Table 2. Effect of tillage on jointed goatgrass and downy brome seedling emergence over 5 yr.

Tillage treatment	Years in soil 1	2	3	4	5	Total
	seedlings/m²					
Jointed goatgrass						
No-till	37.9	24.6	0.6	2.5	10.3	75.9
One tillage	65.9	22.3	0.3	1.3	7.8	97.5
t test	**[a]	NS	NS	NS	NS	**
Downy brome						
No-till	39.6	1.8	2.9	0	0	44.3
One tillage	43.9	1.5	1.3	0	0	46.7
t test	NS	NS	NS	NS	NS	NS

[a] ** means within years are significantly different; NS, not significant.

Five years after tillage, eight to 10 seedlings emerged in both treatments, indicating that increased emergence by tillage in the first year did not reduced seedling numbers in later years.

Loss of viability when weed seeds remain on the soil surface can be significant (Sagar and Mortimer 1976); thus, death of surface seeds may have eliminated the tillage effect over time with jointed goatgrass. A second consideration is that surface seeds may have been incorporated into the soil by the drill's press wheels when barley, proso millet, or winter wheat were planted. Seedling emergence may seem anomalously low in years 3 and 4 (Table 2), but precipitation was below normal for both years (data not shown), leading to less emergence.

Downy brome emergence was not affected by tillage in any year (Table 2). This contrasts with other research that showed less downy brome survival when seeds were buried shallowly compared to remaining on the soil surface (Wicks 1997). One possible explanation for our results may be lack of sufficient soil movement by the sweep plow to bury weed seeds, because this implement does not invert soil but passes just beneath the soil surface. However, jointed goatgrass emergence in the first year was increased by tillage, which indicates that some seed burial occurred. A second explanation may be that environmental conditions for germination were so favorable in 1990 that differences of seed position in soil were minimized, as the majority of downy brome seedlings in both treatments emerged in September and October of the first year (data not shown).

The species differed in longevity of seed survival. Downy brome seedlings were not observed after the third year, whereas 11% of jointed goatgrass total emergence occurred in the fifth year (Table 2). With downy brome, 92% of its seedlings emerged in year 1, but 40% of jointed goatgrass seedlings emerged in years 2 through 5. Because jointed goatgrass seeds persist longer, management systems for this species may require a

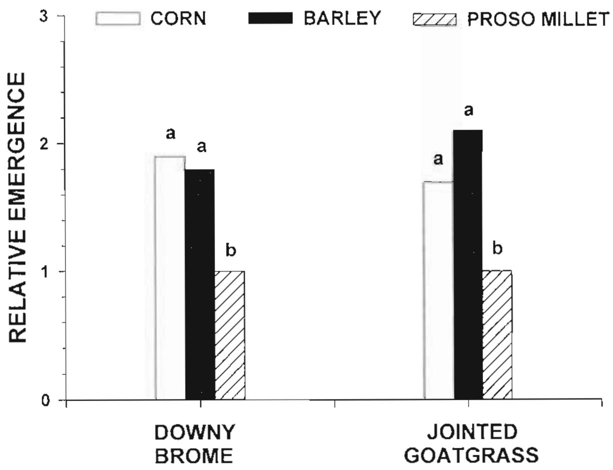

Figure 2. Effect of crop canopy on seedling emergence of jointed goatgrass and downy brome during September and October. Seedling emergence in corn and barley is expressed relative to emergence in proso millet. Canopy means were separated by the Duncan's new multiple range test.

unteer wheat seedling emergence than proso millet or sorghum [*Sorghum bicolor* (L.) Moench.] (Anderson and Nielsen 1996).

Several factors may be involved in stimulating germination and emergence in different crop canopies, such as solar radiation reaching the soil surface (Radosevich and Ghersa 1992), air temperature amplitude (Egley 1986), or allelopathy (Aldrich 1984). In addition, the crop's rooting pattern near the soil surface may contribute to emergence differences. Proso millet roots are more concentrated near the soil surface than corn roots and extract more water from the shallow soil layers (Anderson and Nielsen 1996). The drier soil reduces seedling emergence. Barley favors seedling emergence because its residues after harvest reduce evaporation from the soil surface, which favors seed germination.

Management Suggestions. Producers will not enhance seedbank depletion of jointed goatgrass or downy brome by including limited tillage with a sweep plow in extended crop rotations. However, producers can increase fall emergence of winter annual grasses by growing corn rather than proso millet. Seedlings emerging in corn can easily be controlled after harvest, thus preventing seed production. Barley is less favorable than corn because jointed goatgrass emerges and produces seeds within barley's growing season.

Another potential strategy for producers to supplement the crop rotation effect is to increase the competitiveness of winter wheat. By combining three cultural practices—tall cultivar, high seeding rate, and nitrogen placement—the resulting wheat canopy reduces seed production of jointed goatgrass 40% compared to conventional practices (Anderson 1997). This strategy, when combined with the natural decline of seeds in soil achieved with extended rotations (Anderson 1994), could possibly reduce weed densities in future wheat by 80–95%.

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