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Effects of Tillage and Straw Management on Alaskan Weed Vegetation: a Study on Newly Cleared Land

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ABSTRACT

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The effects of tillage and straw management in a continuous spring barley system were studied during 1983-1985 on land near Delta Junction, Alaska, that had just been cleared for agricultural production. This research was a part of a multidisciplinary approach to design agricultural systems to minimize soil erosion on interior Alaskan agricultural land. Total weed ground cover and cover of native grasses such as bluejoint reedgrass (*Calamagrostis canadensis* (Michx) Nutt.) and native broadleaves was highest in no-till plots and was lowest in plots that were disked twice each year. Total weed ground cover increased during 1983-1985. Ground cover of native grasses was greater when stubble and straw residues were left on the soil surface than when the residues and stubble were removed. Greater snow cover where stubble is left may help to prevent freezing injury to the native grasses.

INTRODUCTION

Since 1978, extensive areas of land near Delta Junction, Alaska, have been cleared for cultivation. Strong seasonal winds, a loess soil and large open fields contribute to a high potential for wind erosion on these new agricultural lands (Boyer, 1983).

Research was conducted from 1980 to 1982 to determine the feasibility of using reduced tillage in spring barley production to increase crop residues to protect the soil against wind erosion. This research was conducted on land that had been under cultivation for 11 years. Ground cover of introduced perennial grasses, including foxtail barley (*Hordeum jubatum* L.) and quackgrass (*Agropyron repens* (L.) Beauv.), increased when tillage was reduced to less than two disking operations per year. Perennial grasses were more abundant

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when barley was grown continuously rather than in rotation with rapeseed (Conn, 1987, this issue).

Since much of the land in the Delta Junction area has been cleared only recently, a multidisciplinary experiment, beginning in 1983, was conducted to determine the effects of tillage on soil properties, barley yield, microclimate and weed vegetation on newly cleared land. Because the weed flora of newly cleared agricultural lands in Alaska has been shown to differ from the flora of older agricultural land (Conn and DeLapp, 1983), it was thought that the weed problems associated with reduced tillage might differ on newly cleared vs. established agricultural land.

The new conservation tillage experiment included a straw management variable in addition to tillage. Crop residues have been shown to intercept herbicide residues (Banks and Robinson, 1982; Ghadiri et al., 1984) which could affect weed populations. In addition, crop residues may have physical and chemical effects on the soil micro-environment (Crutchfield et al., 1986) which could affect herbicide activity, weed seed germination and survival. Thus, one of the goals of this study was to determine the effects of crop residue management on weed populations.

MATERIALS AND METHODS

Site description and history

The experiment site was located near Delta Junction, Alaska (latitude 64°N, longitude 146°W). The site was cleared during the winter of 1977–78, but was left untilled until the spring of 1982. In the spring of 1982 this land was then disked with a breaking disk, root raked, and a seedbed was prepared. 'Lidal' barley was then planted to establish stubble for the 1983 season. The soils at the site consisted of Volkmar (mixed Aquic Cryochrept) and Beales (mixed Typic Cryochrept) silt-loam of pH 5.8 with about 8% organic matter content.

Experimental design

A split-plot design was used with tillage treatments as main plots (22.9×122 m) and straw treatments as sub-plots (22.9×40.7 m). There were three replicates (complete blocks). Four tillage treatments were employed, (1) conventional tillage using one spring and one autumn disking, (2) minimum tillage using chisel plowing in the autumn with 3-inch twisted points, (3) minimum tillage using spring disking only, and (4) no-till. In 1983, the first year of the study, a chisel plus three diskings was used instead of the minimum tillage chisel plow treatment. Three straw management treatments were employed. (1) Residue removed. After combining, the stubble was cut as close to the ground as possible and all residue was baled and removed. (2) Straw removed.

Stubble was left at 15–20 cm height. Loose straw was baled and removed. (3) Straw remaining. Stubble was left at 15–20 cm height and loose straw remained. Since straw management treatments were not in place until autumn 1983, the effects of this variable on weed vegetation were studied only in 1984 and 1985.

In all years, fertilizer was broadcast at rates equivalent to 84 kg ha^{-1} N, 67.2 kg ha^{-1} K_2O and 19 kg ha^{-1} P_2O_5. 'Lidal' barley was seeded in mid–late May at a rate of 112 kg ha^{-1} using a Haybuster[1] double opener, press wheel drill. A starter fertilizer consisting of N and P was banded with the seed at a rate of 12.3 kg ha^{-1} N and 57.1 kg ha^{-1} P_2O_5. All plots except those employing no-tillage were packed to firm the seedbed.

Broadleaf weed control was accomplished using a post-emergence bromoxynil (3,5-dibromo-4-hydroxybenzonitrile) application at a rate of 0.34 kg ha^{-1} (2.81 kg cm^{-2} pressure, volume = 234 l ha^{-1}) at the barley 2–3 leaf stage. In 1985, chlorsulfuron (2-chloro-N-(((4-methoxy-6-methyl-1,3,5-triazin-2-yl)amino)-carbonyl)benzenesulfonamide) was applied at the barley 2–5 leaf stage to control broadleaf weeds at an application rate of 13.2 g ha^{-1} (2.81 kg cm^{-2} pressure, volume = 234 l ha^{-1}).

Weed vegetation was quantified in early August 1983, 1984 and 1985 using a quadrat sampling procedure. Ten 1-m^2 quadrats were located at random along a transect extending through the middle of each plot. The percentage of ground covered by each weed species was estimated in each quadrat. These data were then converted to mean percentage cover for each species in each plot.

Analysis of variance was performed on arc-sine transformed mean percentage cover data to determine whether common weed species and the groups of species listed below were affected by tillage or straw management treatments.

(a) Introduced broadleaves: common lambsquarters (*Chenopodium album* L.); chickweed (*Stellaria media* (L.) Cyrillo); pineappleweed (*Matricaria matricarioides* (Less.) Porter); prostrate knotweed (*Polygonum aviculare* L.); shepherdspurse (*Capsella bursa-pastoris* (L.) Medik.); marsh yellowcress (*Rorippa islandica* (Oeder) Borbas); volunteer rapeseed (*Brassica campestris* L.); flixweed (*Descurainia sophia* (L.) Webb.); Pennsylvania smartweed (*Polygonum pensylvanicum* L.).

(b) Native broadleaves: *Achillea borealis* Bong.; rough cinquefoil (*Potentilla norvegica* L.); fireweed (*Epilobium angustifolium* L. and *E. davuricum* Fisch.); willow (*Salix* spp.); poplar (*Populus* spp.); prickly rose (*Rosa acicularis* Lindl.); American dragonhead (*Dracocephalum parviflorum* Nutt.); *Polemonium acutiflorum*; arctic lupin (*Lupinus arcticus* S. Wats.); bluebell (*Mertensia paniculata* (Ait.) G. Don); pale corydalis (*Corydalis sempervirens* (L.) Pers.); grove sandwort (*Moehringia lateriflora* (L.) Frenzl.); *Stellaria laeta* Richards; arctic sweet coltsfoot (*Petasites frigidus* (L.) Franch.); mountain cranberry (*Vaccinium vitis-idaea* L.).

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[1]Trade names and company names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the product by the U.S. Department of Agriculture.

(c) Native grasses and cryptogams: bluejoint reedgrass; *Agrostis* sp.; field horsetail (*Equisetum arvense* L.); sedges (*Carex* spp.).

(d) Introduced grasses: Kentucky bluegrass (*Poa pratensis* L.); foxtail barley; meadow foxtail (*Alopecurus pratensis* L.).

(e) Total broadleaves = introduced broadleaves + native broadleaves.

(f) Total grasses = introduced grasses + native grasses.

(g) Total weed cover = total broadleaves + total grasses.

RESULTS AND DISCUSSION

Effects of tillage

In all three years, 1983–1985, tillage had a significant effect on the percentage ground cover of *Epilobium davuricum*, native broadleaves, total broadleaves, bluejoint reedgrass, native grasses, total grasses and total weeds. Tillage affected ground cover of American dragonhead and *Polemonium acutiflorum* in 1984 and 1985, but not in 1983. Ground cover of common lambsquarters, *Epilobium angustifolium*, and introduced broadleaves were affected by tillage only in 1985, while that of prickly rose, Kentucky bluegrass and introduced grasses were affected only in 1983 (Table I–III). Except for common lambs-

TABLE I

Analysis-of-variance probabilities that differences in mean percentage cover among block and tillage treatments in 1983 occurred by chance for various weed species groups[a]

Weed species group	Block (B)	Tillage (T)	B×T	r^{2}[b]
Common lambsquarters	***	NS	NS	0.60
Marsh yellowcress	***	NS	NS	0.44
Introduced broadleaves	***	NS	NS	0.54
Epilobium angustifolium	NS	NS	*	0.11
E. davuricum	***	***	**	0.60
Prickly rose	**	**	**	0.37
American dragonhead	NS	NS	NS	0.18
Polemonium acutiflorum	**	NS	*	0.33
Native broadleaves	**	***	**	0.37
Total broadleaves	**	*	NS	0.51
Kentucky bluegrass	***	***	***	0.55
Introduced grasses	***	**	**	0.43
Bluejoint reedgrass	***	***	*	0.66
Agrostis sp.	**	**	*	0.49
Native grasses	***	***	**	0.68
Total grasses	***	***	**	0.67
Total weeds	NS	***	*	0.61

[a]NS, not significant at $P = 0.05$; *, significant at $P = 0.05$; **, significant at $P = 0.01$; ***, significant at $P = 0.001$.

[b]Regression coefficients indicating the proportion of variability explained by ANOVA.

TABLE II

Probabilities that differences in mean percentage cover among block, tillage and straw treatments in 1984 occurred by chance for various weed species groups[a]

Weed species group	Block (B)	Tillage (T)	Straw (S)	B×T	B×S	T×S	r^{2b}
Common lambsquarters	NS	NS	NS	***	NS	NS	0.12
Marsh yellowcress	**	*	*	**	*	NS	0.36
Introduced broadleaves	*	NS	*	**	NS	NS	0.30
Epilobium davuricum	***	***	NS	***	NS	*	0.42
E. angustifolium	NS	NS	NS	NS	NS	NS	0.25
Prickly rose	NS	NS	NS	NS	NS	NS	0.16
American dragonhead	**	***	NS	NS	NS	NS	0.66
Polemonium acutiflorum	NS	**	NS	**	NS	NS	0.28
Native broadleaves	NS	**	NS	*	NS	NS	0.27
Total broadleaves	NS	*	NS	**	NS	NS	0.29
Kentucky bluegrass	NS	NS	NS	NS	NS	NS	0.30
Introduced grasses	NS	NS	NS	NS	NS	NS	0.24
Bluejoint reedgrass	*	***	NS	NS	NS	NS	0.51
Agrostis sp.	**	NS	NS	NS	NS	NS	0.33
Native grasses	***	***	NS	NS	NS	NS	0.60
Total grasses	***	***	NS	NS	NS	NS	0.62
Total weeds	**	***	NS	**	NS	NS	0.56

[a]NS, not significant at $P=0.05$; *, significant at $P=0.05$; **, significant at $P=0.01$; ***, significant at $P=0.001$.
[b]Regression coefficients indicating the proportion of variability explained by ANOVA.

quarters, the percentage ground cover increased as tillage was reduced (Fig. 1). Bluejoint reedgrass and *Agrostis* sp., two native perennial grasses, contributed most of the weed ground cover under reduced tillage (no-till or disked-once plots). Even a single disking or chisel plow operation reduced the cover of these two weeds by over 50% from that of no-till plots in 1984 and 1985 (Table IV). Total weed cover in no-till plots increased from 1983 to 1985 (Fig. 1). Both bluejoint reedgrass and *Agrostis* sp. are rhizomatous, spreading vegetatively. The extreme sensitivity of these species to tillage may be attributable to the short growing season and subsequent lack of recovery time. The chisel treatment (performed in the autumn) was more effective in controlling perennial grasses than was the single disking done in the spring. Grasses that were tilled in the autumn would have less time to recover than grasses tilled in the spring.

A previous study showed that weed ground cover also increased with reduced tillage on nearby land that had been in cultivation for 11 years (Conn, 1987, this issue). In that study, perennial grasses covered up to 40% of the ground under the no-till treatment by the end of the study. However, the grasses in that study were introduced species, quackgrass and foxtail barley, while in this study, performed on newly cleared land, native grasses presented the greatest weed problem. This difference is consistent with the report of Conn and DeLapp (1983) showing shifts from native weed species to introduced species with increasing time in cultivation. At the site that had been in production for 11 years, previous annual cultivation had eliminated the native grasses.

Effects of straw management

Total ground cover of introduced broadleaves was affected by straw treatment both in 1984 and 1985. Flixweed was affected in 1983 only. Bluejoint reedgrass, native grasses, total grasses and total weed cover were affected by straw treatment in 1985 (Tables II and III). In 1984, ground cover of flixweed and introduced broadleaves was significantly greater in plots where straw residues were left on the soil surface than where they were removed (Table V). In 1985 the opposite was true. Ground cover of introduced broadleaves was greatest where all stubble and loose straw had been removed. A possible reason for the difference in effects of straw management on introduced broadleaves between the two years is the switch from bromoxynil, which was used in 1984, to chlorsulfuron used in 1985.

Crop residues are known to intercept herbicides (Banks and Robinson, 1982;

TABLE III

Probabilities that differences in mean percentage cover among block, tillage and straw treatments in 1985 occurred by chance for various weed species groups[a]

Weed species group	Block (B)	Tillage (T)	Straw (S)	B×T	B×S	T×S	r^{2b}
Common lambsquarters	**	***	NS	***	NS	NS	0.14
Marsh yellowcress	NS	NS	NS	NS	NS	NS	0.07
Introduced broadleaves	**	**	**	*	**	NS	0.14
Epilobium davuricum	**	*	*	***	NS	NS	0.14
E. angustifolium	NS	**	NS	NS	**	NS	0.12
Prickly rose	NS	NS	NS	NS	NS	NS	0.05
American dragonhead	NS	***	NS	NS	NS	NS	0.07
Polemonium acutiflorum	NS	*	NS	*	NS	NS	0.07
Native broadleaves	NS	***	NS	*	NS	NS	0.10
Total broadleaves	*	***	NS	NS	NS	NS	0.11
Kentucky bluegrass	NS	NS	NS	NS	NS	NS	0.06
Introduced grasses	NS	NS	NS	NS	NS	NS	0.07
Bluejoint reedgrass	***	***	**	***	***	NS	0.40
Agrostis sp.	***	***	***	NS	***	***	0.55
Native grasses	***	***	***	***	***	*	0.51
Total grasses	***	***	***	***	***	*	0.51
Total weeds	***	***	***	***	***	**	0.51

[a]NS, not significant at $P=0.05$; *, significant at $P=0.05$; **, significant at $P=0.01$; ***, significant at $P=0.001$.
[b]Regression coefficients indicating the proportion of variability explained by the ANOVA.

TABLE IV

The effect of tillage on ground cover of weed species, 1983-1985. Only species in which tillage had a significant effect in at least one year are shown

Species	Year	Tillage				
		No-till	Disked once	Chisel	Disked twice	Disked twice + chisel
Common lambsquarters	1983	0.6	0.3		0.5	2.3
	1984	2.6	3.3	0.8	2.3	
	1985	0.0a[1]	0.3b	0.3b	0.1a	
Marsh yellowcress	1983	2.0a	1.3a		0.8b	1.0ab
	1984	2.4a	0.7b	1.0b	0.2b	
	1985	0.1	0.1	0.0	0.0	
Epilobium angustifolium	1983	0.1	0.1		0.0	0.0
	1984	0.4	0.2	0.1	0.1	
	1985	0.3a	0.0b	0.2a	0.0b	
E. divaricum	1983	0.0	0.0		0.0	0.0
	1984	0.6a	0.3a	0.0b	0.1b	
	1985	0.0	0.0	0.0	0.0	
American dragonhead	1983	0.3a	0.6b		0.7b	0.8b
	1984	0.0a	0.0a	0.3b	0.4b	
	1985	0.1a	0.2b	0.2b	0.1a	
Polemonium acutiflorum	1983	0.3	0.1		0.1	0.2
	1984	0.2a	0.0b	0.1a	0.0	
	1985	0.1a	0.0b	0.1a	0.0b	
Bluejoint reedgrass	1983	10.7a	10.2a		1.5b	1.1b
	1984	12.5a	7.2b	2.8bc	0.4c	
	1985	18.8a	6.2b	4.0b	0.3c	
Agrostis sp.	1983	0.8a	0.8a		0.0b	0.6a
	1984	7.5a	1.2b	0.6b	0.1b	
	1985	9.9a	2.0b	0.6c	1.0bc	

[1]Means followed by different letters in the row are significantly different ($P = 0.05$, LSD).

Bauman and Ross, 1983; Ghadiri et al., 1984; Crutchfield et al., 1986). Crutchfield et al. (1986) working with metolachlor (2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl)acetamide) found that weed control was not reduced even though much of the herbicide was intercepted by crop

TABLE V

Effect of straw management on ground cover of flixweed and introduced broadleaves in 1984

Straw treatment	Mean % ground cover	
	Flixweed	Introduced broadleaves
Straw left on	1.7	6.0
Straw removed	1.1	3.3
Stubble and straw removed	0.6	2.9
LSD (P=0.05)	0.6	2.0

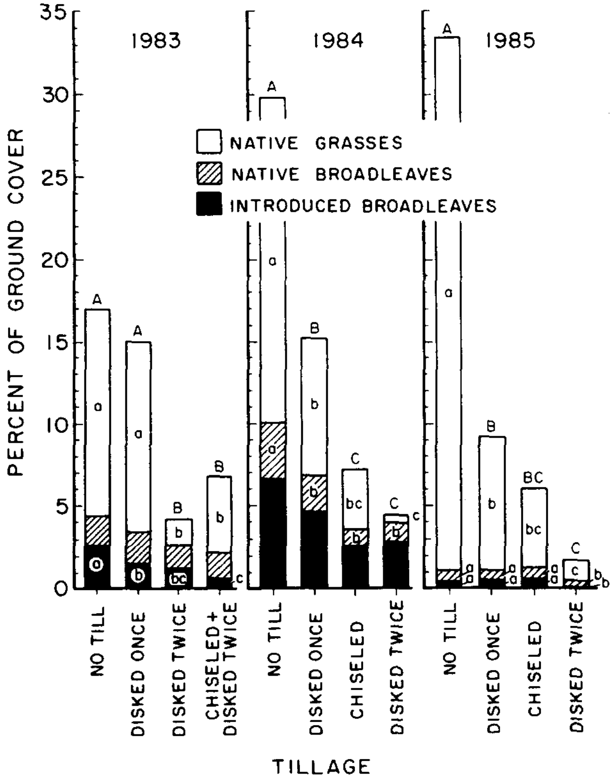

Fig. 1. Effect of tillage on ground cover of various weed categories on newly cleared land 1983-1985. Differences between tillage treatments for particular weed categories are signified by differences in letters a, b and c (LSD, P=0.05).

residues. Metolachlor was leached from the residues with rainfall, and this along with the mulching effect of the straw provided good weed control. A similar phenomenon may have occurred in 1985 in our plots when chlorsulfuron was used. Chlorsulfuron is relatively persistent with a half-life of 1–3 months

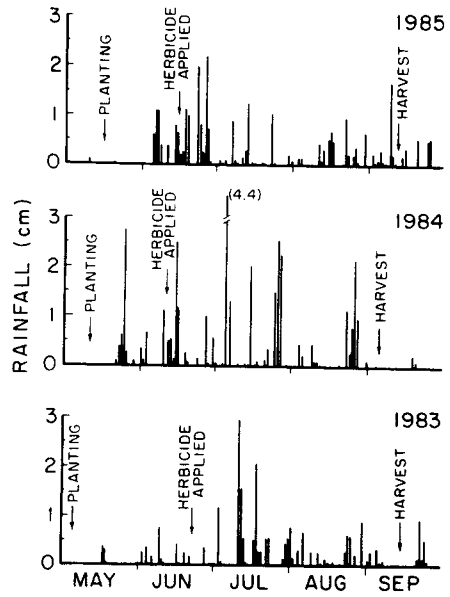

Fig. 2. Temporal pattern of rainfall during the 1983-1985 growing seasons at Delta Junction, Alaska, in relation to dates of planting, herbicide application and harvest.

(Walker and Brown, 1983; Fredrickson and Shea, 1986), and is quite soluble in water (Beste, 1983). This herbicide would have been present when rains occurred (Fig. 2) and would have leached from crop residues. In contrast, bromoxynil is much less persistent (Smith, 1980) and is much less soluble in water (Beste, 1983). Thus, much of the bromoxynil applied to our plots in 1983 may have been lost before the first rains (Fig. 2) and the low water solubility would have prevented much leaching in both 1983 and 1984. The result is that interception of bromoxinyl by straw would have reduced control of broadleaf weeds, while interception of chlorsulfuron would not have reduced control.

In 1985, there was significantly more ground cover of bluejoint reedgrass where crop residues and stubble were left than where they were removed (Table VI). Native grasses, total grasses and total weeds were more abundant in plots where stubble was left than where stubble was removed. These latter weed categories were largely influenced by the effects of straw management on bluejoint reedgrass, the most abundant weed. Crop residues may have protected this native perennial grass from freezing injury due to the snow trapping and insulating qualities of the snow and crop residues.

Although the perennial grasses were different on newly cleared vs. older agricultural land, the implications are similar for management. With present weed control technology, use of no-till in continuous spring barley production is not feasible in Alaska because perennial grasses increase under this regime to the

TABLE VI

Effect of straw management on ground cover of weed categories in 1985. Ground covers are shown only for weed categories significantly affected by straw treatment

Straw treatment	Mean % ground cover				
	Introduced broadleaves	Bluejoint reedgrass	Native grasses	Total grasses	Total weeds
Straw left on	0.3	10.0	16.5	16.5	17.5
Straw removed	0.2	8.7	14.1	14.1	15.0
Stubble and straw removed	0.6	5.8	8.8	8.8	9.8
LSD ($P=0.05$)	0.2	4.0	5.1	5.1	5.1

point that barley yields are negligible (1098 kg ha^{-1} for no-till vs. 3270 kg ha^{-1} for plots disked twice in 1985). Also, due to the short growing season, there is not enough time prior to planting to allow the grasses to green up before applying a non-selective herbicide, and the grasses are largely dormant after the barley is harvested. No-till production of barley will have to include a fallow period or a rotational crop. If spring barley is to be grown continuously, then a minimum amount of tillage must be included.

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