

TABLES 1-34

Table 1. Tillage characteristics for the Center study site (fall, 1987) following grading to level the surface.

Tillage	Average Spacing	Depth Range	Average Depth
		(cm)	
		<u>Topsoil Treatments</u>	
Chisel	30	13-18	15
Deep Rip [†]	127	102-122	114
Grader Rip [†]	137	25-36	30
		<u>Subsoil Treatments</u>	
Chisel	30	10-18	15
Deep Rip [†]	122	122-135	127
Grader Rip [†]	137	20-33	28
Deep Lift [‡]	---	---	---
No Till	---	---	---

[†]Completed with a D9 bulldozer with a 13 cm thick shank.

[†]Standard grader with 8 cm thick shanks.

[‡]Respread as deep as possible with minimal traffic.

Table 2. Tillage characteristics for the Coteau study site (fall, 1987) following grading to level the surface.

Tillage	Average Spacing	Depth Range	Average Depth
		(cm)	
		<u>Topsoil Treatments</u>	
Chisel	30	10-18	15
Deep Rip [†]	107	48-64	58
Grader Rip [†]	68	30-51	43
		<u>Subsoil Treatments</u>	
Chisel	30	10-18	15
Deep Rip [†]	107	61-76	64
Grader Rip [†]	68	30-36	33
Deep Lift [‡]	---	---	---
No Till	---	---	---

[†]Large subsoiler with 4 cm thick shanks.

[†]Standard grader with 8 cm thick shanks.

[‡]Respread as deep as possible with minimal traffic.

Table 3. Tillage characteristics from the Glenharold and Knife River topsoil tillage locations, spring 1989.

Tillage	Depth	Spacing
		(m)
Chisel	0.15	0.30
Subsoil	0.60	0.52

Table 4. Seeding rates of plant materials used at the experiment locations.

Material	Center	Coteau	Glenharold	Knife River
			(kg ha ⁻¹)	
Alfalfa (<i>Medicago sativa</i>)	4.9	4.9	11.2	11.2
Native Mix			20.2	20.2
Sideoats grama (<i>Bouteloua curtipendula</i>) 33%				
Green needle (<i>Stipa viudula</i>) 19%				
Big bluestem (<i>Audropogon gerardii</i>) 17%				
Western wheatgrass (<i>Pascopyrum smithii</i>) 14%				
Blue grama (<i>Bouteloua gracilis</i>) 11%				
Slénder wheatgrass (<i>Elymus trachycaulus</i>) 6%				
Precrop Mix			16.8	16.8
Alfalfa 33%				
Pubescent wheatgrass (<i>Thimopyrum intermedium</i>) 27%				
Tall wheatgrass (<i>Thimopyrum pontium</i>) 20%				
Smooth brome (<i>Bromus inermis</i>) 20%				
Pubescent wheatgrass	4.9	4.9	9.0	11.2
Tall wheatgrass			9.0	11.2
Spring wheat (<i>Tritrium aestivum</i>)			84.0	84.0
Western wheatgrass	4.4	4.4		
Oats (<i>Avena satium</i>) as cover crop	11.2	11.2		

Table 5. Precipitation measured at or near the tillage plot locations.[†]

Dates [†]	Location		
	Glenharold	Center	Knife River
		(cm)	
4/28 to 10/3/88	----	12.8 (-18.8) [§]	----
4/26 to 10/9/89	14.9 ^{††} (-19.4)	24.0 (-8.6)	15.9 ^{††} (-16.2)
4/19 to 10/29/90	31.7 (-5.4)	33.8 (-2.0)	29.6 (-4.2)
4/10 to 10/28/91	29.0 (-6.7)	35.1 (-0.4)	25.0 (-10.0)
4/14 to 10/19/92	22.5 (-13.5)	21.6 (-13.8)	18.9 (-14.9)

[†]No rain gauge in the Coteau location vicinity. At Center the rain gauge was approximately 1.5 km from the location.

^{††}Rain gauges were generally installed at small grain planting and removed prior to daytime temperatures remaining below freezing.

[§]Deviation from long-term average using NOAA data for the time period listed.

^{†††}Rain gauges installed May 25.

Table 6. Mean dry bulk densities from access tube installation cores for the Center tillage study location (fall, 1987)

Tillage Treatment [†]		Depth (cm)									
Topsoil	Subsoil	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150
(g/cm ³)											
<u>Topsoil Treatment[†]</u>											
CHIS		1.26	1.42	1.58	1.64	1.62	1.52	1.53	1.57	1.70	1.74
DR		1.15	1.36	1.42	1.60	1.60	1.55	1.47	1.55	1.62	1.65
GR		1.30	1.36	1.55	1.65	1.68	1.57	1.59	1.59	1.66	1.72
LSD(0.10) [‡]		0.06	NS	0.06	NS	0.05	NS	0.08	NS	NS	NS
<u>Subsoil Treatment[†]</u>											
	CHIS	1.22	1.36	1.53	1.61	1.61	1.58	1.53	1.58	1.70	1.69
	DL	1.34	1.40	1.49	1.63	1.65	1.46	1.54	1.57	1.56	1.67
	DR	1.18	1.39	1.51	1.62	1.63	1.57	1.51	1.58	1.66	1.74
	GR	1.17	1.35	1.51	1.62	1.61	1.53	1.48	1.52	1.69	1.76
	NT	1.28	1.39	1.54	1.68	1.67	1.60	1.58	1.58	1.68	1.67
LSD(0.10)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
<u>Topsoil x Subsoil Treatment[†]</u>											
CHIS	CHIS	1.18	1.39	1.57	1.59	1.57	1.62	1.60	1.59	1.69	1.68
	DL	1.34	1.43	1.52	1.66	1.60	1.26	1.48	1.56	1.64	1.78
	DR	1.31	1.43	1.56	1.70	1.66	1.59	1.49	1.58	1.67	1.71
	GR	1.26	1.41	1.64	1.61	1.59	1.52	1.48	1.50	1.73	1.80
	NT	1.23	1.43	1.62	1.67	1.70	1.60	1.59	1.61	1.74	1.76
DR	CHIS	1.21	1.35	1.43	1.55	1.56	1.46	1.36	1.49	1.70	1.67
	DL	1.35	1.36	1.39	1.58	1.60	1.60	1.54	1.51	1.44	1.53
	DR	1.00	1.39	1.41	1.60	1.60	1.53	1.46	1.58	1.64	1.80
	GR	1.10	1.34	1.42	1.63	1.59	1.52	1.41	1.53	1.68	1.71
	NT	1.11	1.33	1.46	1.64	1.66	1.64	1.58	1.62	1.63	1.53
GR	CHIS	1.26	1.35	1.59	1.68	1.69	1.65	1.62	1.68	1.71	1.71
	DL	1.34	1.42	1.56	1.65	1.75	1.52	1.62	1.65	1.60	1.69
	DR	1.23	1.34	1.56	1.56	1.63	1.56	1.60	1.58	1.69	1.72
	GR	1.16	1.30	1.47	1.64	1.65	1.56	1.55	1.52	1.66	1.77
	NT	1.49	1.40	1.54	1.72	1.66	1.56	1.59	1.51	1.65	1.71
LSD(0.10)		0.14	NS	NS	NS	NS	0.16	NS	NS	NS	NS

[†]CHIS = chiselled, DR = deep ripped (D9 bulldozer), GR = grader ripped, DL = deep lift replacement, and NT = no tillage.

[‡]15 replications for topsoil, 9 for subsoil, 3 for topsoil x subsoil.

[§]Least significant difference at the 10% level. NS indicates no significant differences between values.

Table 7. Mean dry bulk densities from access tube installation cores for the Coteau tillage study location (fall, 1987)

Tillage Treatment [†]		Depth (cm)									
Topsoil	Subsoil	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120	120-135	135-150
		(g/cm ³)									
		<u>Topsoil Treatment[†]</u>									
CHIS		1.17	1.32	1.47	1.49	1.53	1.49	1.50	1.49	1.54	1.57
DR		1.13	1.31	1.42	1.48	1.51	1.49	1.52	1.49	1.51	1.55
GR		1.25	1.43	1.45	1.51	1.48	1.50	1.48	1.52	1.54	1.56
LSD(0.10) [‡]		NS	0.10	NS	NS	NS	NS	NS	NS	NS	NS
		<u>Subsoil Treatment[†]</u>									
	CHIS	1.19	1.31	1.40	1.45	1.47	1.44	1.47	1.53	1.54	1.59
	DL	1.25	1.38	1.52	1.53	1.47	1.46	1.48	1.47	1.51	1.58
	DR	1.12	1.36	1.45	1.54	1.51	1.48	1.52	1.50	1.56	1.55
	GR	1.13	1.38	1.44	1.46	1.52	1.49	1.47	1.44	1.51	1.55
	NT	1.23	1.36	1.43	1.48	1.56	1.58	1.56	1.55	1.52	1.53
LSD(0.10)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
		<u>Topsoil x Subsoil Treatment[†]</u>									
CHIS	CHIS	1.23	1.36	1.47	1.47	1.51	1.46	1.46	1.52	1.58	1.60
	DL	1.18	1.24	1.52	1.54	1.47	1.46	1.45	1.51	1.49	1.62
	DR	1.19	1.32	1.52	1.53	1.54	1.54	1.52	1.43	1.58	1.53
	GR	1.01	1.31	1.46	1.48	1.55	1.42	1.48	1.43	1.49	1.58
	NT	1.23	1.34	1.39	1.43	1.57	1.55	1.56	1.54	1.55	1.51
DR	CHIS	1.04	1.24	1.34	1.39	1.43	1.44	1.50	1.52	1.47	1.59
	DL	1.30	1.40	1.48	1.48	1.45	1.52	1.48	1.45	1.52	1.52
	DR	1.05	1.31	1.40	1.55	1.56	1.43	1.57	1.48	1.53	1.49
	GR	1.17	1.36	1.41	1.47	1.48	1.50	1.47	1.46	1.54	1.58
	NT	1.10	1.27	1.48	1.52	1.62	1.55	1.60	1.55	1.48	1.55
GR	CHIS	1.28	1.32	1.38	1.49	1.45	1.43	1.46	1.56	1.58	1.58
	DL	1.27	1.49	1.57	1.58	1.51	1.40	1.49	1.45	1.51	1.58
	DR	1.13	1.43	1.42	1.54	1.43	1.50	1.48	1.60	1.58	1.64
	GR	1.20	1.46	1.46	1.45	1.53	1.53	1.47	1.44	1.50	1.48
	NT	1.35	1.46	1.42	1.51	1.50	1.63	1.51	1.57	1.52	1.53
LSD(0.10)		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[†]CHIS = chiselled, DR = deep ripped (subsoiler), GR = grader ripped, DL = deep lift replacement, and NT = no tillage.

[‡]15 replications for topsoil, 9 for subsoil, 3 for topsoil x subsoil.

[§]Least significant difference at the 10% level. NS indicates no significant differences between values.

Table 8. ANOVA significance summaries by sampling date for bulk density from soil coring at the Center tillage location.

Anova Variable	Year of Data [†]							
	1987C	1989R	1990P	1990R	1991P	1991R	1992P	1992R
<u>Depth: 0-0.3 m</u>								
Topsoil Tillage (Top)		* [†]			***			
Subsoil Tillage (Sub)	**			***				**
Top x Sub	**	***						
<u>Depth: 0.3-0.6 m</u>								
Top	***	*		*	*		***	
Sub	***			***	**	**		
Top x Sub		**						*
<u>Depth: 0.6-0.9 m</u>								
Top		ND [§]	ND			**		
Sub		ND	ND		*			
Top x Sub		ND	ND			**	**	
<u>Depth: 0.9-1.2 m</u>								
Top		ND	ND			ND	***	
Sub		ND	ND		**	ND		
Top x Sub		ND	ND			ND		

[†]C = access tube installation, P = penetrometer cores, and R = root cores.

*[†], **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate levels greater than P = 0.10.

[§]No data or insufficient data for analysis.

Table 9. ANOVA significance summaries by sampling date for bulk density from soil coring at the Coteau tillage location.

ANOVA Variable	Year of Data [†]					
	1987C	1989R	1990P	1990R	1991P	1991R
			<u>Depth: 0-0.3m</u>			
Topsoil Tillage (Top)	*** [†]	***		**		
Subsoil Tillage (Sub)						
Top x Sub						
			<u>Depth: 0.3-0.6m</u>			
Top	**					
Sub					**	
Top x Sub	**					
			<u>Depth: 0.6-0.9m</u>			
Top	***	ND ^δ				
Sub		ND			*	
Top x Sub		ND				***
			<u>Depth: 0.9-1.2m</u>			
Top		ND				ND
Sub	***	ND			*	ND
Top x Sub		ND				ND

[†]C = access tube installation, P = penetrometer cores (spring), and R = root cores (fall).

** , * , and *** indicate significant at the P = 0.10, 0.05, and 0.10 levels, respectively. Blanks indicate levels greater than P = 0.10.

^δNo data or insufficient data for analysis.

Table 10. ANOVA summaries with time for core bulk density values at the Center and Coteau locations.

ANOVA Variable	Profile Depth (m)			
	0-0.3	0.3-0.6	0.6-0.9	0.9-1.2
<u>Center Location [†]</u>				
Year of Data (Yr)	* [†]	*	*	*
Topsoil Tillage (Top)	*	*	*	**
Subsoil Tillage (Sub)	*	*	*	*
Yr x Top			**	**
Yr x Sub			**	
Top x Sub		**	*	**
Yr x Top x Sub		**	**	**
<u>Coteau Location[†]</u>				
Yr	*	***	*	**
Top	**		***	
Sub	*	**	*	*
Yr x Top	**		***	
Yr x Sub	*	*	*	*
Top x Sub				
Yr x Top x Sub				

[†]*, **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate levels greater than P = 0.10.

[†]Data from 1987 through 1992 for Center, 1987 through 1991 for Coteau.

Table 11. ANOVA significance summaries by year and tillage depths for mean cone index values at the Center and Coteau locations.

ANOVA Variable	Profile Depth (cm)									
	0-15	15-30	30-35	35-50	50-65	65-100	0-20	20-100		
	<u>Center Location</u>					<u>Deep Rip Plots[†]</u>				
	<u>1990</u>									
Topsoil Tillage (Top)			***	*		ND [‡]		**		
Subsoil Tillage (Sub)	***	***	***			ND				
Top x Sub						ND				
	<u>1991</u>									
Top	***	**	*	*				*		
Sub	***									
Top x Sub								*		
	<u>1992</u>									
Top		**	*	**				*		
Sub				*						
Top x Sub										
	<u>Profile Depth (cm)</u>									
	0-15	15-40	40-56	56-73	73-85	85-100	0-20	20-60	60-100	
	<u>Coteau Location</u>					<u>Deep Rip Plots</u>				
	<u>1990</u>									
Top		*				*		*		
Sub						***				
Top x Sub						**				
	<u>1991</u>									
Top		*						**		
Sub		***	**							
Top x Sub					***					

[†]Comparison of between and within shank tracks of this topsoil tillage treatment only.

^{**}, ^{*}, and ^{***} indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate levels greater than P = 0.10.

[‡]No data or insufficient data for analysis.

Table 12. ANOVA significance summaries for cone index values by tillage depth over years at the Center tillage location.

ANOVA Factor	Profile Depth (cm)					
	0-15	15-30	30-35	35-50	50-65	65-100
Year (Yr)	*†	**	***	*	***	
Subsoil Tillage (Sub)				*	***	
Topsoil Tillage (Top)		*	*	*		
Yr x Sub				*		
Top x Sub		***				
Yr x Top					***	
Yr x Top x Sub						

<u>Deep Rip Topsoil Plots Only[†]</u>		
	Profile Depth (cm)	
	0-20	20-100
Yr	*	*
Sub		
Top		*
Yr x Sub		
Top x Sub		**
Yr x Top		*
Yr x Top x Sub		

†*, **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate significance levels greater than P = 0.10.

†Comparison of within versus between shank tracks.

Table 13. ANOVA significance summaries for cone index values by tillage depth over years at the Coteau tillage location.

ANOVA Factor	Profile Depth (cm)					
	0-15	15-40	40-56	56-73	73-85	85-100
Year (Yr)	**+	**	**	*	***	**
Subsoil Tillage (Sub)			**			
Topsoil Tillage (Top)		*				
Yr x Sub						
Top x Sub					***	
Yr x Top						
Yr x Top x Sub						

	Deep Rip Topsoil Plots Only ⁺		
	Profile Depth (cm)		
	0-20	20-60	60-100
Yr	*	**	**
Sub			
Top		*	
Yr x Sub			
Top x Sub			
Yr x Top			
Yr x Top x Sub			

+*, **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate significance levels greater than P = 0.10.

⁺Comparison of within versus between shank tracks.

Table 14. Correlation/regression analyses of mean cone index values for topsoil and subsoil over years at Center and Coteau.[†]

Topsoil [†]		Subsoil [§]	
Variable	Coefficient	Variable	Coefficient
<u>Center Location</u>			
Intercept	- 6.02	Intercept ^{††}	- 4.51
DBD	55.90	DBD	11.82
WBD	-44.76	CLAY	- 0.29
	N = 238 R ² = 0.26		N = 311 R ² = 0.16
<u>Coteau Location</u>			
Intercept	-17.32	Intercept	7.84
DBD	28.88	DBD	4.32
VFS	0.79	GRAVPC	- 0.20
CLAY	0.43	SILT	- 0.11
WBD	-23.09		
	N = 180 R ² = 0.41		N = 348 R ² = 0.10
<u>Combined Locations</u>			
Intercept	- 9.80	Intercept	- 6.33
DBD	83.23	DBD	16.80
WBD	-70.77	WBD	- 8.47
GRAVPC	- 0.62	SAND	0.07
	N = 418 R ² = 0.36		N = 659 R ² = 0.14

[†]Mean values for 15 cm segments. Model form: Cone Index (MPa) = ax+...+ intercept. Unless otherwise noted, all variables are significant at the P = 0.10 level.

[†]0 to 30 cm depth.

[§]30 to 105 cm depth.

*DBD = dry bulk density, WBD = wet bulk density, VFS = % very fine sand, CLAY = % clay, GRAVPC = % gravimetric soil water, SILT = % silt, and SAND = % sand.

^{††}Variable not significant at the P = 0.10 level.

Table 15. Correlation/regression analyses of mean cone index values to physical parameters at the tillage locations.[†]

Location					
Center		Coteau		Combined Locations	
Variable [‡]	Coefficient	Variable	Coefficient	Variable	Coefficient
<u>1990 Data</u>					
Intercept [§]	- 0.66	Intercept	23.47	Intercept	23.06
DBD	5.92	DBD	5.94	DBD	5.99
VFSSILT	- 0.07	GRAVPC	- 0.17	GRAVPC	- 0.20
		VFS	0.24	SAND	- 0.24
		SAND	- 0.26	SILT	- 0.40
		SILT	- 0.45		
N = 174		N = 238		N = 412	
R ² = 0.29		R ² = -0.66		R ² = 0.49	
<u>1991 Data</u>					
Intercept	-13.62	Intercept	39.02	Intercept [§]	6.28
DBD	17.38	DBD	6.27	DBD	88.34
VFSSILT	- 0.09	GRAVPC	- 0.19	GRAVPC	-0.92
N = 217		VFSSILT	0.25	SAND	- 0.17
R ² = 0.63		SAND	- 0.39	SILT	- 0.40
		SILT	- 0.91	WBD	-71.48
		N = 290		N = 507	
		R ² = 0.51		R ² = 0.53	
<u>1992 Data</u>					
Intercept	-15.54	No Data		Same as Center	
DBD	14.77				
GRAVPC	- 0.50				
SAND	0.11				
N = 158					
R ² = 0.59					
<u>Over Years</u>					
Intercept [§]	- 0.69	Intercept	37.48	Intercept	15.20
DBD	10.84	DBD	5.27	DBD	9.71
GRAVPC	- 0.25	GRAVPC	- 0.28	SAND	- 0.16
VFSSILT	- 0.13	VFSSILT	0.20	SILT	- 0.38
		SAND	- 0.36	VOLPC	- 0.16
		SILT	- 0.80		
N = 549		N = 528		N = 1077	
R ² = 0.42		R ² = 0.51		R ² = 0.44	

[†]Using mean values for 15 cm segments to 105 cm. Equation form: Cone Index (MPa) = ax+...+ intercept.

[‡]DBD = dry bulk density (g/cm³), VFSSILT = % very fine sand + % silt, GRAVPC = % gravimetric moisture, VOLPC = % volumetric moisture, VFS = % very fine sand, SAND = % sand, and SILT = % silt.

[§]Variable not significant at the P = 0.10 level.

Table 17. ANOVA summary with time for alfalfa root length density at the two topsoil/subsoil tillage locations.

ANOVA Factor	Profile Depth (cm)							
	5-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120
	<u>Center Location</u>							
Year (Yr)	†	*	*			***	*	*
Subsoil Tillage (Sub)	***				**	***		
Topsoil Tillage (Top)								
Yr x Sub	**				**			***
Yr x Top								
Sub x Top								
Yr x Sub x Top								
	<u>Coteau Location</u>							
Yr	**	**	**					
Sub				**	*	**		
Top			**	*				
Yr x Sub				***	*	**		
Yr x Top	**			**				
Sub x Top		***	**					
Yr x Sub x Top			***	**				

†, **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate P levels greater than 0.10.

Table 18. ANOVA summary with time for alfalfa root mass at the two topsoil/subsoil tillage locations.

ANOVA Factor	Profile Depth (cm)							
	0-15	15-30	30-45	45-60	60-75	75-90	90-105	105-120
	<u>Center Location</u>							
Year (Yr)	*+	*	*			***	**	**
Subsoil Tillage (Sub)	*					*		
Topsoil Tillage (Top)								
Yr x Sub	***					*		
Yr x Top								
Sub x Top		**						
Yr x Sub x Top		***						
	<u>Coteau Location</u>							
Yr	*	**	***			**		
Sub	**			***	*	***		
Top		**	**					
Yr x Sub	***					*		
Yr x Top								
Sub x Top		**						
Yr x Sub x Top	**							

+*, **, and *** indicate significance at the P = 0.01, 0.05, and 0.10 levels, respectively. Blanks indicate P levels greater than 0.10.

Table 19. Coefficients of determinations regressing root length density versus bulk density or mean cone index values by depth at the topsoil/subsoil tillage locations.[†]

Profile Depth (cm)	N [‡]	Independent Variable			
		Bulk Density		Cone Index	
		Linear	Quadratic	Linear	Quadratic
<u>Center Location</u>					
5-15	16	0.36	0.36	<0.01	0.09
15-30	15	<0.01	0.12	0.01	0.02
30-45	15	0.03	0.05	0.16	0.16
45-60	9	0.06	0.20	0.04	0.33
60-75	6	0.01	0.12	0.10	0.36
75-90	6	0.80	0.83	0.50	0.65
90-105	5	0.06	0.23	0.09	0.24
<u>Coteau Location</u>					
5-15	30	0.19	0.19	<0.01	0.02
15-30	30	0.01	0.13	0.03	0.06
30-45	30	0.15	0.16	0.24	0.42
45-60	28	<0.01	<0.01	<0.01	<0.01
60-75	17	<0.01	0.03	<0.01	<0.01
75-90	4	0.88	0.99	0.26	0.72

[†]Using 1992 data from Center, 1991 data from Coteau.

[‡]Number of samples in model.

Table 20. Least significant difference ($P = 0.10$) among mean soil bulk densities obtained from access tube installation at the Glenharold and Knife River tillage location, spring, 1989.

Main Effect	Depth (cm)				
	0-0.3	0.3-0.6	0.6-0.9	0.9-1.2	1.2-1.5
	(Mg m ⁻³)				
	<u>Glenharold</u>				
Tillage	NS	NS	NS	NS	NS
Crop	NS	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	NS	NS
	<u>Knife River</u>				
Tillage	NS	NS	0.01	NS	NS
Crop	NS	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	NS	NS

NS indicates no significant difference.

Table 21. Least significant difference ($P = 0.10$) among mean soil bulk densities obtained during access tube installation (1989) and penetrometer measurements (1990-1992) from the Glenharold and Knife River tillage locations.

Main Effect	Year			
	1989	1990	1991	1992
(Mg m ⁻³)				
Glenharold				
<u>Depth = 0.0 - 0.3 m</u>				
Tillage	NS	NS	0.08	NS
Crop	NS	NS	NS	NS
Tillage x Crop	NS	NS	0.10	NS
<u>Depth = 0.3 - 0.6 m</u>				
Tillage	NS	NS	NS	NS
Crop	NS	NS	NS	NS
Tillage x Crop	NS	0.07	NS	NS
<u>Depth = 0.6 - 0.9 m</u>				
Tillage	NS	NS	NS	NS
Crop	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	NS
Knife River				
<u>Depth = 0.0 - 0.3 m</u>				
Tillage	NS	0.06	NS	NS
Crop	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	NS
<u>Depth = 0.3 - 0.6 m</u>				
Tillage	NS	NS	NS	NS
Crop	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	NS
<u>Depth = 0.6 - 0.9 m</u>				
Tillage	NS	NS	NS	0.02
Crop	NS	NS	NS	NS
Tillage x Crop	NS	NS	NS	0.16

NS indicates no significant difference.

Table 22. Least significant differences ($P = 0.10$) among mean cone indices from the Glenharold tillage location.

Main Effects	Depth (m)				
	0.05	0.25	0.45	0.65	0.85
Year	0.32	0.63	0.45	NS	1.09
Tillage	NS	0.57	0.91	NS	NS
Year x Tillage	NS	NS	NS	NS	NS
Crop	0.24	0.72	NS	1.11	NS
Year x Crop	0.47	1.38	2.02	NS	NS
Tillage x Crop	0.34	NS	NS	NS	NS
Year x Tillage x Crop	NS	NS	NS	NS	NS

NS indicates no significant difference.

Table 23. Least significant differences ($P = 0.10$) among mean cone indices from the Knife River tillage location.

Main Effects	Depth (m)				
	0.05	0.25	0.45	0.65	0.85
Year	0.39	NS	NS	0.97	0.93
Tillage	NS	1.29	0.82	NS	NS
Year x Tillage	NS	NS	NS	NS	NS
Crop	0.32	1.21	1.82	1.30	1.75
Year x Crop	0.61	NS	NS	NS	3.18
Tillage x Crop	NS	NS	NS	NS	NS
Year x Tillage x Crop	NS	NS	NS	NS	NS

NS indicates no significant difference.

Table 24. Results of regressions of mean cone indices to mean soil physical parameters from the Glenharold and Knife River locations.

Parameter	Coefficient	
<u>Glenharold (n = 216)</u>		
Intercept	- 3.63	R ² = 0.54
Soil Dry Bulk Density (Mg m ⁻³)	8.86	
Gravimetric Water Content (kg kg ⁻¹)	-30.35	
<u>Knife River (N = 206)</u>		
Intercept	- 5.93	R ² = 0.32
Soil Dry Bulk Density (Mg m ⁻³)	11.28	
Gravimetric Water Content (kg kg ⁻¹)	-34.25	

Table 25. Least significant differences (P = 0.10) among mean wheat yields from the Glenharold and Knife River tillage locations.

Main Effect	Glenharold	Knife River
	(Mg ha ⁻¹)	
Year	0.17	0.07
Tillage	NS	0.05
Year x Tillage	NS	0.11

NS indicates no significant difference

Table 26. Least significant difference ($P = 0.10$) between mean wheat yields by tillage from the Glenharold and Knife River tillage locations.

Location	Year			
	1989	1990	1991	1992
	(Mg ha ⁻¹)			
Glenharold	NS	NS	NS	0.05
Knife River	0.11	NS	0.12	NS

NS indicates no significant difference.

Table 27. Least significant differences ($P=0.10$) among mean wheat yields grown on prior-cropping strips from the Glenharold and Knife River tillage locations.

Main Effects	Glenharold	Knife River
	(Mg ha ⁻¹)	
Tillage	NS	NS
Prior Crop	0.22	0.13
Tillage x Prior Crop	NS	0.19

NS indicates no significant difference.

Table 28. Mean soil fertility at planting (June 1989) and at time of prior cropping strip installation (October, 1991) from the Knife River and Glenharold locations.

Crop	Depth (cm)	N	P	K
(kg/ha)				
<u>Knife River - June 1989</u>				
Small Grain	0-15	116	25	330
	15-60	171		
Forages	0-15	120	105	364
	15-60	171		
<u>October 1991</u>				
Small Grain	0-15	31	23	403
	15-60	193		
Alfalfa	0-15	26	19	336
	15-60	47		
Native Mix	0-15	11	19	370
	15-60	34		
Precrop Mix	0-15	18	17	330
	15-60	74		
Pubescent Wheatgrass	0-15	10	17	347
	15-60	67		
Tall Wheatgrass	0-15	16	18	342
	15-60	86		
<u>Glenharold - June, 1989</u>				
Small Grain	0-15	181	18	431
	15-60	114		
Forages	0-15	160	54	431
	15-60	114		
<u>October 1991</u>				
Small Grain	0-15	74	16	465
	15-60	137		
Alfalfa	0-15	26	8	476
	15-60	31		
Native Mix	0-15	21	9	543
	15-60	22		
Precrop Mix	0-15	23	9	510
	15-60	68		
Pubescent Wheatgrass	0-15	17	9	521
	15-60	26		
Tall Wheatgrass	0-15	22	10	482
	15-60	27		

[†]Small grains were fertilized annually as needed to produce 2.7 Mg/ha yields. Forages were not fertilized after June 1989, and remaining forages were harvested annually after yield samples were taken.

Table 29. Least significant differences ($P = 0.10$) between tillage treatment mean forage yields from the Glenharold and Knife River tillage locations.

Location	Year		
	1990	1991	1992
	(Mg ha ⁻¹)		
	<u>Alfalfa</u>		
Glenharold	NS	NS	NS
Knife River	NS	NS	NS
	<u>Native Mix</u>		
Glenharold	NS	NS	NS
Knife River	NS	NS	NS
	<u>Precrop Mix</u>		
Glenharold	NS	NS	0.27
Knife River	NS	NS	NS
	<u>Pubescent Wheatgrass</u>		
Glenharold	NS	NS	NS
Knife River	NS	NS	NS
	<u>Tall Wheatgrass</u>		
Glenharold	NS	NS	NS
Knife River	NS	NS	NS

Table 30. Least significant difference ($P = 0.10$) among mean root length and mass densities from the Glenharold tillage location.

Main Effects	Depth (m)				
	0-0.15	0.3-0.45	0.6-0.75	0.9-1.05	1.2-1.35
<u>Root Length Densities</u>					
Year	0.6	0.3	0.1	<0.1	<0.1
Tillage	0.3	0.2	NS	NS	NS
Year x Tillage	0.7	NS	0.1	0.1	NS
Crop	0.7	0.4	0.1	0.1	<0.1
Year x Crop	1.6	1.0	0.2	0.2	0.1
Tillage x Crop	1.0	0.5	0.1	NS	NS
Year x Tillage x Crop	NS	1.2	0.3	0.3	NS
<u>Root Mass Densities</u>					
Year	<0.01	<0.01	<0.01	<0.01	<0.01
Tillage	<0.01	<0.01	NS	NS	NS
Year x Tillage	<0.01	<0.01	<0.01	<0.01	NS
Crop	<0.01	<0.01	<0.01	<0.01	NS
Year x Crop	<0.01	<0.01	<0.01	<0.01	<0.01
Tillage x Crop	<0.01	<0.01	<0.01	<0.01	NS
Year x Tillage x Crop	<0.01	<0.01	<0.01	<0.01	NS

NS indicates no significant difference.

Table 31. Least significant difference (P = 0.10) among mean root length and mass densities from the Knife River tillage location.

Main Effects	Depth (m)				
	0-0.15	0.3-0.45	0.6-0.75	0.9-1.05	1.2-1.35
<u>Root Length Densities</u>					
Year	0.8	0.2	0.1	0.1	0.1
Tillage	NS	0.1	0.1	<0.1	<0.1
Year x Tillage	0.4	0.2	0.1	0.1	0.1
Crop	0.6	0.2	0.1	0.1	0.1
Year x Crop	1.5	0.4	0.3	0.1	0.1
Tillage x Crop	0.9	0.2	0.2	0.1	0.2
Year x Tillage x Crop	2.1	0.5	0.4	0.2	0.5
<u>Root Mass Densities</u>					
Year	<0.01	<0.01	<0.01	<0.01	<0.01
Tillage	<0.01	<0.01	<0.01	<0.01	<0.01
Year x Tillage	<0.01	<0.01	NS	<0.01	<0.01
Crop	<0.01	<0.01	<0.01	<0.01	<0.01
Year x Crop	<0.01	<0.01	<0.01	<0.01	<0.01
Tillage x Crop	<0.01	NS	<0.01	<0.01	<0.01
Year x Tillage x Crop	<0.01	NS	<0.01	<0.01	<0.01

NS indicates no significant difference.

Table 32. Results of regressions of mean root length and mass densities on soil physical properties from the Glenharold and Knife River tillage locations.

Parameter	Coefficient	
Glenharold		
Root Length Density (km m⁻³)		
Intercept	85.1	R ² = 0.33
Cone Index (MPa)	- 3.1	
Wet Bulk Density (Mg m ⁻³)	-34.5	
Root Mass Density (kg m⁻³)		
Intercept	23.8	R ² = 0.11
Cone Index (MPa)	- 1.0	
Wet Bulk Density (Mg m ⁻³)	- 9.8	
Knife River		
Root Length Density (km m⁻³)		
Intercept	86.3	R ² = 0.23
Cone Index (MPa)	- 1.0	
Wet Bulk Density (Mg m ⁻³)	-35.9	
Root Mass Density (kg m⁻³)		
Intercept	28.1	R ² = 0.07
Cone Index (MPa)	- 0.3	
Wet Bulk Density (Mg m ⁻³)	-12.0	

Table 33. Least significant difference (P = 0.10) among mean soil bulk densities obtained in 1979 and 1990 from the Falkirk trench location.

Main Effect	Depth (m)			
	0-0.3	0.3-0.6	0.6-0.9	0.9-1.2
	(Mg m ⁻³)			
Year	NS	NS	NS	NS
Topsoil Depth	NS	0.03	NS	NS
Year x Topsoil Depth	NS	0.04	NS	NS
Subsoil	0.08	0.10	0.13	NS
Year x Subsoil	0.11	NS	NS	0.25
Topsoil Depth x Subsoil	0.15	NS	NS	NS
Year x Topsoil Depth x Subsoil	NS	NS	NS	NS

NS indicates no significant difference.

Table 34. Least significant difference ($P = 0.10$) among mean soil bulk densities from the Center and Falkirk topography locations.

Main Effect	Depth (m)				
	0-0.3	0.3-0.6	0.6-0.9	0.9-1.2	1.2-1.5
(Mg m ⁻³)					
Center					
<u>Forage Area</u>					
Year	NS	0.08	NS	NS	0.02
Position	NS	NS	NS	NS	NS
Year x Position	0.10	NS	NS	NS	NS
<u>Small Grain Area</u>					
Year	0.04	NS	NS	0.14	NS
Position	NS	0.12	NS	NS	NS
Year x Position	NS	NS	NS	NS	NS
Falkirk					
<u>Forage Area</u>					
Year	NS	0.02	NS	0.12	NS
Position	NS	NS	0.15	NS	NS
Year x Position	NS	NS	NS	NS	NS
<u>Small Grain Area</u>					
Year	NS	NS	0.11	0.16	NS
Position	NS	0.14	0.14	0.07	NS
Year x Position	NS	NS	NS	NS	NS

NS indicates no significant difference.