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Weed seed bank affected by tillage intensity for barley in Alaska

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Abstract

The weed seed bank of a long-term tillage study in subarctic Alaska was studied at the end of 10 years of continuous spring barley (*Hordeum vulgare* L.). Tillage treatments were: no-till, disked once (spring), disked twice (spring and fall), and chisel plow (fall). Soil cores were obtained from each tillage treatment and seeds were manually separated from soil after washing through sieves. Tillage treatment had a significant effect on seed density of shepherds purse (*Capsella bursa-pastoris* (L.) Medic.), cinquefoil (*Potentilla norvegica* L.), foxtail barley (*Hordeum jubatum* L.), and on total seed density. Seed density was higher for these species and total seed density was greater under no-till than under other tillage treatments. Seed density was higher near the soil surface under no-till and chisel plow treatments than under disked treatments, which helps explain the greater difficulty of controlling weeds under reduced tillage.
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Keywords: Subarctic; Seed bank; Tillage

1. Introduction

Weeds are often a major problem when tillage is reduced to minimize soil erosion. Adequate weed control was difficult to achieve in minimum and no-till soybean (*Glycine max* (L.) Merr.) (Kapusta, 1979), corn (*Zea mays* L.) (Triplett and Lytle, 1972), and small grain (Cleary and Peeper, 1983) production systems. Weed species shifts were noted in Great Britain where tillage was reduced for small grain production. In spring barley, annual dicotyledonous species increased in abundance when tillage was reduced while perennial species and annual grasses increased (Pollard and Cussans, 1976). In winter wheat, much the same pattern was found (Pollard and Cussans, 1981; Pollard et al., 1982). In the USA, greater and more diverse populations of perennial weeds developed in reduced tillage systems than in a moldboard plow system in corn and soybean production (Buhler et al., 1994). Inadequate control of *Bromus* spp. is often given as a reason for reduced winter wheat yield when tillage is reduced (Cleary and Peeper, 1983).

Weed species shifts caused by changes in tillage have also been found in Alaska. On newly cleared land at Delta Junction, Alaska, Conn (1987a) found that total weed ground cover and cover of native grasses and broadleaves were highest under no-till and lowest when soil was disked twice each year. On land that had been under cultivation for 11 years, Conn (1987b) found that ground cover of the non-native perennial grasses, foxtail barley (*Hordeum jubatum* L.) and quackgrass (*Agropyron repens* (L.) Beauv.) increased when tillage was reduced to less than two spring disking operations. Greater cover by perennial weeds occurred under no-till than under tilled treatments. Only a minimum amount of tillage (a single spring disking) was required to reduce total weed cover by half.

Tillage methods have also been found to alter weed germination and soil weed seed banks. Roberts and Feast (1972, 1973) showed that emergence of weed seed

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was increased while longevity was decreased in cultivated versus undisturbed soil. Reduced tillage, therefore, should increase the weed seed bank. Cardina et al. (1991, 2002) found that total soil seed density was generally greater under no-till than under moldboard plow. Yenish et al. (1992) showed that soil seed density did not differ between chisel plow and no-till treatments, but was significantly higher than under moldboard plow. Seeds were uniformly distributed in the soil profile under moldboard plow but were primarily found in the top 1 cm of soil under no-till (Yenish et al., 1992; Cardina et al., 2002). Schreiber (1992) and Swanton et al. (2000) also found that weed seed density was much higher in surface soil when tillage was reduced compared with chisel and no-till systems.

Changes in seed depth distribution caused by tillage methods can result in shifts in weed species. For example, species that depend on burial to escape seed predators and species that have dormancy requirements can be expected to decline under no-till conditions (Buhler, 1995).

Wind erosion is a major problem in Alaska where forests have recently been cleared for agricultural production suggesting that reduced tillage practices could be used to conserve soil (Sharratt, 1998). Little is known regarding seed bank dynamics in these new subarctic agro-ecosystems where seed banks are shifting after forest clearing and still contain seeds from the forest system (Conn et al., 1984). The objective of this study was to determine the effects of various tillage systems in spring barley production on the density of weed seeds and their vertical distribution in the soil profile.

2. Materials and methods

The experiment site was located near Delta Junction, Alaska (latitude 63°55′N, longitude 145°20′W). Delta Junction has a continental, semiarid climate characterized by short, warm summers and cold winters. The soil at the site is a Volkmar silt loam (Aquic Cryochrept). Detailed site and experimental design for the tillage/crop residue study are given in Conn (1987a) and Sharratt (1998).

The tillage/crop residue management treatments were started in 1983. Spring barley was planted each year. Broadleaf weeds controlled by annual applications of MCPA [(4-chloro-2-methylphenoxy)acetic acid]. Four tillage treatments were used in the study: disked twice (once in the fall, once in the spring), disked once in spring, chisel plow in fall, and no-till. The study also employed residue management treatments, but the seed bank was only studied in plots where crop residues were removed.

On September 15, 1994, twenty 1.5-cm diameter soil cores were collected within each of the three replicates of the tillage treatments. The cores were divided into three depth increments: 0–5, 5–15, and 15–30 cm and then combined by depth for each replicate of each tillage treatment. Seeds were separated from soil by washing the soil through a four-tiered sieve with 2.00-, 0.85-, 0.42-, and 0.30-mm screen openings. Size groupings allowed the seed to be more easily recognized from soil and debris. After washing, soils were dried and then inspected under a dissecting microscope and seed removed. Seeds were identified using a seed reference collection and counted. Viability of seed was determined with a tetrazolium (2,3-5-tetrazolium chloride) test. Seeds were pierced prior to placing them in a 1% tetrazolium (w/v) at pH 7.0. After soaking for 2 days at 14 °C, seeds were cut open and those with pink to red embryos were recorded as viable.

Data were analyzed as a nested design with soil depth nested in tillage using the general linear model (GLM) procedure of SAS (SAS Institute Inc., 1988). An analysis was performed for each species and for the following groups: annual broadleaves, native colonizing species, grasses, introduced weeds, and total seeds. Data were not transformed prior to analysis.

3. Results and discussion

Seed from 15 species was found, including 3 native colonizing species (cinquefoil, bluejoint reedgrass [*Calamagrostis Canadensis* (Michx.) Nutt.], and dragonhead [*Drachocephalum parviflorum* Nutt.]). Total seed bank density ranged from 4261 seed m^{-2} under no-till treatment to 1505 seed m^{-2} in the disked-twice treatment. Tillage had a significant effect on soil seed bank density of three species: shepherds purse, cinquefoil, and foxtail barley. Tillage also had a significant effect on seed density of native colonizers and total weeds (Table 1). Foxtail barley plant population increased under no-till in this study (Conn, 1987a,b), resulting in increased seed bank of this species under reduced tillage. Control of grass weeds is the major constraint for no-till under continuous spring barley production in Alaska.

Variability was quite high. Similar variability has been seen in other seed bank studies (Benoit et al., 1989; Forcella et al., 1992; Cardina and Sparrow, 1996) and reflects the non-random spatial distribution of weed seed (Bigwood and Inouye, 1988; Wiles et al., 1992;

Table 1
Effects of tillage on vertical distribution of weed seeds in soil near Delta Junction, Alaska

Name	ANOVA		Seed bank (seed m^{-2})					
	Variable	Significance	Depth (cm)	Tillage treatment				Depth means[a]
				No-till	Chisel	Disk once	Disk twice	
Annual broadleaves								
Shepherds purse [*Capsella bursa-pastoris* (L.) Medic]	Tillage	*	0–5	595	38	0	9	61 a
	Depth (tillage)	**	5–15	0	0	0	0	0 b
			15–30	0	0	0	0	0 b
			Tillage means[a]	198 a	13 b	0 b	3 b	
Common lambsquarters (*Chenopodium album* L.)	Tillage	NS	0–5	1416	784	538	888	906 a
	Depth (tillage)	***	5–15	76	201	143	201	155 b
			15–30	19	0	0	0	5 b
			Tillage means	504	328	227	363	
Prostrate knotweed (*Polygonum arviculare* L.)	Tillage	NS	0–5	0	9	123	0	33
	Depth (tillage)	NS	5–15	19	9	0	9	9
			15–30	0	0	0	0	0
			Tillage means	6	6	41	3	
Wild buckwheat (*Polygonum convolvulus* L.)	Tillage	NS	0–5	9	0	0	0	2
	Depth (tillage)	NS	5–15	0	0	0	0	0
			15–30	0	0	0	0	0
			Tillage means	3	0	0	0	
Pennsylvania smartweed (*Polygonum pensylvanicum* L.)	Tillage	NS	0–5	28	0	9	0	9
	Depth (tillage)	NS	5–15	0	0	9	0	2
			15–30	0	0	0	0	0
			Tillage means	9	0	6	0	
Marsh yellowcress [*Rorippa islandica* (Oeder) Borbas]	Tillage	NS	0–5	415	0	9	0	106
	Depth (tillage)	NS	5–15	0	9	0	0	2
			15–30	0	0	0	0	0
			Tillage means	138	3	3	0	
Corn spurry (*Spergula arvensis* L.)	Tillage	NS	0–5	0	0	368	0	92
	Depth (tillage)	NS	5–15	0	0	9	0	2
			15–30	0	0	0	0	0
			Tillage means	0	0	126	0	
Common chickweed [*Stellaria media* (L.) Cyrillo]	Tillage	NS	0–5	0	57	9	0	17
	Depth (tillage)	NS	5–15	0	0	9	9	5
			15–30	0	0	0	0	0
			Tillage means	0	19	6	3	
Total annual broadleaves	Tillage	NS	0–5	2463	888	1056	897	1326 a
	Depth (tillage)	**	5–15	95	219	170	219	176 b
			15–30	19	0	0	0	5 c
			Tillage means	859	369	409	372	
Native colonizers								
Dragonhead (*Drachocephallum parviflorum* Nutt.)	Tillage	NS	0–5	217	179	368	179	236 a
	Depth (tillage)	*	5–15	297	230	201	163	223 a
			15–30	28	0	0	9	9 b
			Tillage means	181	136	190	117	
Cinquefoil (*Potentilla norvegica* L.)	Tillage	**	0–5	906	0	19	19	236 a
	Depth (tillage)	**	5–15	28	19	0	0	12 b
			15–30	19	0	0	0	5 b
			Tillage means	318 a	6 b	6 b	6 b	

Table 1 (*Continued*)

Name	ANOVA Variable	ANOVA Significance	Seed bank (seed m^{-2}) Depth (cm)	Tillage treatment No-till	Chisel	Disk once	Disk twice	Depth means[a]
Grasses								
Quackgrass	Tillage	NS	0–5	0	0	0	0	0
[*Elymus repens* (L.) Gould]	Depth (tillage)	NS	5–15	19	0	9	0	7
			15–30	0	0	0	0	0
			Tillage means	6	0	3	0	
Wild oat (*Avena fatua* L.)	Tillage	NS	0–5	0	0	0	0	0
	Depth (tillage)	NS	5–15	19	0	0	9	7
			15–30	0	0	0	9	2
			Tillage means	6	0	0	6	
Bluejoint reedgrass [*Calamagrostis*	Tillage	NS	0–5	28	0	0	0	7
canadensis (Michx.) Nutt.]	Depth (tillage)	NS	5–15	9	0	0	0	2
			15–30	0	0	0	0	0
			Tillage means	12	0	0	0	
Foxtail barley	Tillage	*	0–5	114	0	76	9	51 a
(*Hordeum jubatum* L.)	Depth (tillage)	**	5–15	0	0	9	0	2 b
			15–30	9	0	0	0	2 b
			Tillage means	41 a	0 b	28 ab	3 b	
Total grasses	Tillage	NS	0–5	142	0	76	9	57 a
	Depth (tillage)	**	5–15	47	0	18	9	19 b
			15–30	9	0	0	9	5 b
			Tillage means	66	0	31	9	
Total introduced weeds	Tillage	NS	0–5	2577	888	1132	906	1376 a
	Depth (tillage)	***	5–15	133	219	188	228	192 b
			15–30	28	0	0	9	9 c
			Tillage means	913	369	440	381	
Total native colonizers	Tillage	*	0–5	1151	179	387	198	479 a
	Depth (tillage)	*	5–15	334	249	201	163	237 b
			15–30	47	0	0	9	14 c
			Tillage means	511	143	196	123	
Total seed bank	Tillage	*	0–5	3728	1067	1519	1104	1855 a
	Depth (tillage)	***	5–15	467	468	389	391	429 b
			15–30	75	0	0	18	23 c
			Tillage means	1423 a	512 b	636 b	504 b	

[a] Means for each species or group of species followed by different letters are significantly different ($p \leq 0.05$) using Duncan's multiple range test.

Wiles and Schweizer, 2002; Ambrosio et al., 2004). The high variability explains why significant treatment differences were found for some species but not others.

Seed density was significantly higher under no-till than other tillage treatments for shepherds purse, cinquefoil, native colonizers, and total weeds. For foxtail barley, soil seed populations were highest under no-till and disked once treatments, and were lowest under disked twice and chisel plow conditions (Table 1). Cardina and Sparrow (1996) also found that soil weed seed density was generally greater under no-till than in plowed corn in Ohio. The larger seed bank found under no-till conditions may be due to a combination of reduced weed control and lack of tillage. Roberts and Feast (1972, 1973) found that tillage increased weed seed germination, which could reduce weed seed bank density if weeds were controlled before seeds mature.

Seed from a number of species were found primarily in the top 5 cm of soil. This was true for the introduced weeds shepherds purse, common lambsquarters (*Chenopodium album* L.), foxtail barley, and the native colonizers, dragonhead (*Drachocephalum parviflorum*

Nutt.) and cinquefoil, and for the total seed density of grasses, introduced weeds, native colonizers, and total weeds (Table 1).

Conn et al. (1984) found that weed seed banks in Alaska agricultural fields changed with increasing time in cultivation. There was a shift from a seed bank dominated by native species in newly cleared sites to a seed bank dominated by colonizers in the older fields. A similar pattern was found for above-ground weed vegetation (Conn and DeLapp, 1983). Despite the shift in weeds and in the weed seed bank, seed of native colonizers (especially dragonhead) continued to be an important component of the weed seed bank over the 20-year time series. Many of these native colonizers depend on extreme seed longevity and persistence in the soil seed bank as a strategy for exploiting newly disturbed sites, whereas naturalized agricultural weeds depend more on dispersal and less on extreme seed longevity. For example, after almost 10 years of burial, dragonhead, a native colonizer, retained 60% seed viability in comparison to less than 5% seed viability remaining for all 15 naturalized weeds (Conn and Deck, 1995). In the present study, shifts were found in weed seed bank composition under various tillage treatments, but the native colonizer seed remained a component of all seed banks, due to the long-lived nature of these seeds.

Conservation tillage practices are needed for interior Alaska to minimize wind and water erosion of shallow, friable, and highly erodible agricultural soils. In this long-term conservation tillage experiment, no-till was found to conserve soil moisture and produce higher barley yield than conventional tillage in years when soil moisture was limiting (Sharratt, 1998). However, production of barley under continuous no-till was limited by the build-up of perennial grass populations (Conn, 1987b) and control of these grasses required use of herbicides that were detrimental to barley, necessitating that fallow be incorporated into the cropping system. This study shows that in addition to the increases in perennial grasses that occurred with no-till, the soil seed bank of other native and introduced species increased, which makes weed management with reduced tillage even more challenging.

4. Conclusions

Reduced tillage in a continuous spring barley cropping system increased the total soil seed density as well as the seed density of shepherds purse, cinquefoil, foxtail barley, and native colonizing species. No-till increased the seed bank in the top portion of the soil profile for common lambsquarter, foxtail barley, dragonhead, cinquefoil, and for the total number of seed of grasses, introduced weeds, native colonizers, and total weeds. Greater soil seed banks cause weed pressure and management challenges under reduced tillage.

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