Weed Technology. 1998. Volume 12:262–267

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

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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

[1] Received for publication July 30, 1997, and in revised form February 3, 1998. Contribution from Agriculture Research Service, United States Department of Agriculture.

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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, 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*-(phosophonomethyl)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).

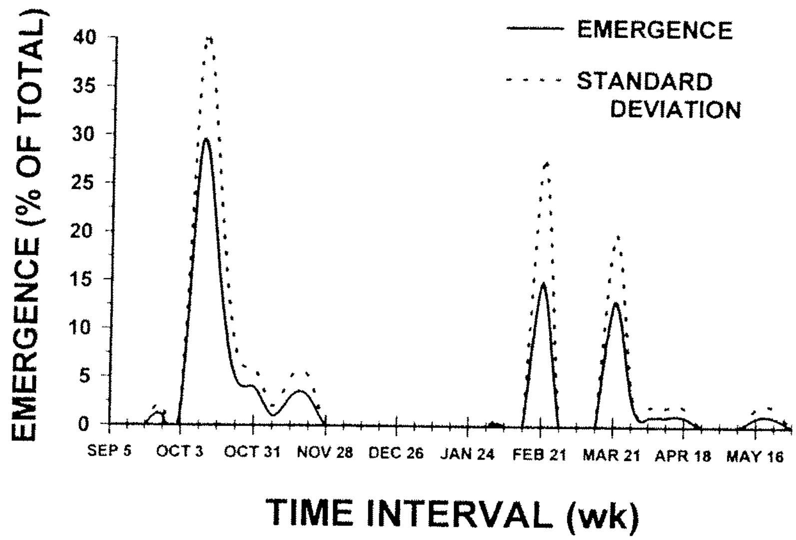

Figure 1. Seedling emergence pattern (solid line) for jointed goatgrass, 1990–1995. Dotted line represents one standard deviation.

longer rotational sequence than needed for downy brome. With both species, seeds were not found in soil samples collected after 5 yr.

Jointed Goatgrass Seedling Emergence Pattern. Knowledge of a weed's emergence pattern can be used to plan preventive approaches for weed control (Aldrich 1984; Mortimer 1984), such as altering planting date or crop choice. With jointed goatgrass over 5 yr, 64% of seedlings emerged during the fall from late September to early November (Figure 1). Emergence in the spring occurred from late February through May.

Barley and oat (*Avena sativa* L.) are planted in late March and early April in this region. If these crops are planted after winter wheat to lengthen the rotation for seedbank management, jointed goatgrass may emerge in the canopy. Jointed goatgrass seedlings emerging in the spring can vernalize and produce seeds (Anderson 1993); therefore, the resultant seed production would negate the rotation impact of these crops on seedbank depletion.

Biological Characteristics of Seedling Emergence. To help producers in choosing weed management strategies,

Table 3. Daily air temperatures (±1 SD) for 10 d preceding initiation or following termination of jointed goatgrass emergence over 5 yr.

	Temperature		
	High	Low	Average
		C	
Fall emergence			
Initiation	22 ± 4	7 ± 3	14 ± 3
Termination	8 ± 5	−8 ± 4	0 ± 4
Spring emergence			
Initiation	10 ± 5	−3 ± 2	3 ± 3
Termination	27 ± 5	7 ± 3	17 ± 4

scientists are developing decision aid models based on biological characteristics of weeds (Maxwell et al. 1996). A key component of these models is seedbank dynamics (Bauer and Mortensen 1992), including prediction of seedling emergence and percent of seed bank that produces seedlings.

Weed seedling emergence has been related to temperature. Roberts and Feast (1973) suggested that initial seedling emergence is governed by a temperature threshold, whereas Egley (1986) found that amplitude of daily air temperature fluctuation accurately described temperature effect on initial seedling emergence. Temperature also has been correlated with inducing secondary dormancy and terminating emergence of several weed species (Forcella et al. 1997).

Jointed goatgrass began emerging in the fall when daily air temperature fluctuation over a 10-d period ranged from 7 to 22 C, with the daily average being 14 C (Table 3). Jointed goatgrass ceased emergence in May when temperature amplitude was 7–27 C, with a daily average of 17 C.

Another biological component needed to model seedbank dynamics is an estimate of the percentage of the seed bank that will produce seedlings. In our study, approximately 23% of the downy brome seed bank produced seedlings, whereas 38–48% of jointed goatgrass seeds produced seedlings over 5 yr (Table 1).

Canopy Effect on Seedling Emergence. Seedling emergence during September and October was two times greater in corn and barley than in proso millet (Figure 2). This result agrees with previous research in which corn produced a more favorable microclimate for vol-

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