Dickinson Research Extension Center

NORTH DAKOTA STATE UNIVERSITY

Annual Research

December 2025

NDSU NORTH DAKOTA STATE UNIVERSITY

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2025 Winter Wheat - Recrop											Dickinson, ND
		Seeds					--------- Grain Yield---------			Average Yield	
	Heading	per	KWT	Plant	Test					2	3
Variety	Date	Pound	(g/1000)	Height	Weight	Protein	2023	2024	2025	Year	Year
	Julian			in	lbs/bu	%	-----bu/ac-----			bu/ac	bu/ac
AAC Coldfront	172	13,266	34.3	33.5	62.1	11.7	--	74.2	102.3	88.2	--
AAC Overdrive	171	15,262	29.8	33.2	58.6	12.5	--	81.2	95.3	88.3	--
AAC Vortex	172	13,103	34.7	35.8	61.2	12.6	47.1	71.7	99.2	85.4	72.7
AAC Wildfire	175	13,096	34.6	35.6	60.5	12.4	55.8	70.9	100.5	85.7	75.7
AAC Goldrush	174	14,849	30.5	34.5	60.1	12.4	47.5	70.4	93.0	81.7	70.3
AC Emerson	173	15,372	29.5	38.9	61.7	12.9	40.2	63.4	88.8	76.1	64.1
CS Bridger CLP	171	17,142	26.4	30.4	57.0	12.6	--	--	85.7	--	--
Jerry	172	12,573	36.1	43.4	60.2	12.7	42.3	54.7	92.6	73.7	63.2
LCS Steel AX	170	14,107	32.2	32.4	59.4	11.3	--	88.3	97.4	92.9	--
MS Maverick	170	12,603	36.0	31.3	59.7	12.8	32.4	78.9	75.7	77.3	62.3
ND Allison	173	14,334	31.6	36.6	61.1	11.6	48.8	88.1	98.7	93.4	78.5
ND Noreen	171	11,505	39.2	37.3	62.9	12.7	52.1	53.8	100.5	77.1	68.8
Northern	173	14,736	30.9	34.3	58.2	12.5	54.7	87.6	91.2	89.4	77.8
SD Vivian	171	13,697	33.1	34.4	60.2	12.5	--	--	107.5	--	--
SD Andes	171	13,612	33.4	34.0	61.5	12.2	56.6	99.3	96.1	97.7	84.0
SD Midland	170	12,120	37.6	34.4	61.5	11.8	47.9	86.9	98.5	92.7	77.8
SD Pheasant	170	12,196	37.3	34.5	60.9	12.7	37.7	70.7	106.8	88.7	71.7
SY Monument	170	13,915	32.6	32.2	58.6	11.8	32.3	64.4	97.3	80.8	64.7
WB4422	169	13,527	33.6	32.5	60.2	12.5	--	86.7	94.1	90.4	--
WB4540	169	13,743	33.2	32.3	58.7	11.9	--	--	96.7	--	--
Winner	169	12,632	36.0	30.0	59.9	12.4	37.0	83.4	90.9	87.1	70.4
Trial Mean	171	13,594	33.7	34.4	60.1	12.3	41.0	77.4	96.1	--	--
CV %	0.8	4.4	5.0	7.1	0.8	2.5	15.0	11.1	6.0	--	--
LSD 0.10	1	554	1.6	2.2	0.4	0.3	7.3	7.8	5.4	--	--

Planting Date: September 20, 2024
Harvest Date: August 13, 2025
Protein adjusted to 12% moisture
Previous Crop: Cover crop for hay
Seeding Rate: 1.2 million live seeds/ac

2025 Barley - Recrop	Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	% Plump	------- Grain Yield-------- 2023	2024	2025	Average Yield 2 Year	3 Year
			in	lbs/bu	%	>6/64	----------bu/ac---------			----bu/ac----	
Six Row											
ND Treasure	71	11,953	28	48.0	11.6	93	62.6	91.1	120.6	105.9	91.5
Tradition	69	11,565	31	49.5	12.5	94	57.6	87.8	105.2	96.5	83.5
Two Row											
ND Genesis	72	10,135	30	50.3	10.9	95	70.5	88.3	123.0	105.7	94.0
AAC Synergy	71	9,836	30	49.9	11.9	95	65.1	79.3	122.4	100.8	88.9
CDC Churchill	75	10,355	29	49.9	11.9	92	--	--	134.9	--	--
CDC Fraser	76	10,207	30	48.7	11.2	95	62.9	72.4	129.9	101.2	88.4
Explorer	75	9,668	25	49.4	11.3	93	63.4	89.5	129.4	109.4	94.1
Brewski	74	9,832	29	49.6	11.3	95	67.0	90.6	130.7	110.6	96.1
AAC Prairie	75	10,862	30	49.9	12.0	91	66.7	67.4	120.3	93.9	84.8
ABI Cardinal	74	10,438	30	49.4	11.8	95	64.3	73.5	118.7	96.1	85.5
Firefoxx	75	10,157	24	46.9	10.1	91	--	--	129.6	--	--
Trial Mean	72	10,096	28	49.1	11.5	94	63.1	84.2	124.5	--	--
CV %	1.8	2.3	7.1	0.7	4.0	0.9	11.4	7.4	6.1	--	--
LSD 0.10	1	212	2	0.3	0.4	1	6.6	5.8	7.1	--	--

Planting Date: April 10, 2025
Harvest Date: August 6, 2025
Previous Crop: oat hay
Seeding Rate: 1.2 million live seeds/ac
Grain protein percentages reported on a 0% moisture basis

2025 Durum - Recrop	Dickinson, ND

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Protein	2023	2024	2025	Average Yield 2 Year	Average Yield 3 Year
						--------- Grain Yield---------				
			in	lbs/bu	%	----------bu/ac----------			----bu/ac----	
Maier	72	12,629	32	60.9	13.5	48.1	63.7	72.1	67.9	61.3
Mountrail	74	13,299	34	60.6	12.7	58.2	65.8	77.8	71.8	67.2
Alkabo	73	12,441	32	61.1	13.0	56.9	58.7	80.4	69.5	65.3
Divide	73	12,141	31	61.1	13.0	51.8	61.5	73.8	67.7	62.4
Carpio	75	11,245	35	61.9	13.2	57.1	60.2	81.2	70.7	66.2
Joppa	73	12,004	32	61.1	12.6	49.2	59.7	80.0	69.8	62.9
ND Grano	74	12,877	33	61.3	13.7	57.6	61.0	77.4	69.2	65.3
ND Riveland	74	11,636	35	60.8	13.2	48.2	58.5	77.9	68.2	61.5
ND Stanley	74	11,858	32	61.5	13.7	54.3	61.5	78.4	70.0	64.7
Strongfield	74	11,560	32	60.9	14.2	47.4	57.7	78.3	68.0	61.1
AAC Spitfire	74	12,693	31	59.5	13.8	--	--	77.8	--	--
CDC Defy	72	12,399	37	61.6	13.5	--	62.5	83.8	73.1	--
AAC Stronghold	72	12,118	32	61.1	14.4	--	59.3	77.7	68.5	--
MT Blackbeard	74	11,092	37	61.2	14.1	45.4	60.5	79.3	69.9	61.7
TCG Bright	73	13,755	32	60.8	13.2	--	--	80.7	--	--
Trial Mean	74	11,975	33	61.1	13.6	52.9	61.0	78.6	--	--
CV %	1.2	6.4	5.3	0.5	3.8	11.1	5.5	6.1	--	--
LSD 0.10	1	703	2	0.3	0.5	5.3	3.1	4.4	--	--

Planting Date: April 9, 2025
Harvest Date: August 12, 2025
Previous Crop: oat hay
Seeding Rate: 1.2 million live seeds/ac

2025 Field Pea - Recrop														Dickinson, ND

Variety	Brand	Days to Flower	Days to Mature	1000 Seed Weight	Seeds per Pound	Plant Height	Test Weight	Protein	--Grain Yield-- 2023	2024	2025	Average Yield 2 Year	3 Year
				gm		in	lbs/bu	%	--------bu/ac--------			--bu/ac--	
Yellow Types													
DS Admiral	Pulse USA	58	92	257	1,767	27	66.1	26.1	24.2	50.0	56.5	53.3	43.6
CDC Inca	Meridian Seeds	60	95	256	1,772	32	66.9	25.8	27.3	45.9	62.5	54.2	45.2
ND Dawn	NDSU	55	96	259	1,748	27	66.0	25.5	23.2	51.1	54.6	52.8	43.0
AAC Julius	NDSU	60	96	249	1,824	28	66.9	26.1	33.6	49.2	60.8	55.0	47.8
CP5222Y	Croplan	54	95	299	1,520	28	67.9	26.7	27.9	40.8	59.9	50.3	42.8
MS GrowPro	Meridian Seeds	55	96	324	1,398	28	67.0	27.1	28.9	48.0	59.3	53.7	45.4
MS Prostar	Meridian Seeds	58	95	274	1,658	27	67.6	25.6	31.5	53.9	59.6	56.8	48.3
AAC Beyond	Meridian Seeds	59	96	255	1,779	29	67.6	25.8	36.1	45.7	64.1	54.9	48.6
AAC Carver	Meridian Seeds	57	94	261	1,735	31	67.1	24.5	--	51.3	58.7	55.0	--
CDC Engage	Alliance Seeds	60	97	268	1,690	31	68.0	25.9	--	--	67.3	--	--
21162	Peterson Farms	61	97	273	1,663	30	67.2	28.4	--	--	57.2	--	--
21163	Peterson Farms	61	98	261	1,742	28	66.7	28.2	--	--	57.3	--	--
GTPR004	GeneTech	60	97	259	1,754	27	67.1	26.5	--	51.0	57.3	54.2	--
GTPR005	GeneTech	59	96	258	1,761	27	66.9	26.4	--	53.5	58.2	55.9	--
GTPR007	GeneTech	60	96	272	1,667	29	68.0	25.9	--	--	61.3	--	--
Orchestra	Premier Genetics	54	97	304	1,491	29	68.1	27.7	25.3	53.4	65.4	59.4	48.0
PG Bank	Premier Genetics	59	97	267	1,700	27	67.1	26.4	--	--	54.5	--	--
PG Cash	Premier Genetics	57	92	276	1,646	27	66.9	26.7	35.2	51.1	64.4	57.7	50.2
PG Prairie	Premier Genetics	59	97	281	1,613	31	68.4	25.7	--	38.8	57.4	48.1	--
Green Types													
PG Greenback	Premier Genetics	60	96	264	1,720	31	67.5	24.8	33.0	49.9	66.1	58.0	49.6
Aragorn	Pulse USA	54	92	238	1,904	25	65.1	27.1	21.6	37.2	48.0	42.6	35.6
Arcadia	Pulse USA	58	94	232	1,952	25	66.5	25.5	25.5	45.6	59.1	52.3	43.4
ND Victory	NDSU	58	100	228	1,990	33	66.3	26.0	24.5	23.0	54.7	38.9	34.1
Trial Mean		58	96	260	1,756	28	67.0	26.3	27.9	46.8	59.0	--	--
CV %		2.4	0.7	1.6	1.6	7.2	0.5	1.4	9.1	7.7	5.2	--	--
LSD 0.10		1	1	4	26	2	0.3	0.3	2.0	3.3	2.8	--	--

Planting Date: April 23, 2025
Harvest Date: August 6, 2025
Previous Crop: oat hay
Seeding Rate: 325,000 live seeds/ac
Grain protein percentages reported on 0% moisture basis

2025 Flax - Recrop	Dickinson, ND

Variety	Days to Flower	Days to Mature	Plant Height	Test Weight	Oil Content	-- Grain Yield-- 2023	2024	2025	Average Yield 2 Year	3 Year
			in	lbs/bu	%	------bu/ac------			----bu/ac----	
AAC Marvelous	59	103	24	54.7	38.0	28.4	22.7	38.2	30.5	29.8
CDC Glass	58	99	26	53.9	37.0	28.4	21.8	39.0	30.4	29.8
CDC Kernen	56	96	25	54.6	37.9	31.5	20.7	37.9	29.3	30.0
CDC Neela	57	100	26	54.6	37.4	29.0	21.3	37.9	29.6	29.4
CDC Rowland	58	99	25	54.7	36.8	28.5	21.5	34.9	28.2	28.3
ND Hammond	58	100	25	54.3	36.2	27.2	19.1	34.4	26.8	26.9
Webster	56	98	26	54.8	36.9	27.1	19.9	37.8	28.8	28.3
York	55	100	27	54.6	37.1	26.6	18.7	40.9	29.8	28.7
AAC Bright	57	98	25	53.2	36.9	24.2	22.1	36.8	29.4	27.7
CDC Dorado	54	99	24	54.1	37.9	25.8	20.6	27.2	23.9	24.5
Carter	56	99	24	55.0	36.3	27.6	20.2	30.3	25.2	26.0
Gold ND	56	101	26	54.8	35.6	29.1	19.7	34.6	27.2	27.8
Omega	55	98	25	55.0	35.5	25.2	20.5	33.5	27.0	26.4
Trial Mean	57	100	25	54.5	36.9	28.1	20.6	36.1	--	--
CV %	1.6	2.5	6.1	0.4	1.1	12.3	10.6	10.0	--	--
LSD 0.10	1	3	2	0.2	0.4	3.7	2.3	3.9	--	--

Planting Date: April 29, 2025
Harvest Date: August 27, 2025
Previous Crop: oat hay
No Lodging observed
Oil content reported on 9% moisture basis

2025 New Salem Barley - Recrop					Dickinson, ND

Variety	Seeds per Pound	Test Weight	% Plump	Protein	Grain Yield
		lbs/bu	>6/64	%	bu/ac
Six Row					
ND Treasure	11,776	45.7	96	12.1	81.1
Two Row					
ABI Cardinal	9,429	48.3	98	11.8	85.4
Brewski	10,216	46.4	95	11.7	78.2
ND Genesis	9,763	46.5	96	11.2	72.4
AAC Prairie	9,917	48.7	97	12.2	73.3
AAC Synergy	9,620	48.0	98	12.6	76.4
CDC Fraser	9,325	46.7	98	13.0	75.8
Trial Mean	10,213	47.1	97	12.1	77.9
CV %	3.0	1.4	1.0	4.5	9.9
LSD 0.10	283	0.6	1	0.5	7.2

Planting Date: May 25, 2025
Harvest Date: August 19, 2025
Previous Crop: Corn
Seeding Rate: 1.2 million live seeds/ac
Grain protein percentages reported on a 0% moisture basis

2025 New Salem Spring Wheat - Recrop				Dickinson, ND

Variety	Seeds per Pound	Test Weight	Protein	Grain Yield
		lbs/bu	%	bu/ac
WB 9590	12,254	62.7	12.9	63.4
AP Elevate	13,855	62.2	12.7	62.5
AP Gunsmoke CL2	14,462	60.9	12.6	58.9
Brawn-SD	12,897	64.1	11.4	73.1
CP 3055	12,591	59.8	11.3	69.3
Enhance-SD	13,989	61.8	12.8	59.6
LCS Rimfire	12,050	62.7	12.7	61.9
MN Rothsay	14,011	62.6	12.6	63.2
MS Nova	15,112	62.8	12.5	63.5
MT Carlson	12,857	61.5	11.9	63.5
ND Heron	13,461	63.0	13.1	56.3
ND Roughrider	13,931	61.6	11.7	74.8
ND Stampede	13,466	62.0	12.3	68.2
ND Thresher	14,597	61.6	12.6	60.0
TCG Zelda	12,550	62.5	13.0	63.9
ND Nighthawk	11,608	62.6	12.5	68.8
Trial Mean	13,356	62.1	12.4	64.4
CV %	3.5	0.4	4.3	6.3
LSD 0.10	445	0.3	0.5	3.8

Planting Date: May 25, 2025
Harvest Date: August 27, 2025
Previous Crop: Corn
Seeding Rate: 1.2 million live seeds/ac

2025 Oat - Recrop **Dickinson, ND**

Variety	Days to Head	Seeds per Pound	Plant Height	Test Weight	Grain Yield 2023	Grain Yield 2024	Grain Yield 2025	Average Yield[1] 2 Year	Average Yield[1] 3 Year
			in	lbs/bu	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
AAC Douglas	77	12,066	36	36.0	172.4	123.3	188.5	155.9	161.4
Beach	77	10,373	35	39.5	123.1	120.7	149.3	135.0	131.0
CDC Endure	80	11,006	36	35.6	175.5	131.4	197.7	164.6	168.2
ND Crema (hull-less)	83	15,247	41	43.3	95.7	70.8	113.5	92.2	93.3
Deon	80	13,233	37	36.5	132.3	119.8	168.1	144.0	140.1
HiFi	81	13,529	38	36.6	145.1	121.3	164.7	143.0	143.7
Jury	79	13,278	41	36.5	138.3	128.4	190.7	159.6	152.5
Leggett	81	12,192	35	37.6	151.6	116.3	160.3	138.3	142.7
MN Pearl	79	12,365	35	36.4	155.3	117.9	171.6	144.7	148.3
ND Carson	82	12,937	36	35.7	153.8	108.5	177.2	142.9	146.5
ND Heart	78	12,780	35	37.1	124.3	112.2	157.2	134.7	131.2
ND Miller	81	12,467	37	36.8	135.0	113.8	165.7	139.7	138.2
ND Spilde	78	12,066	37	35.2	127.2	138.3	175.3	156.8	146.9
ND Williams	79	10,972	41	37.3	135.3	117.0	164.2	140.6	138.8
Newburg	76	12,624	37	36.1	160.8	127.5	162.8	145.1	150.4
Otana	78	14,329	38	37.9	122.0	127.6	172.2	149.9	140.6
Paul (hull-less)	82	17,730	39	42.9	107.5	80.2	128.9	104.5	105.5
Rockford	79	13,851	38	38.9	131.9	122.5	174.9	148.7	143.1
SD Buffalo	78	12,303	34	37.5	146.5	113.9	157.0	135.5	139.1
SD Momentum	78	13,276	45	39.2	--	114.7	183.7	149.2	--
SD Titan	77	11,635	41	39.2	--	115.1	172.4	143.7	--
Trial Mean	79	12,792	37	37.8	139.2	117.1	162.8	--	--
CV %	2.2	6.0	6.6	1.1	9.4	5.9	8.2	--	--
LSD 0.10	2	703	2	0.4	11.9	6.3	12.4	--	--

Planting Date: April 10, 2025
Harvest Date: August 15, 2025
Previous Crop: field pea
Seeding Rate: 1 million live seeds/ac

2025 Hard Red Spring Wheat - Recrop										Dickinson, ND
	Days	Seeds				------- Grain Yield-------			Average Yield[1]	
	to	per	Plant	Test					2	3
Variety	Head	Pound	Height	Weight	Protein	2023	2024	2025	Year	Year
			in	lbs/bu	%	----------bu/ac----------			----bu/ac----	
WB 9590	69	12,901	26	61.0	14.7	44.1	70.5	79.0	74.7	64.5
Sy Valda	70	13,395	32	61.6	13.8	55.6	63.1	85.5	74.3	68.1
AP Murdock	70	14,119	27	60.6	14.0	41.6	69.3	74.2	71.7	61.7
MN Torgy	70	13,422	29	61.6	14.1	53.4	66.3	83.5	74.9	67.7
Sy Ingmar	71	14,311	29	62.0	14.7	49.8	65.1	77.5	71.3	64.1
AP Smith	71	13,906	28	61.5	14.5	53.1	57.7	77.2	67.4	62.6
Faller	71	12,942	32	61.0	13.6	--	51.7	85.6	68.7	68.7
AP Dagr	71	13,459	28	60.2	13.8	--	--	80.4	--	--
AP Iconic	70	14,702	30	61.1	14.3	--	--	79.2	--	--
AP Elevate	71	13,979	31	61.4	14.4	--	67.4	80.7	74.0	--
AP Gunsmoke CL2	71	13,455	31	61.1	14.3	53.0	67.0	83.2	75.1	67.7
Ascend-SD	72	14,884	35	61.8	14.3	48.6	66.4	86.7	76.5	67.2
Brawn-SD	71	13,293	31	62.8	13.1	50.1	66.8	86.6	76.7	67.8
CP 3055	77	12,937	32	59.1	12.6	--	65.0	89.7	77.3	--
CP 3555	71	13,265	31	61.0	13.8	--	--	83.6	--	--
CP 3678	72	12,340	30	61.4	14.7	--	--	88.9	--	--
Dagmar	68	11,841	30	60.9	15.0	--	--	82.3	--	--
Driver	73	13,873	31	62.1	13.9	46.5	67.8	84.0	75.9	66.1
Enhance-SD	69	13,900	32	60.8	14.0	--	73.5	76.5	75.0	--
Lang-MN	71	14,452	31	62.2	14.6	--	--	79.7	--	--
LCS Ascent	68	14,486	31	62.0	13.3	54.3	72.9	94.1	83.5	73.8
LCS Rimfire	70	12,580	27	61.1	14.0	--	--	83.2	--	--
LCS Cannon	68	13,801	29	62.8	14.0	54.3	70.5	76.1	73.3	67.0
MN Rothsay	74	13,992	28	61.7	13.8	51.4	63.2	88.0	75.6	67.5
MS Charger	71	13,586	31	60.7	12.6	52.7	59.1	91.4	75.2	67.7
MS Cobra	71	14,876	30	61.4	14.0	45.7	71.2	84.4	77.8	67.1
MS Nova	69	15,320	31	61.6	13.8	--	70.4	86.3	78.4	--
MT Carlson	71	12,938	29	60.8	13.5	--	73.2	80.4	76.8	--
ND Frohberg	71	11,983	34	62.2	14.8	44.2	71.1	79.2	75.1	64.8
ND Heron	69	13,927	30	62.4	14.5	45.2	65.1	75.9	70.5	62.1
ND Horizon	70	13,601	30	61.1	14.6	47.0	63.2	82.0	72.6	64.1
ND Roughrider	71	14,019	31	60.7	13.3	54.1	60.9	92.7	76.8	69.2
ND Stampede	70	13,248	31	61.4	14.3	49.7	60.9	86.1	73.5	65.6
ND Thresher	73	14,042	29	60.1	14.3	46.3	57.9	77.8	67.9	60.7
PFS Muffins	71	13,095	30	61.0	13.7	--	--	91.9	--	--
PFS Rolls	71	13,263	31	60.8	13.5	--	63.0	91.7	77.3	--
PG Predator	71	14,004	29	61.3	14.5	--	--	82.0	--	--
Shelly	72	13,080	30	61.9	13.6	51.6	66.5	88.8	77.6	69.0
SY 611 CL2	70	14,326	28	62.6	14.6	49.4	69.6	80.7	75.2	66.6
TCG Arsenal	75	12,778	30	61.6	12.9	--	--	100.9	--	--
TCG Badlands	71	14,124	31	61.1	13.9	--	73.2	87.5	80.3	--
TCG-Wildcat	71	12,529	31	62.3	14.3	50.5	69.1	83.0	76.1	67.5
TCG Zelda	70	13,243	30	61.3	14.0	--	66.9	89.1	78.0	--
TW Olympic	71	13,668	32	62.2	13.7	--	--	88.7	--	--
TW Trailfire	68	14,019	32	60.8	14.3	--	--	76.0	--	--
ND Nighthawk	71	11,931	33	60.8	15.3	--	--	81.9	--	--
AAC Concord	71	12,247	35	60.1	14.3	--	--	77.0	--	--
MS Ranchero	70	13,941	30	61.2	13.2	59.4	64.9	91.5	78.2	71.9
LCS Boom	68	13,909	28	62.7	14.3	46.5	76.8	81.9	79.4	68.4
Trial Mean	71	13,477	30	61.4	14.1	49.8	65.6	83.9	--	--
CV %	1	4	6	0.6	2.9	10.3	6.3	6.2	--	--
LSD 0.10	1	545	2	0.3	0.4	4.7	3.8	4.8	--	--

Planting Date: April 9, 2025
Harvest Date: August 13, 2025
Protein adjusted to 12% moisture
Previous Crop: oat hay
Seeding Rate: 1.2 million live seeds/ac

2025 Organic Hard Red Spring Wheat - Recrop										Dickinson, ND
	Days	Seeds							Average Yield	
	to	per	Plant	Test			Grain Yield		2	3
Variety	Head	Pound	Height	Weight	Protein	2023	2024	2025	Year	Year
			in	lbs/bu	%		-----bu/ac-----		----bu/ac----	
Dagmar	58	13,716	27	59.7	11.3	16.7	19.3	32.4	25.9	22.8
Driver	62	14,770	27	60.6	10.5	18.8	15.6	37.4	26.5	23.9
Faller	62	13,932	27	58.8	10.5	21.5	16.7	33.7	25.2	24.0
Glenn	59	15,534	28	62.7	10.7	13.8	16.7	30.1	23.4	20.2
MN Torgy	59	15,694	25	59.5	11.0	16.5	17.6	28.7	23.2	20.9
ND VitPro	59	14,880	28	61.4	12.4	20.5	16.9	36.9	26.9	24.8
Shelly	62	14,674	24	59.6	10.7	14.9	16.0	39.2	27.6	23.4
Prosper	58	13,694	25	59.8	10.9	15.8	17.9	29.4	23.7	21.1
Dapps	59	15,014	33	59.0	11.8	18.8	16.0	32.8	24.4	22.5
Mida	59	12,325	35	58.8	12.4	14.3	17.5	31.6	24.6	21.1
Ceres	59	15,102	34	59.2	11.5	14.9	18.7	27.1	22.9	20.2
FBC Dylan	61	14,646	28	59.1	11.3	14.8	18.2	29.5	23.9	20.8
Red Fife	65	12,504	38	59.8	10.5	14.8	14.9	31.6	23.3	20.4
Elgin-ND	59	15,307	30	59.4	11.3	17.3	18.5	37.7	28.1	24.5
ND Heron	59	15,013	27	61.0	11.2	14.5	19.3	28.8	24.0	20.8
MN Rothsay	64	15,857	25	59.9	10.7	--	15.6	33.8	24.7	--
ND Thresher	64	16,603	25	58.9	10.8	--	15.8	28.0	21.9	--
ND Stampede	59	15,460	25	59.6	10.6	--	20.1	32.7	26.4	--
Ascend SD	63	17,583	28	60.0	10.9	--	17.7	37.3	27.5	--
Brawn SD	63	14,970	28	61.1	9.8	--	17.7	32.8	25.2	--
ND Nighthawk	61	12,499	30	59.9	10.9	--	--	32.8	--	--
ND Frohberg	62	13,569	29	60.4	11.5	11.9	16.7	35.2	26.0	21.3
Trial Mean	61	14,698	29	59.9	11.1	16.4	17.2	32.7	--	--
CV %	1.4	3.0	7.4	0.6	5.1	26.1	8.2	14.0	--	--
LSD 0.10	1	407	2	0.3	0.5	NS	1.3	4.3	--	--

Planting Date: April 25, 2025
Harvest Date: August 19, 2025
Protein adjusted to 12% moisture
Previous Crop: oat hat
Seeding Rate: 1.5 million live seeds/ac

2025 Soybean - Recrop										Dickinson, ND
Company/Brand	Variety	Maturity	Days to Mature	Plant Height	Seeds per Pound	KWT	Test Weight	Oil Content	Protein	Grain Yield
				inches		g/1000	lbs/bu	%	%	bu/ac
NDSU	ND Benson	0.4	136	28	5,190	88	56.6	18.4	29.3	30.3
NDSU	ND Dickey	0.7	140	31	4,114	111	56.8	16.4	32.4	38.8
NDSU	ND Rolette	00.9	127	28	4,811	94	57.8	18.7	29.6	41.1
NDSU	ND17009GT	00.9	127	31	3,735	122	59.1	18.4	31.1	31.1
Channel	0325RXF	0.3	134	30	3,943	115	56.5	18.2	30.2	41.3
Channel	0525RXF	0.5	138	31	4,376	104	56.5	17.9	28.6	39.1
Channel	0823RXF	0.8	141	28	4,912	93	56.8	17.1	31.0	43.4
Trial Mean			135	29	4,571	101	57.4	17.8	30.5	35.8
CV %			1.3	6.3	5.1	4.7	1.0	2.8	4.1	11.6
LSD 0.10			2	2	213	4	0.5	0.5	1.1	3.8

Planting Date: May 12, 2025
Harvest Date: October 3, 2025
Protein adjusted to 13% moisture
Oil adjusted to 13% moisture
Previous Crop: oat

2025 New Salem Soybean - Recrop								Dickinson, ND
Company/Brand	Variety	Maturity	KWT	Seeds per Pound	Test Weight	Oil Content	Protein	Grain Yield
			g/1000		lbs/bu	%	%	bu/ac
NDSU	ND17009GT	00.9	121	3,753	61.8	16.3	36.0	38.0
Channel	0325RXF	0.3	111	4,127	59.6	16.1	34.5	43.2
Channel	0525RXF	0.5	98	4,660	58.8	15.8	33.8	41.3
Channel	0823RXF	0.8	96	4,762	59.9	14.9	35.3	44.9
Trial Mean			103	4,486	59.9	15.8	34.5	40.8
CV %			6.4	6.8	0.6	3.2	2.2	9.4
LSD 0.10			6	281	0.4	0.5	0.7	3.5

Planting Date: May 5, 2025
Harvest Date: October 7, 2025
Protein adjusted to 13% moisture
Oil adjusted to 13% moisture
Previous Crop: corn

Restoration of Grassland Ecosystems to Full Functionality Requires Replacement of Traditional Grazing Practices

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Traditional grazing practices used to manage Northern Plains grasslands cause serious problems that are so common that most people consider them to be inherent characteristics of the grasslands.

The three serious problems that every grassland managed by traditional grazing practices has are low quantities of available mineral nitrogen which causes the typical reduction of grass herbage production of 49.6% below the biological production level (Wight and Black 1972, 1979). Second year grass lead tillers drop below the nutrient requirements of modern high performance cattle around late July and livestock graze forage that is deficient of nutrients for the remainder of the grazing season. Traditionally managed cows produce milk below their biological potential and their calves gain weight at rates below their genetic potentials.

In order to correct these problems, we need to know both the basic science and the applied science of grassland ecosystems. During the period from early 1970's through the 1990's, numerous laboratory physiological scientists described the basic science of the grassland ecosystem biogeochemical processes performed by rhizosphere microbes, and the basic science of the internal grass plant growth mechanisms. These breakthrough scientific discoveries were not reported on the six o'clock news nor in the farm journals, so this important information is not widely known. Unfortunately, these basic physiological scientists did not do the necessary applied science field work to determine how to actually activate the rhizosphere microbes and all of the ecosystem processes and the grass growth mechanisms. That indispensable applied science research was conducted at the NDSU Dickinson REC by the rangeland research program scientist and assistants during the 1980's and 1990's.

Traditional grazing practices typically cause the quantity of mineral nitrogen to be available at 30 lbs to 60 lbs/ac, and long-term nongrazed treatments cause the amount of mineral nitrogen to drop to 10 lbs to 30 lbs/ac. In order for Northern Plains grasslands to produce grass herbage at biological potential, the grasslands must be grazed by large graminivores, and the available mineral nitrogen must be at the threshold quantity of 100 lbs/ac or greater (Wight and Black 1972).

Since the last climate change, that occurred around 5,000 years ago (Bluemle 2000) the Northern Plains grasslands have received by deposition at least 2 lbs of nitrogen per acre per year from the effects of the high temperatures of lightning. Nitrogen from lightning has resulted in a wide range of 3 to 8 tons of nitrogen per acre, with most intact grasslands containing 5 to 6 tons of nitrogen per acre (Brady 1974). However, this high amount of nitrogen is in the form of organic nitrogen, which is not available for plant use. Intact grassland soils do not require supplemental nitrogen to be added. Grassland soils require a greater biomass of rhizosphere microbes to transform organic nitrogen into mineral nitrogen (Manske 2018).

A limiting factor for increasing the biomass of rhizosphere microbes is that they do not possess chlorophyll and even if they had access to sunlight, soil microbes cannot capture their own carbon energy. The rhizosphere microbes require an outside source that can provide large quantities of short chain carbon energy before the microbes can increase in biomass. The small amount of carbohydrate leakage from grass plant roots is not enough energy, and the very low amount of 2% to 5% carbohydrate contained in dead grass material is not enough energy to greatly increase the biomass of soil microbes.

Fortunately, the outside source of short chain carbon energy for the soil microbes is conveniently located throughout the grassland. Grass lead tillers capture and fix large quantities of surplus carbohydrate energy during the vegetative growth stages occurring in the early portion of their second year of development. However, this surplus carbohydrate energy is not naturally released into the soil. Exudation of this surplus energy requires specific partial defoliation of lead tillers by large grazing graminivores that removes only 25% to 33% of the aboveground portion of the vegetative growth of grass lead tillers after the 3.5 new leaf stage and before the flower (anthesis) stage each growing season which will slowly release sizable proportions of the lead tiller surplus carbon energy through the roots into the microbial rhizosphere surrounding the grass roots (Manske 2018).

This extremely important outside source of short chain carbon energy will facilitate the rhizosphere microbes to greatly increase their biomass and then be able to transform organic nitrogen into mineral nitrogen, within about three growing seasons, the resulting rhizosphere microbe biomass will be large enough to transform mineral nitrogen at quantities at 100 lbs/ac or greater.

The rhizosphere microorganisms are responsible for the performance of all of the ecosystem nutrient flow activities and for the biogeochemical processes that determine grassland ecosystem productivity and functionality (Coleman et al. 1983).

- Biogeochemical processes transform stored essential elements from organic forms or ionic forms into plant usable mineral forms.
- Biogeochemical processes capture replacement quantities of lost or removed major essential elements of carbon, hydrogen, nitrogen, and oxygen with assistance from active live plants and transform the replacement essential elements into storage as soil organic matter for later use.
- Biogeochemical processes decompose complex unusable organic material into compounds and then into reusable major and minor essential elements (Manske 2018).

The typical grassland problems of low grass herbage biomass production and the annual occurrence of nutrient quality deficiency of grass lead tiller forage after late July can be corrected with full activation of the four main internal grass plant growth mechanisms with partial defoliation by large grazing graminivores that remove 25% to 33% of the aboveground portion of the grass lead tillers at vegetative growth stages after the 3.5 new leaf stage and before the flower (anthesis) stage each growing season (Manske 2018).

The compensatory physiological grass growth mechanisms (McNaughton 1979, 1983, Briske 1991) give grass plants the capability to replace lost leaf and shoot biomass following partial grazing defoliation by increasing meristematic tissue activity, increasing photosynthetic capacity, inhibiting or reducing the rate of senescence, increasing the life span and leaf mass of remaining mature leaves, and increasing allocation of currently fixed carbon and available mineral nitrogen transformed by rhizosphere microbes. Fully activated growth mechanisms can produce replacement foliage at 140% of the herbage weight removed during grazing.

This increase in grass growth activity requires alternative sources of large quantities of carbon and nitrogen. Most of the nitrogen and carbon that was in the shoot is lost during partial defoliation. The preferential alternative source of nitrogen is the mineral nitrogen that has been converted from soil organic nitrogen by active rhizosphere microbes and available in the media around the roots. The alternative source of carbon is currently fixed by photosynthesis in remaining mature leaf and shoot tissue and rejuvenated portions of older leaves. The quantity of leaf area required to fix adequate quantities of carbon is 67% to 75% of the predefoliated leaf area (Manske 1999). Some of this currently fixed carbon is used to produce growth of replacement grass biomass and some of it is moved to the rhizosphere microbes for increased biomass and activity. Eventually, this carbon reaches the soil with an annual input rate of 2.5 tons C/ac.

The vegetative reproduction by tillering mechanisms (Mueller and Richards 1986, Richards et al. 1988, Murphy and Briske 1992, Briske and Richards 1994, 1995) develop secondary tiller shoots from growth of axillary buds on lead tillers. Meristematic activity in axillary buds and the subsequent development of vegetative secondary tillers is regulated by auxin, a growth-inhibiting hormone produced in the apical meristem and young developing leaves which prevents a growth hormone, cytokinin, from activation of the metabolic functions of the axillary buds. Partial defoliation by large grazing graminivores of young leaf material of grass lead tillers at vegetative growth stages temporarily reduces the production of the blockage hormone, auxin, which then allows the cytokinin synthesis or utilization in multiple axillary buds, stimulating the development of vegetative secondary tillers. Activation of secondary tillers from axillary buds on 60% to 80% of the grass lead tillers produce large quantities of vegetative tillers that have adequate nutrient quality that meet the requirements of modern beef cows from mid-July to mid-October each growing season. Vegetative tiller growth is the dominant form of grass reproduction in grasslands (Belsky 1992, Chapman and Peat 1992, Briske and Richards 1995, Chapman 1996, Manske 1999) not sexual reproduction and the development of seedlings. Recruitment of new grass plants developed from seedlings is negligible in healthy grassland ecosystems.

The precipitation water use efficiency mechanisms (Wight and Black 1972, 1979) are highly variable and do not function at an assumed fixed rate for each plant species. The factor that effects the rate of precipitation use efficiency is the quantity of available mineral nitrogen. When mineral nitrogen is available at the threshold quantity of 100 lbs/ac or greater, the grass precipitation use efficiency is fully engaged and highly effective resulting in increased grass herbage biomass production of 50.4% greater per inch of precipitation received than in grasslands with mineral nitrogen available at less than 100 lbs/ac. The efficiency of precipitation use in grass plants function at extremely low levels when mineral nitrogen is deficient below the threshold quantity of 100 lbs/ac. The level of precipitation water use efficiency determines the quantity of grass herbage biomass productivity on grassland ecosystems.

The nutrient resource uptake mechanisms (Crider 1955, Whitman 1974, Li and Wilson 1998, Kochy and Wilson 2000, Peltzer and Kochy 2001) regulate grass plant competitiveness at nutrient and soil water resource uptake and determine the relative dominance of grass plants within a grassland community. Healthy vigorous grass plants have a high nutrient resource uptake efficiency and are superior competitors for mineral nitrogen and soil water and are able to suppress the expansion of shrub rhizomes and prevent successful establishment of invasive shrubs, weedy forbs, and undesirable grass seedlings into the grasslands. However, the use of degrading traditional management practices and the removal of 50% or more of the grass plant aboveground leaf material cause reduced root growth, root respiration, and root nutrient absorption resulting in a reduction of functionality of the grass plants, a diminishment of grass plant health and vigor, a loss of resource uptake efficiency, and a suppression of the competitiveness of grass plants to take up mineral nitrogen, essential elements, and soil water. Undesirable shrub, forb, and grass plants are able to become established within the degraded grass community and then able to uptake the belowground resources no longer consumed by the smaller, less vigorous, deteriorated grass plants, and proportionally increase the undesirable plant biomass production and increase their occupied space in the deteriorated grassland community. Traditionally, the observation of increases of undesirable trees, shrubs, forbs, and grasses into degraded grassland ecosystems would have been explained as a result of fire suppression (Humphrey 1962, Stoddart Smith, and Box 1975, Wright and Bailey 1982) rather than the actual physiological reduction of the grass plant nutrient resource uptake mechanisms.

We now have access to the basic science reports on how the ecosystem biogeochemical processes and the four main grass growth mechanisms work. We know how to increase the biomass of the rhizosphere microbes. We have knowledge from the applied science work on how and when we can activate the biogeochemical processes and the four main grass growth mechanisms to function properly. With the accumulation of all this scientific information, we can replace the detrimental traditional management practices, and develop and establish a biologically effective strategy for proper ecological management of the grasslands of the Northern Plains.

The biologically effective twice-over rotation strategy is designed to coordinate partial defoliation events of large grazing graminivores with grass phenological growth stages, in order to meet the nutrient requirements of the graminivores, the biological requirements of the grass plants and the rhizosphere microbes, to enhance the ecosystem biogeochemical processes, and to activate the four main internal grass plant growth mechanisms for the biologically effective facilitation of grassland ecosystems to full functionality at the greatest achievable levels.

The twice-over rotation grazing strategy uses three to six native grassland pastures. Each pasture is grazed for two periods per growing season. The number of grazing periods is determined by the number of sets of tillers: one set of lead tillers and one set of vegetation secondary tillers per growing season. The first grazing period is 45 days long, ideally, from 1 June to 15 July, with each pasture grazed for 7 to 17 days (never less or more). The number of days of the first grazing period on each pasture is the same percentage of 45 days as the percentage of the total season's grazeable forage contributed by each pasture to the complete system. The forage is measured as animal unit months (AUM's). The average grazing season month is 30.5 days long (Manske 2012). The number of days grazed are not counted by calendar dates, but by the number of 24-hr periods grazed from the date and time the livestock are turned out to pasture. The second grazing period is 90 days long, ideally from 15 July to 14 October, each pasture is grazed for twice the number of days as in the first period. The length of the total summer grazing period is best at 135 days; 45 days during the first period plus 90 days during the second period (Manske 2018).

During the first period, partial defoliation that removes 25% to 33% of the leaf biomass from grass lead tillers between the 3.5 new leaf stage and the flower stage increases the rhizosphere microbe biomass and activity, enhances the ecosystem biogeochemical processes, and activates the four main internal grass plant growth mechanisms. Manipulation of these processes and mechanisms does not occur at any other time during the growing season. During the second grazing period, the lead tillers are maturing and declining in nutritional quality, and partial defoliation can remove up to

50% of the leaf biomass. Adequate forage nutritional quality during the second period depends on the activation of the vegetative tillering mechanisms with sufficient quantities of vegetative secondary tiller growth from axillary buds during the first period. Livestock must be removed from intact native grassland pastures in mid October, towards the end of the perennial grass growing season, in order to allow the carryover tillers to store the carbohydrates and nutrients which will maintain plant life functions over the winter. Most of the upright vegetative tillers on grassland ecosystems during the autumn will be carryover tillers which will resume growth as lead tillers during the next growing season. Almost all grass tillers live for two growing seasons, the first season as vegetative secondary tillers, and the second season as lead tillers. Grazing carryover tillers after mid October causes the termination of a large proportion of the grass population, resulting in greatly reduced herbage biomass production in subsequent growing seasons. The pasture grazed first in the rotation sequence is the last pasture grazed during the previous year; i.e. ABC, CAB, and BCA, because the last pasture grazed has the greatest green live herbage weight on 1 June of the start of the following grazing season (Manske 2018).

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Range Plant Growth Related to Climatic Factors of Western North Dakota, 1982-2024.

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Introduction

Successful long-term management of grassland ecosystems requires knowledge of the relationships of range plant growth and regional climatic factors. Range plant growth and development are regulated by climatic conditions. Length of daylight, temperature, precipitation, and water deficiency are the most important climatic factors that affect rangeland plants (Manske 2011).

Light

Light is necessary for plant growth because light is the source of energy for photosynthesis. Plant growth is affected by variations in quality, intensity, and duration of light. The quality of light (wavelength) varies from region to region, but the quality of sunlight does not vary enough in a given region to have an important differential effect on the rate of photosynthesis. However, the intensity (measurable energy) and duration (length of day) of sunlight change with the seasons and affect plant growth. Light intensity varies greatly with the season and with the time of day because of changes in the angle of incidence of the sun's rays and the distance light travels through the atmosphere. Light intensity also varies with the amount of humidity and cloud cover because atmospheric moisture absorbs and scatters light rays.

The greatest variation in intensity of light received by range plants results from the various degrees of shading from other plants. Most range plants require full sunlight or very high levels of sunlight for best growth. Shading from other plants reduces the intensity of light that reaches the lower leaves of an individual plant. Grass leaves grown under shaded conditions become longer but narrower, thinner (Langer 1972, Weier et al. 1974), and lower in weight than leaves in sunlight (Langer 1972). Shaded leaves have a reduced rate of photosynthesis, which decreases the carbohydrate supply and causes a reduction in growth rate of leaves and roots (Langer 1972). Shading increases the rate of senescence in lower, older leaves. Accumulation of standing dead leaves ties up carbon and nitrogen. Decomposition of leaf material through microbial activity can take place only after the leaves have made contact with the soil. Standing dead material not in contact with the soil does not decompose but breaks down slowly as a result of leaching and weathering. Under ungrazed treatments the dead leaves remain standing for several years, slowing nutrient cycles, restricting nutrient supply, and reducing soil microorganism activity in the top 12 inches of soil. Standing dead leaves shade early leaf growth in spring and therefore slow the rate of growth and reduce leaf area. Long-term effects of shading, such as that occurring in ungrazed grasslands and under shrubs or leafy spurge, reduce the native grass species composition and increase composition of shade-tolerant or shade- adapted replacement species like smooth bromegrass and Kentucky bluegrass.

Day-length period (photoperiod) is one of the most dependable cues by which plants time their activities in temperate zones. Day-length period for a given date and locality remains the same from year to year. Changes in the photoperiod function as the timer or trigger that activates or stops physiological processes bringing about growth and flowering of plants and that starts the process of hardening for resistance to low temperatures in fall and winter. Sensory receptors, specially pigmented areas in the buds or leaves of a plant, detect day length and night length and can activate one or more hormone and enzyme systems that bring about physiological responses (Odum 1971, Daubenmire 1974, Barbour et al. 1987).

The phenological development of rangeland plants is triggered by changes in the length of daylight. Vegetative growth is triggered by photoperiod and temperature (Langer 1972, Dahl 1995), and reproductive initiation is triggered primarily by photoperiod (Roberts 1939, Langer 1972, Leopold and Kriedemann 1975, Dahl 1995) but can be slightly modified by temperature and precipitation (McMillan 1957, Leopold and Kriedemann 1975, Dahl and Hyder 1977, Dahl 1995). Some plants are long-day plants and others are short-day plants. Long-day plants reach the flower phenological stage after exposure to a critical photoperiod and during the period of increasing daylight between mid

April and mid-June. Generally, most cool-season plants with the C_3 photosynthetic pathway are long-day plants and reach flower phenophase before 21 June. Short-day plants are induced into flowering by day lengths that are shorter than a critical length and that occur during the period of decreasing day length after mid-June. Short-day plants are technically responding to the increase in the length of the night period rather than to the decrease in the day length (Weier et al. 1974, Leopold and Kriedemann 1975). Generally, most warm-season plants with the C_4 photosynthetic pathway are short-day plants and reach flower phenophase after 21 June.

The annual pattern in the change in daylight duration follows the seasons and is the same every year for each region. Grassland management strategies based on phenological growth stages of the major grasses can be planned by calendar date after the relationships between phenological stage of growth of the major grasses and time of season have been determined for a region.

Temperature

Temperature is an approximate measurement of the heat energy available from solar radiation. At both low and high levels temperature limits plant growth. Most plant biological activity and growth occur within only a narrow range of temperatures, between 32° F (0° C) and 122° F (50° C) (Coyne et al. 1995). Low temperatures limit biological reactions because water becomes unavailable when it is frozen and because levels of available energy are inadequate. However, respiration and photosynthesis can continue slowly at temperatures well below 32° F if plants are "hardened". High temperatures limit biological reactions because the complex structures of proteins are disrupted or denatured.

Periods with temperatures within the range for optimum plant growth are very limited in western North Dakota. The frost-free period is the number of days between the last day with minimum temperatures below 32° F (0° C) in the spring and the first day with minimum temperatures below 32° F (0° C) in the fall and is approximately the length of the growing season for annually seeded plants. The frost-free period for western North Dakota generally lasts for 120 to 130 days, from mid to late May to mid to late September (Ramirez 1972). Perennial grassland plants are capable of growing for periods longer than the frost-free period, but to continue active growth they require temperatures above the level that freezes water in plant tissue and soil. Many perennial plants begin active growth more than 30 days before the last frost in spring and continue growth after the first frost in fall. The growing season for perennial plants is considered to be between the first 5 consecutive days in spring and the last 5 consecutive days in fall with mean daily temperature at or above 32° F (0° C). In western North Dakota the growing season for perennial plants is considered to be generally from mid April through mid October. Low air temperature during the early and late portions of the growing season greatly limits plant growth rate. High temperatures, high evaporation rates, drying winds, and low precipitation levels after mid summer also limit plant growth.

Different plant species have different optimum temperature ranges. Cool-season plants, which are C_3 photosynthetic pathway plants, have an optimum temperature range of 50° to 77° F (10° to 25° C). Warm-season plants, which are C_4 photosynthetic pathway plants, have an optimum temperature range of 86° to 105° F (30° to 40° C) (Coyne et al. 1995).

Water (Precipitation)

Water, an integral part of living systems, is ecologically important because it is a major force in shaping climatic patterns and biochemically important because it is a necessary component in physiological processes (Brown 1995). Water is the principal constituent of plant cells, usually composing over 80% of the fresh weight of herbaceous plants. Water is the primary solvent in physiological processes by which gases, minerals, and other materials enter plant cells and by which these materials are translocated to various parts of the plant. Water is the substance in which processes such as photosynthesis and other biochemical reactions occur and a structural component of proteins and nucleic acids. Water is also essential for the maintenance of the rigidity of plant tissue and for cell enlargement and growth in plants (Brown 1977, Brown 1995).

Water Deficiency

Temperature and precipitation act together to affect the physiological and ecological status of range plants. The biological situation of a plant at any time is determined by the balance between rainfall and potential evapotranspiration. The higher the temperature, the greater the rate of evapotranspiration and the greater the need for rainfall to maintain homeostasis. When the amount of rainfall received is less than potential evapotranspiration demand, a water deficiency exists. Evapotranspiration demand is greater than precipitation in the mixed grass and short grass prairie regions. The tall grass prairie region has greater precipitation than evapotranspiration demand. Under water deficiency conditions, plants are unable to absorb adequate water to match the transpiration rate, and plant water stress develops. Range plants have mechanisms that help reduce the damage from water stress, butsome degree of reduction in herbage production occurs.

Plant water stress limits growth. Plant water stress develops in plant tissue when the rate of water loss through transpiration exceeds the rate of water absorption by the roots. Water stress can vary in degree from a small decrease in water potential, as in midday wilting on warm, clear days, to the lethal limit of desiccation (Brown 1995).

Early stages of water stress slow shoot and leaf growth. Leaves show signs of wilting, folding, and discoloration. Tillering and new shoot development decrease. Root production may increase. Senescence of older leaves accelerates. Rates of cell wall formation, cell division, and protein synthesis decrease. As water stress increases, enzyme activity declines and the formation of necessary compounds slows or ceases. The stomata begin to close; this reaction results in decreased rates of transpiration and photosynthesis. Rates of respiration and translocation decrease substantially with increases in water stress. When water stress becomes severe, most functions nearly or completely cease and serious damage occurs. Leaf and root mortality induced by water stress progresses from the tips to the crown. The rate of leaf and root mortality increases with increasing stress. Water stress can increase to a point that is lethal, resulting in damage from which the plant cannot recover. Plant death occurs when meristems become so dehydrated that cells cannot maintain cell turgidity and biochemical activity (Brown 1995).

Study Area

The study area is the region around the Dickinson Research Extension Center (DREC) Ranch, Dunn County, western North Dakota, USA. Native vegetation in western North Dakota is the Wheatgrass-Needlegrass Type (Barker and Whitman 1988, Shiflet 1994) of the mixed grass prairie.

The climate of western North Dakota has changed several times during geologic history (Manske 1999). The most recent climate change occurred about 5,000 years ago, to conditions like those of the present, with cycles of wet and dry periods. The wet periods have been cool and humid, with greater amounts of precipitation. A brief wet period occurred around 4,500 years ago. Relatively long periods of wet conditions occurred in the periods between 2,500 and 1,800 years ago and between 1,000 and 700 years ago. Recent short wet periods occurred in the years from 1905 to 1916, 1939 to 1947, and 1962 to 1978. The dry periods have been warmer, with reduced precipitation and recurrent summer droughts. A widespread, long drought period occurred between the years 1270 and 1299, an extremely severe drought occurred from 1863 through 1875, and other more recent drought periods occurred from 1895 to 1902, 1933 to 1938, and 1987 to 1992. The current climatic pattern in western North Dakota is cyclical between wet and dry periods and has existed for the past 5,000 years (Bluemle 1977, Bluemle 1991, Manske 1994a).

Procedures

Daylight duration data for the Dickinson location of latitude 46° 48' N, longitude 102° 48' W, were tabulated from daily sunrise and sunset time tables compiled by the National Weather Service, Bismarck, North Dakota.

Temperature and precipitation data were taken from historical climatological data collected at the Dickinson Research Extension Center Ranch, latitude 47° 14' N, longitude 102° 50' W, Dunn County, near Manning, North Dakota, 1982-2024.

A technique reported by Emberger et al. (1963) was used to develop water deficiency months data from historical temperature and precipitation data. The water deficiency months data were used to identify months with conditions unfavorable for plant growth. This method plots mean monthly temperature (° C) and monthly precipitation (mm) on the same axis, with the scale of the precipitation data at twice that of the temperature data. The temperature and precipitation data are plotted against an axis of time. The resulting ombrothermic diagram shows general monthly trends and identifies months with conditions unfavorable for plant growth. Water deficiency conditions exist during months when the precipitation data bar drops below the temperature data curve and plants are under water stress. Plants are under temperature stress when the temperature curve drops below the freezing mark (0° C).

Results and Discussion

Light

The tilt of the earth's axis in conjunction with the earth's annual revolution around the sun produces the seasons and changes the length of daylight in temperate zones. Dickinson (figure 1) has nearly uniform day and night lengths (12 hours) during only a few days, near the vernal and autumnal equinoxes, 20 March and 22 September, respectively, when the sun's apparent path crosses the equator as the sun travels north or south, respectively. The shortest day length (8 hours, 23 minutes) occurs at winter solstice, 21 December, when the sun's apparent path is farthest south of the equator. The longest day length (15 hours, 52 minutes) occurs at summer solstice, 21 June, when the sun's apparent path is farthest north of the equator. The length of daylight during the growing season (mid April to mid October) oscillates from about 13 hours in mid April, increasing to nearly 16 hours in mid June, then decreasing to around 11 hours in mid October (figure 1).

Temperature

The DREC Ranch in western North Dakota experiences severe, windy, dry winters with little snow accumulation. The springs are relatively moist in most years, and the summers are often droughty but are interrupted periodically by thunderstorms. The long-term (43-year) mean annual temperature is 42.3º F (5.7º C) (table 1). January is the coldest month, with a mean temperature of 15.0º F (-9.5º C). July and August are the warmest months, with mean temperatures of 69.7º F (21.0º C) and 68.4º F (20.2º C), respectively. Months with mean monthly temperatures below 32.0º F (0.0º C) are too cold for active plant growth. Low temperatures define the growing season for perennial plants, which is generally from mid April to mid October (6.0 months, 183 days). During the other 6 months each year, plants in western North Dakota cannot conduct active plant growth. Soils are frozen to a depth of 3 to 5 feet for a period of 4 months (121 days) (Larson et al. 1968). The early and late portions of the 6- month growing season have very limited plant activity and growth. The period of active plant growth is generally 5.5 months (168 days).

Western North Dakota has large annual and diurnal changes in monthly and daily air temperatures. The range of seasonal variation of average monthly temperatures between the coldest and warmest months is 55.0º F (30.5º C), and temperature extremes in western North Dakota have a range of 161.0º F (89.4º C), from the highest recorded summer temperature of 114.0º F (45.6º C) to the lowest recorded winter temperature of -47.0º F (-43.9º C). The diurnal temperature change is the difference between the minimum and maximum temperatures observed over a 24-hour period. The average diurnal temperature change during winter is 22.0º F (12.2º C), and the change during summer is 30.0º F (16.7º C). The average annual diurnal change in temperature is 26.0º F (14.4º C) (Jensen 1972). The large diurnal change in temperature during the growing season, which has warm days and cool nights, is beneficial for plant growth because of the effect on the photosynthetic process and respiration rates (Leopold and Kriedemann 1975).

Precipitation

The long-term (43-year) annual precipitation for the Dickinson Research Extension Center Ranch in western North Dakota is 16.91 inches (429.68 mm). The long-term mean monthly precipitation is shown in table 1. The growing-season precipitation (April to October) is 14.28 inches (362.61 mm) and is 85.22% of annual precipitation. June has the greatest monthly precipitation, at 3.04 inches (77.15 mm).

The seasonal distribution of precipitation (table 2) shows the greatest amount of precipitation occurring in the spring (7.11 inches, 42.05%) and the least amount occurring in winter (1.60 inches, 9.46%). Total precipitation received for the 5-month period of November through March averages less than 2.63 inches (15.55%). The precipitation received in the 3-month period of May, June, and July accounts for 47.25% of the annual precipitation (7.99 inches).

The annual and growing-season precipitation levels and percent of the long-term mean for 43 years (1982 to 2024) are shown in table 3. Drought conditions exist when precipitation amounts for a month, growing season, or annual period are 75% or less of the long-term mean. Wet conditions exist when precipitation amounts for a month, growing season, or annual period are 125% or greater of the long-term mean. Normal conditions exist when precipitation amounts for a month, growing season, or annual period are greater than 75% and less than 125% of the long-term mean. Between 1982-2024, 6 drought years (13.95%) (table 4) and 8 wet years (18.60%) (table 5) occurred. Annual precipitation amounts at normal levels, occurred during 29 years (67.44%) (table 3). The area experienced 6 drought growing seasons (13.95%) (table 6) and 8 wet growing seasons (18.60%) (table 7). Growing- season precipitation amounts at normal levels occurred during 29 years (67.44%) (table 3). The 6-year period (1987-1992) was a long period with near-drought conditions. The average annual precipitation for these 6 years was 12.12 inches (307.89 mm), only 71.67% of the long-term mean. The average growing-season precipitation for the 6- year period was 9.97 inches (253.11 mm), only 69.82% of the long-term mean (table 3).

Water Deficiency

Monthly periods with water deficiency conditions are identified on the annual ombrothermic graphs when the precipitation data bar drops below the temperature data curve. On the ombrothermic graphs, periods during which plants are under low-temperature stress are indicated when the temperature curve drops below the freezing mark of 0.0º C (32.0º F). The long-term ombrothermic graph for the DREC Ranch (figure 2) shows that near water deficiency conditions exist for August, September, and October. This finding indicates that range plants generally may have a difficult time growing and accumulating herbage biomass during these 3 months. Favorable water relations occur during May, June, and July, a condition indicating that range plants should be able to grow and accumulate herbage biomass during these 3 months.

The ombrothermic relationships for the Dickinson Research Extension Center Ranch in western North Dakota are shown for each month in table 8. The 43-year period (1982 to 2024) had a total of 258 months during the growing season. Of these growing-season months, 78.5 months had water deficiency conditions, which indicates that range plants were under water stress during 30.4% of the growing-season months (tables 8 and 9): this amounts to an average of 2.0 months during every 6.0-month growing season range plants have been limited in growth and herbage biomass accumulation because of water stress. The converse indicates that only 4.0 months of an average year have conditions in which plants can grow without water stress.

Most growing seasons have months with water deficiency conditions. In only 6 of the 43 years (table 8) did water deficiency conditions not occur in any of the six growing-season months. In each growing-season month of 1982, 2013, 2015, 2016, 2019, and 2023, the amounts and distribution of the precipitation were adequate to prevent water stress in plants. Twenty years (47.51%) had water deficiency for 0.5 to 2.0 months during the growing season. Sixteen years (37.21%) had water deficiency conditions for 2.5 to 4.0 months during the growing season. One year (2.33%), 1988, had water deficiency conditions for 5.0 months during the growing season. None of the 43 years had water deficiency conditions for all 6.0 months of the growing season (table 8). The 6-year period (1987-1992) was a long period with low precipitation; during this period, water deficiency conditions existed for an average of 3.1 months during each growing season, which amounts to 51.33% of this period's growing-season months (table 8).

May, June, and July are the 3 most important precipitation months and therefore constitute the primary period of production for range plant communities. May and June are the 2 most important months for dependable precipitation. Only 4 (9.30%) of the 43 years had water deficiency conditions during May, and 6 years (13.95%) had water deficiency conditions during June. One year (2017) had water deficiency conditions in both May and June. Fifteen (34.88%) of the 43 years had water deficiency conditions in July (table 9). Only one year (2017) has had water deficiency conditions during May, June, and July (table 8b).

Most of the growth in range plants occurs in May, June, and July (Goetz 1963, Manske 1994b). Peak aboveground herbage biomass production usually occurs during the last 10 days of July, a period that coincides with the time when plants have attained 100% of their growth in height (Manske 1994b). Range grass growth coincides with the 3- month period of May, June, and July, when 47.25% of the annual precipitation occurs.

August, September, and October are not dependable for positive water relations. August and September had water deficiency conditions in 46.51% and 53.49% of the years, respectively, and October had water deficiency conditions in 34.88% of the years (table 9). Visual observations of range grasses with wilted, senescent leaves in August indicate that most plants experience some level of water stress when conditions approach those of water deficiency. August, September, and/or October had water deficiency conditions during 81.40% of the growing seasons in the previous 43 years (table 8). These 3 months make up 42% of the growing season, and they had water deficiency conditions on the average of 45% of the time (table 9). The water relations in August, September, and October limit range plant growth and herbage biomass accumulation.

Over the last 43 years, drought years occurred 14.0% of the time. Drought growing seasons occurred 14.0% of the time. Water deficiency months occurred 30.4% of the time. Water deficiency occurred in May and June 9.3% and 14.0% of the time, respectively. July had water deficiency conditions 34.9% of the time. August, September, and October had water deficiency conditions 46.5%, 53.5%, and 34.9%. Water deficiency periods lasting for a month place plants under water stress severe enough to reduce herbage biomass production. These levels of water stress are a major factor limiting the quantity and quality of plant growth in western North Dakota and can limit livestock production if not considered during the development and implementation of long-term grazing management strategies.

The ombrothermic procedure to identify growing season months with water deficiency treats each month as an independent event. Precipitation during the other months of the year may buffer or enhance the degree of water stress experienced by perennial plants during water deficiency months. The impact of precipitation during other months on the months with water deficiency can be evaluated from annual running total precipitation data (table 10). Water deficiency conditions occurred during 3.5 months in 2024 (table 10).

Conclusion

The vegetation in a region is a result of the total effect of the long-term climatic factors for that region. Ecologically, the most important climatic factors that affect rangeland plant growth are light, temperature, water (precipitation), and water deficiency.

Light is the most important ecological factor because it is necessary for photosynthesis. Changes in time of year and time of day coincide with changes in the angle of incidence of the sun's rays; these changes cause variations in light intensity. Daylight duration oscillation for each region is the same every year and changes with the seasons. Shading of sunlight by cloud cover and from other plants affects plant growth.

Day-length period is important to plant growth because it functions as a trigger to physiological processes. Most cool-season plants reach flower phenophase between mid-May and mid-June. Most warm-season plants flower between mid-June and mid-September.

Plant growth is limited by both low and high temperatures and occurs within only a narrow range of temperatures, between 32º and 122º F. Perennial plants have a 6-month growing season, between mid-April and mid-October. Diurnal temperature fluctuations of warm days and cool nights are beneficial for plant growth. Cool- season plants have lower optimum temperatures for photosynthesis than do warm-season plants, and cool-season plants do not use water as efficiently as do warm-season plants. Temperature affects evaporation rates, which has a dynamic effect on the annual ratios of cool-season to warm-season plants in the plant communities. A mixture of cool- and warm-season plants is highly desirable because the grass species in a mixture of cool- and warm-season species have a wide range of different optimum temperatures and the herbage biomass production is more stable over wide variations in seasonal temperatures.

Water is essential for living systems. Average annual precipitation received at the DREC Ranch is 16.9 inches, with 84.4% occurring during the growing season and 47.3% occurring in May, June, and July. Plant water stress occurs when the rate of water loss through transpiration exceeds the rate of replacement by absorption. Years with drought conditions have occurred 14.0% of the time during the past 43 years. Growing seasons with drought conditions have occurred 14.0% of the time.

Water deficiencies exist when the amount of rainfall received is less than evapotranspiration demand. Temperature and precipitation data can be used in ombrothermic graphs to identify monthly periods with water deficiencies. During the past 43 years, 30.4% of the growing-season months had water deficiency conditions that placed range plants under water stress: range plants were limited in growth and herbage biomass accumulation for an average of 2.0 months during every 6-month growing season. May, June, and July had water deficiency conditions 9.3%, 14.0%, and 34.9% of the time, respectively. August, September, and October had water deficiency conditions 46.5%, 53.5% and 34.9% of the time, respectively. One month with water deficiency conditions causes plants to experience water stress severe enough to reduce herbage biomass production.

Most of the growth in range grasses occurs in May, June, and July. In western North Dakota, 100% of range grass leaf growth in height and 86% to 100% of range flower stalk growth in height are completed by 30 July. Peak aboveground herbage biomass production usually occurs during the last 10 days of July, a period that coincides with the time during which plants are attaining 100% of their height. Most range grass growth occurs during the 3- month period of May, June, and July, when 47.3% of the annual precipitation occurs.

Grassland management should be based on phenological growth stages of the major grasses and can be planned by calendar date. Management strategies for a region should consider the climatic factors that affect and limit range plant growth.

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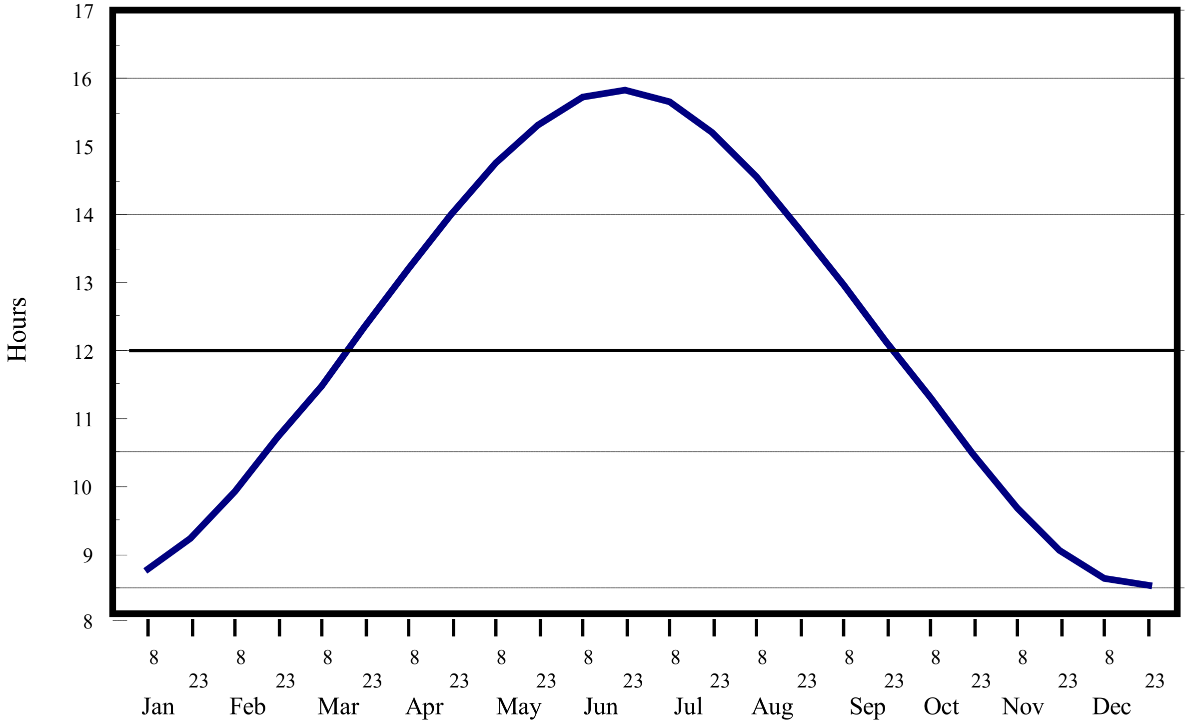

Figure. 1. Annual pattern of daylight duration at Dickinson, North Dakota.

Table 1. Long-term mean monthly temperature and monthly precipitation, 1982-2024.

	º F	º C	in.	mm
Jan	14.98	-9.46	0.42	10.68
Feb	18.35	-7.58	0.43	10.96
Mar	29.06	-1.64	0.75	19.14
Apr	41.26	5.14	1.42	35.99
May	53.54	11.97	2.65	67.30
Jun	63.31	17.40	3.04	77.15
Jul	69.74	20.97	2.30	58.50
Aug	68.43	20.24	1.97	50.05
Sep	56.84	14.22	1.59	40.27
Oct	43.88	6.60	1.31	33.35
Nov	29.22	-1.54	0.54	13.73
Dec	18.36	-7.58	0.49	12.56
	MEAN		**TOTAL**	
	42.25	**5.73**	**16.91**	**429.68**

Table 2. Seasonal precipitation distribution, 1982-2024.

Season	in.	%
Winter (Jan, Feb, Mar)	1.60	9.46
Spring (Apr, May, Jun)	7.11	42.05
Summer (Jul, Aug, Sep)	5.86	34.65
Fall (Oct, Nov, Dec)	2.34	13.84
TOTAL	**16.91**	

Table 3. Precipitation in inches and percent of long-term mean for perennial plant growing season months, 1982-2024.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2024	1.42	2.65	3.04	2.30	1.97	1.59	1.31	14.28	16.91
1982	1.37	2.69	4.30	3.54	1.75	1.69	5.75	21.09	25.31
% of LTM	96.48	101.51	141.45	153.91	88.83	106.29	438.93	147.73	149.62
1983	0.21	1.53	3.26	2.56	4.45	0.86	0.72	13.59	15.55
% of LTM	14.79	57.74	107.24	111.30	225.89	54.09	54.96	95.20	91.92
1984	2.87	0.00	5.30	0.11	1.92	0.53	0.96	11.69	12.88
% of LTM	202.11	0.00	174.34	4.78	97.46	33.33	73.28	81.89	76.14
1985	1.24	3.25	1.58	1.07	1.84	1.69	2.13	12.80	15.13
% of LTM	87.32	122.64	51.97	46.52	93.40	106.29	162.60	89.66	89.44
1986	3.13	3.68	2.58	3.04	0.46	5.29	0.18	18.36	22.96
% of LTM	220.42	138.87	84.87	132.17	23.35	332.70	13.74	128.61	135.74
1987	0.10	1.38	1.15	5.39	2.65	0.78	0.08	11.53	14.13
% of LTM	7.04	52.08	37.83	234.35	134.52	49.06	6.11	80.77	83.53
1988	0.00	1.85	1.70	0.88	0.03	0.73	0.11	5.30	9.03
% of LTM	0.00	69.81	55.92	38.26	1.52	45.91	8.40	37.13	53.38
1989	2.92	1.73	1.63	1.30	1.36	0.70	0.96	10.60	13.07
% of LTM	205.63	65.28	53.62	56.52	69.04	44.03	73.28	74.25	77.26
1990	2.03	2.39	3.75	1.13	0.31	0.68	0.85	11.14	11.97
% of LTM	142.96	90.19	123.36	49.13	15.74	42.77	64.89	78.03	70.76
1991	1.97	1.16	3.95	1.43	0.55	2.17	1.31	12.54	13.30
% of LTM	138.73	43.77	129.93	62.17	27.92	136.48	100.00	87.84	78.62
1992	0.81	0.68	1.59	2.70	2.02	0.72	0.16	8.68	11.23
% of LTM	57.04	25.66	52.30	117.39	102.54	45.28	12.21	60.80	66.38
1993	1.41	1.71	4.57	5.10	1.24	0.18	0.05	14.26	17.36
% of LTM	99.30	64.53	150.33	221.74	62.94	11.32	3.82	99.89	102.62
1994	0.86	1.46	4.51	1.07	0.31	1.08	4.58	13.87	16.14
% of LTM	60.56	55.09	148.36	46.52	15.74	67.92	349.62	97.16	95.41

Table 3 (cont). Precipitation in inches and percent of long-term mean for perennial plant growing season months, 1982-2024.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2024	1.42	2.65	3.04	2.30	1.97	1.59	1.31	14.28	16.91
1995	1.01	4.32	0.68	4.62	3.16	0.00	0.67	14.46	16.24
% of LTM	71.13	163.02	22.37	200.87	160.41	0.00	51.15	101.29	96.00
1996	0.14	3.07	1.86	2.55	1.72	2.51	0.09	11.94	15.97
% of LTM	9.86	115.85	61.18	110.87	87.31	157.86	6.87	83.64	94.40
1997	2.89	0.95	5.02	5.41	0.76	1.75	0.78	17.56	18.61
% of LTM	203.52	35.85	165.13	235.22	38.58	110.06	59.54	123.01	110.01
1998	0.40	1.51	5.98	2.11	4.60	0.71	4.38	19.69	22.42
% of LTM	28.17	56.98	196.71	91.74	233.50	44.65	334.35	137.93	132.53
1999	1.10	4.93	1.59	1.80	2.70	2.40	0.00	14.52	15.56
% of LTM	77.46	186.04	52.30	78.26	137.06	150.94	0.00	101.71	91.98
2000	1.26	1.90	3.77	2.77	2.74	1.09	1.46	14.99	20.23
% of LTM	88.73	71.70	124.01	120.43	139.09	68.55	111.45	105.00	119.59
2001	2.70	0.53	6.36	4.87	0.00	1.94	0.00	16.40	18.03
% of LTM	190.14	20.00	209.21	211.74	0.00	122.01	0.00	114.88	106.58
2002	1.14	2.18	5.40	4.27	4.24	0.74	0.88	18.85	21.88
% of LTM	80.28	82.26	177.63	185.65	215.23	46.54	67.18	132.04	129.34
2003	1.30	4.34	1.42	2.03	0.82	2.37	0.74	13.02	19.12
% of LTM	91.55	163.77	46.71	88.26	41.62	149.06	56.49	91.20	113.03
2004	0.89	1.31	1.65	2.30	0.93	2.57	3.10	12.75	16.51
% of LTM	62.68	49.43	54.28	100.00	47.21	161.64	236.64	89.31	97.60
2005	0.96	6.01	6.05	0.60	1.52	0.50	1.96	17.60	21.51
% of LTM	67.61	226.79	199.01	26.09	77.16	31.45	149.62	123.29	127.15
2006	2.78	2.82	2.13	0.96	2.87	1.42	2.01	14.99	17.70
% of LTM	195.77	106.42	70.07	41.74	145.69	89.31	153.44	105.00	104.63
2007	1.58	4.64	1.80	1.05	0.78	0.76	0.26	10.87	13.94
of LTM	111.27	175.09	59.21	45.65	39.59	47.80	19.85	76.14	82.40

Table 3 (cont). Precipitation in inches and percent of long-term mean for perennial plant growing season months, 1982-2024.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2024	1.42	2.65	3.04	2.30	1.97	1.59	1.31	14.28	16.91
2008	0.61	2.79	4.02	1.06	1.02	1.04	1.68	12.22	14.88
% of LTM	42.96	105.28	132.24	46.09	51.78	65.41	128.24	85.60	87.96
2009	1.49	2.47	3.84	3.24	0.95	1.15	1.95	15.09	17.89
% of LTM	104.93	93.21	126.32	140.87	48.22	72.33	148.86	105.70	105.75
2010	1.43	3.70	3.50	1.94	1.39	4.09	0.13	16.18	19.03
% of LTM	100.70	139.62	115.13	84.35	70.56	257.23	9.92	113.34	112.49
2011	1.66	6.87	2.15	2.33	2.70	1.76	0.44	17.91	21.28
% of LTM	116.90	259.25	70.72	101.30	137.06	110.69	33.59	125.46	125.79
2012	2.38	1.58	4.31	1.98	0.82	0.21	2.35	13.63	15.46
% of LTM	167.61	59.62	141.78	86.09	41.62	13.21	179.39	95.48	91.39
2013	1.05	7.55	2.23	2.13	2.81	2.44	3.35	21.56	23.22
% of LTM	73.94	284.91	73.36	92.61	142.64	153.46	255.73	151.02	137.26
2014	1.41	3.73	3.38	0.37	8.84	1.03	0.59	19.35	21.11
% of LTM	99.30	140.75	111.18	16.09	448.73	64.78	45.04	135.54	124.79
2015	0.60	1.65	4.68	2.87	1.69	1.35	1.96	14.80	17.01
% of LTM	42.25	62.26	153.95	124.78	85.79	84.91	149.62	103.67	100.55
2016	3.44	2.26	1.96	3.61	1.86	2.66	1.80	17.59	19.70
% of LTM	242.25	85.28	64.47	156.96	94.42	180.95	137.40	123.22	116.45
2017	1.30	0.84	1.27	0.72	2.67	2.28	0.08	9.16	10.55
% of LTM	91.55	31.70	41.78	31.30	135.53	143.40	6.11	64.16	62.36
2018	0.48	1.22	4.23	2.01	0.55	1.84	0.66	10.99	14.39
% of LTM	33.80	46.04	139.14	87.39	27.92	115.72	50.38	76.98	85.06
2019	1.35	2.52	2.60	1.61	4.70	9.10	1.26	23.14	25.88
% of LTM	95.07	95.09	85.53	70.00	238.58	572.33	96.18	162.09	152.99
2020	0.59	1.45	1.10	2.67	2.56	0.86	0.26	9.49	11.01
% of LTM	41.55	54.72	36.18	116.09	129.95	54.09	19.85	66.48	65.08

Table 3 (cont). Precipitation in inches and percent of long-term mean for perennial plant growing season months, 1982-2024.

	Apr	May	Jun	Jul	Aug	Sep	Oct	Growing Season	Annual Total
Long-Term Mean 1982-2024	1.42	2.65	3.04	2.30	1.97	1.59	1.31	14.28	16.91
2021	0.26	5.07	1.07	1.03	1.63	0.14	2.70	11.90	13.75
% of LTM	18.31	191.32	35.20	44.78	82.74	8.81	206.11	83.36	81.28
2022	4.16	3.17	2.02	3.71	0.28	0.93	1.84	16.11	20.16
% of LTM	292.96	119.62	66.45	161.30	14.21	58.49	140.46	112.85	119.17
2023	0.30	2.69	1.91	2.21	3.25	1.32	1.24	12.92	15.42
% of LTM	21.13	101.51	62.83	96.09	164.97	83.02	94.66	90.50	91.15
2024	1.35	2.35	2.75	0.88	1.28	0.12	0.00	8.73	10.89
% of LTM	95.07	88.68	90.46	38.26	64.97	7.55	0.00	61.15	64.37

Table 4. Years with annual precipitation amounts of 75% or less of the long-term mean (LTM).

	Year	%LTM
1	1988	53.38
2	2017	62.36
3	2024	64.37
4	2020	65.08
5	1992	66.38
6	1990	70.76

Table 5. Years with annual precipitation amounts of 125% or more of the long-term mean (LTM).

	Year	%LTM
1	2019	152.99
2	1982	149.62
3	2013	137.26
4	1986	135.74
5	1998	132.53
6	2002	129.34
7	2005	127.15
8	2011	125.79

Table 6. Years with growing-season precipitation amounts of 75% or less of the long-term mean (LTM).

	Year	%LTM
1	1988	37.13
2	1992	60.80
3	2024	61.15
4	2017	64.16
5	2020	66.48
6	1989	74.25

Table 7. Years with growing-season precipitation amounts of 125% or more of the long-term mean (LTM).

	Year	%LTM
1	2019	162.09
2	2013	151.02
3	1982	147.73
4	1998	137.93
5	2014	135.54
6	2002	132.04
7	1986	128.61
8	2011	125.46

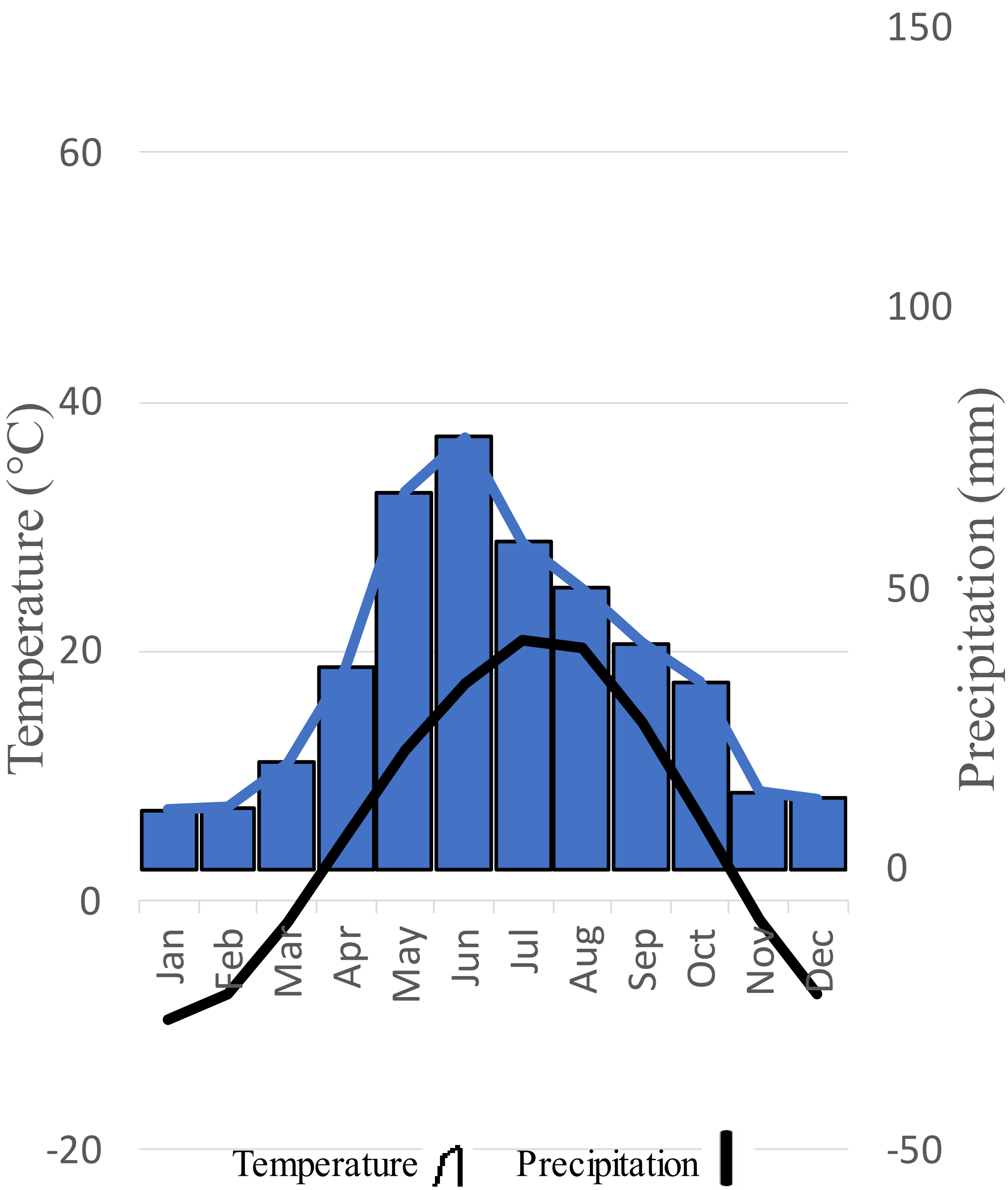

Figure 2. Ombrothermic diagram of long-term mean monthly temperature and monthly precipitation at the DREC Ranch, western North Dakota, 1982 -2024.

Table 8a. Growing season months with water deficiency conditions that caused water stress in perennial plants (1982-1989, 1990-1999).

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
1980								-	-
1981	-	-						-	-
1982								0.0	0
1983								1.5	25
1984								3.0	50
1985								1.0	17
1986								1.5	25
1987								3.0	50
1988								5.0	83
1989								3.0	50
								18.0	**38**
1990								3.0	50
1991								2.0	33
1992								2.5	42
1993								2.5	42
1994								3.0	50
1995								2.0	33
1996								1.0	17
1997								1.0	7
1998								1.5	25
1999								0.5	8
								19.0	**32**

Table 8b. Growing season months with water deficiency conditions that caused water stress in perennial plants (2000-2009, 2010-2019).

	APR	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**# Months**	**% 6 Months 15 Apr-15 Oct**
2000								1.0	17
2001								2.5	42
2002								1.0	17
2003								1.0	17
2004								1.0	17
2005								3.0	50
2006								1.0	17
2007								3.5	58
2008								3.0	50
2009								2.0	33
								19.0	**32**
2010								1.5	25
2011								0.5	8
2012								2.0	33
2013								0.0	0
2014								2.5	42
2015								0.0	0
2016								0.0	0
2017								3.5	58
2018								1.0	17
2019								0.0	0
								11.0	**18**

Table 8c. Growing season months with water deficiency conditions that caused water stress in perennial plants (2020-2029, 2030-2029).

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
2020								2.5	42
2021								3.5	58
2022								2.0	33
2023								0.0	0
2024								3.5	58
2025								1.0	17
2026									
2027									
2028									
2029									
								12.5	**35**

Table 9. Growing season months with water deficiency, 1982-2024.

	APR	MAY	JUN	JUL	AUG	SEP	OCT	# Months	% 6 Months 15 Apr-15 Oct
TOTAL	6	4	6	15	20	23	15	78.5	30.4
% of 43 **YEARS**	14.0	9.3	14.0	34.9	46.5	53.5	34.9		

Table 10. Monthly precipitation and running total precipitation compared to the long-term mean (LTM), 2024.

	Monthly Precipitation (in)			Running Total Precipitation (in)		
Months	LTM 1982-2023	Precipitation 2024	% of LTM	Running LTM 1982-2023	Running Precipitation 2024	% of LTM
Jan	0.43	0.23	53.49	0.43	0.23	53.49
Feb	0.43	0.29	67.44	0.86	0.52	60.47
Mar	0.76	0.57	75.00	1.62	1.09	67.28
Apr	1.42	1.35	95.07	3.04	2.44	80.26
May	2.66	2.35	88.35	5.70	4.79	84.04
Jun	3.04	2.75	90.46	8.74	7.54	86.27
Jul	2.34	0.88	37.61	11.08	8.42	75.99
Aug	1.99	1.28	64.32	13.07	9.70	74.22
Sep	1.62	0.12	7.41	14.69	9.82	66.85
Oct	1.34	0.00	0.00	16.03	9.82	61.26
Nov	0.55	0.15	27.27	16.58	9.97	60.13
Dec	0.48	0.92	191.67	17.06	10.89	63.83
Total	17.06	10.89	63.83			

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Wildryes as Fall Complementary Pastures for the Northern Plains

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Fall Complementary Pastures

The wildryes are the only perennial grass type that retains adequate nutritional quality to meet a lactating cows requirements during fall grazing from mid-October to mid-November. Despite these unique important characteristics, wildryes are not a popular fall pasture in the Northern Plains. The problem isn't the grasses. The problem is the management. The wildryes do not grow and behave like native grasses of the Northern Mixed Grass Prairie and cannot be managed with the same techniques that the native grasses are managed. The native grasses plus crested wheatgrass and smooth bromegrass grow and behave as if they were types of perennial spring wheat. The wildrye grasses grow and behave as if they were types of perennial winter wheat. Proper management of wildrye fall pastures must be adjusted to accommodate these differences in growth and behavior.

There are numerous types of wildryes in the world. The two common types in the Northern Plains are Altai and Russian Wildryes.

Altai wildrye, *Leymus angustus* (Trin.) Pilg., is a member of the grass family, Poaceae, tribe, Triticeae, syn.: *Elymus angustus* Trin., and is a long lived perennial, monocot, cool-season, mid grass, that is drought tolerant, very winter hardy, highly tolerant of saline soils nearly at the level of tall wheatgrass, and fairly tolerant of alkaline soils. Altai wildrye was introduced into Canada as two seed lots. The first seed lot arrived in 1934 from Voronezh, USSR, located in the far western European Russian Steppe. The second seed lot arrived in 1939 from the Steppe of Kustanay located in the northern region of Kazakhstan. Three synthetic strains were developed from seed increase plots started in 1950 at the Swift Current Research Station followed by more sites at seven research stations in Alberta, Manitoba, and Saskatchewan, which produced the first released cultivar, Prairieland, in 1976. Seed from the increase fields at Swift Current was used to establish 60 acres of Altai wildrye monoculture at the NDSU Dickinson Research Extension Center for a replicated study of late season grazing during mid-October to mid-November conducted from 1983 to 2005 for 23 years. Early aerial growth consists of basal leaves from crown tiller buds. Basal leaf blades are 15-25 cm (6-10 in) long, 0.5-0.7 cm wide, erect, coarse, light green to bluegreen to blue, and can remain upright under deep wet snow. The leaf sheath is usually shorter than the internodes and grayish green. The membrane ligule is 0.5-1.0 mm long with an obtuse apex. Some early specimens of introduced strains showed vigorous rhizome charateristics and aggressive spreading which was considered to be undesirable. The available released plant material are generally weakly rhizomatous with short rhizomes. Unfortunately, fields seeded with plant material that has nonaggressive short rhizomes is limited by around a 20 to 25 year life expectancy. However, the uniquely deep extensive fibrous root system that can penetrate to depths of 3-4 m (9.8-13.1 ft) and efficiently absorb available soil water was retained. Regeneration is primarily asexual propagation by crown and short rhizome tiller buds. Seedlings have slow, weak growth and are successful only when competition from established plants is nonexistant. Flower stalks are erect, 60-100 cm (24-39 in) tall, mostly leafless and few in numbers. Inflorescence is a terminal spike 15-20 cm (6-8 in) long, 1 cm in diameter, that has closely spread overlapping spikelets of 2 or 3 florets, with 2 or 3 spikelets per node. Basal leaves are palatable to livestock and seed stalks are not. Wildryes maintain slightly higher levels of protein and digestibility with advancing maturity better than other species of perennial grasses. Wildryes are best used for late season grazing from mid-October to mid-November. Fire top kills aerial parts and kills deeply into the crown when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reduction in biomass production and tiller density. This summary information on growth development and regeneration of Altai wildrye was based on works of Lawrence 1976, and St. John et al. 2010.

Russian wildrye, *Psothyrostachys juncea* (Fisch.) Nevski., is a member of the grass family, Poaceae, tribe, Triticeae, syn.: *Elymus junceus* Fisch., and is a long-lived perennial, monocot, cool-season, mid grass, that is exceptionally drought tolerant, tolerant of extremely cold temperatures, highly tolerant of saline soils, fairly tolerant of alkaline soils, intolerant of spring flooding or high water tables, and does not perform well on sandy soils. Russian wildrye was introduced into the United States from Siberia. It was brought to North Dakota in 1907, grown at the Dickinson Research Extension Center in 1913, and grown at the USDA-ARS at Mandan, ND. in 1927. It was introduced into Canada from Siberia in 1926. Early aerial growth consists of basal leaves from crown tiller buds. Basal leaf blades are 7-40 cm (3-16 in) long, 2-6 mm wide, soft, lax, numerous and dense. The split sheath has overlapping margins and open at the top. Previous years sheath bases are persistent and shredded into fibers. The collar is broad and continuous. The membrane ligule is 1 mm long with a blunt flat edge that has numerous small irregular cuts. The small auricles are 2 mm long, clasping, and clawlike. Some plants form no rhizomes, while other plants have several short rhizomes, while other plants have several short rhizomes that form clumps 20-30 cm (8-12 in) wide. Unfortunately, fields seeded with plant material that has nonaggressive short rhizomes is limited by around a 20 to 25 year life expectancy. All bunches have an extensive network of dense, fibrous roots with a lateral spread of 1.2-1.5 m (4-5 ft) that descend downward to 2.5-3.0 m (8-10 ft) deep. About 75% of the root biomass is in the top 15-61 cm (6-24 in) of soil that provides high plant competition to most other species. Regeneration is primarily asexual propagation by crown and short rhizome tiller buds. Seedlings are weak, develop slowly and are successful only when competition from established plants is nonexistant. Flower stalks are erect, hollow, 60-100 cm (24-39 in) tall, mostly leafless and few in number. Inflorescence is a terminal spike 6-11 cm (2.4-4.3 in) long, 5-9 mm wide, that has closely spaced overlapping spikelets of 1 to 4 florets, with 2 or 3 spikelets per node. Flower period in the Great Plains is May and June. Basal leaves are palatable to livestock and seed stalks are not. Wildryes maintain slightly higher levels of protein and digestibility with advancing maturity better than other species of perennial grasses. Wildryes are best used for late season grazing from mid-October to mid-November. Fire top kills aerial parts and kills deeply into the crown when soil is dry. Fire halts the processes of the four major defoliation resistance mechanisms and causes great reduction in biomass production and tiller density. This summary information on growth development and regeneration of Russian wildrye was based on works of Stevens 1963, Dodds 1979, Great Plains Flora Association 1986, Ogle et al. 2005, Taylor 2005, and Johnson and Larson 2007.

Wildryes Require Different Management Practices

Growth characteristics of Altai wildrye is quite different from native cool season grasses. Grazing cool season native grasses during vegetative growth stage prior to the flower stage activates vegetative tiller development from axillary buds. Lightly grazing of Altai wildrye prior to the flower stage did not activate vegetative tillers. Early season grazing actually decreased tiller basal cover. However, fall grazing during mid-October to mid-November that removed 50% or less of the standing leaf biomass greatly increased vegetative secondary tillers and fall tillers that develop during the following summer and early fall.

During early spring, the carryover tillers that survived the winter in the 50% residual herbage biomass of Altai wildrye tussocks regreened providing most of the carbohydrates and energy used for growth of the current leaves of the new seasons lead tillers. Removal of most of the herbage biomass during the fall grazing period causes termination of a major portion of the living crown tillers with greatly reduced active lead tiller growth and critical reductions in herbage biomass and nutritional quality the following growing season.

Lead tillers produce 3.5 new leaves around early June. The seed stalks develop early and are visible before 21 June. The carryover leaves senescence during June. Most of the aboveground herbage biomass weight in June (1668.80 lbs/ac) is the new leaves and stalks of the current lead tillers (figure 11). After the flower stage, the crude protein content of the lead tillers starts to decrease slowly. The vegetative tillers, that have been activated during the previous fall grazing period, begin visible growth shortly after the lead tillers reach the flower stage. The aboveground herbage biomass during July (2210.59 lbs/ac) and August (2291.83 lbs/ac) is the slowly senescent lead tillers and the rapidly growing vegetative tillers. From mid-August to about mid-October, the fall tillers develop and produce the additional herbage biomass during September (3021.91 lbs/ac) and October (3140.89 lbs/ac). By mid-October, the fall tillers should have around 10% to 12% crude protein, the vegetative tillers should have around 10% to 8% crude protein, and the lead tillers should have 8% to 6% crude protein. The ratio of the three tiller types would effect the mean crude protein level of the Altai wildrye forage during the fall grazing period from mid-October to mid-November (table 16, figure 11).

The lead tillers terminate at the end of their second growing season, the year they produce a seed head. The vegetative tillers carryover during the winter and become the next seasons lead tillers. The fall tillers carryover during the winter and become the next seasons vegetative tillers, a few well developed fall tillers may become lead tillers. The survival of the carryover vegetative tillers and fall tillers depends on the amount of leaf area they retain at the end of the fall grazing period. When 50% or more of the aboveground herbage remains on mid-November (1500.00 lbs/ac), most of the vegetative tillers and fall tillers survive to the next spring. However, when greater than 50% of the aboveground herbage is removed by mid November or during an injudicious longer grazing period after mid November, most of the vegetative tillers and fall tillers will have lost greater leaf biomass than they can recover from, resulting in an extremely low survival rate and a rapidly degrading wildrye stand. This devastating reduction in herbage biomass has been incorrectly blamed unto the grass, not on the management practice that truly caused the reductions.

The wildryes do not increase vegetative tiller growth by light grazing during the early vegetative growth stages of lead tillers before the flower stage. So do not graze wildryes during May or June. Vegetative secondary tillers and fall tillers are stimulated by fall grazing from mid-October to mid-November. There is no data of grazing stimulation during mid-September to mid-October. We know that grazing from mid-October to mid-November works when 1500 lbs/ac residual herbage remain from mid-November to spring. That seems like a lot of herbage to leave. Remember that at least 1500 lbs/ac of forage is available to be removed. If the 50% quantity of residual is not remaining at the end of the fall grazing period, the quantity of herbage produced for the next fall grazing period will be much less than the potential 3000 lbs/ac, plus a loss of a potential 1000 lbs/ac to 2000 lbs/ac in additional herbage that could be produced when the grasses remain healthy. The residual of 1500 lbs/ac must remain or your management will fail the vegetation, the stand will deteriorate in 20 to 25 years, and the grass receives the blame. By leaving 50% residual annually, the wildrye stand life expectancy could be perpetual. This will require another long-term research study.

Performance of Grass and Livestock

Altai wildrye is an excellent fall pasture during mid-October to mid-November. The wildryes have been considered to be difficult to grow because they respond differently than the native grasses and common domesticated grasses to standard grassland practices. The wildryes are different and require different management practices. The wildryes are not the problem. The standard management practices are the problem. With 27 years of research, the problems with the standard practices can be corrected.

Four different forage sources for fall complementary pastures have been evaluated that compared two perennial grass forage types and compared two cropland forage types. Two biologically effective fall complementary pastures are Altai wildrye (perennial grass) and Spring Seeded Winter Cereal (cropland). Two traditional fall pastures are Native Rangeland (perennial grass) and Cropland Aftermath (cropland).

The biologically effective fall complementary perennial grass pasture was Altai wildrye. Cow and calf pairs grazed one pasture of Altai wildrye (replicated two times) at 1.41 ac/AUM for 30 days (1.39 ac/AU) from mid-October to mid-November (table 17).

The traditional fall complementary perennial grass pasture was native rangeland. Cow and calf pairs grazed one pasture of native rangeland (replicated two times) at 4.11 ac/AUM for 30 days (4.04 ac/AU) from mid-October to mid-November (table 17).

The one pasture traditional concept of native rangeland provided 891 lbs/ac herbage during the mid-October to mid-November grazing period leaving a residual of 668 lbs/ac, which would indicate a utilization rate of 223 lbs/ac. There is no new growth of native rangeland after mid October and leaf senescence is greatly accelerated, with nutritional quality below a lactating cows crude protein requirements.

The one pasture biologically effective concept of Altai wildrye provided 3141 lbs/ac herbage during the mid-October to mid-November grazing period leaving a residual of 1496 lbs/ac, which would indicate a utilization rate of 1645 lbs/ac. The residual herbage would include highly senescent lead tiller leaves that would contain 8% to 6% crude protein, secondary vegetative tiller leaves that would contain 10% to 8% crude protein, and fall tiller leaves that would contain 12% to 10% crude protein. Some of the residual would contain the totally senescent seed heads of which the cows do not consume.

On the Altai wildrye strategy, calf weight gain was 1.82 lbs per day, 37.12 lbs per acre, and accumulated weight gain was 50.34 lbs per head. Cow weight gain was 1.62 lbs per day, 32.22 lbs per acre, and accumulated weight gain was 42.60 lbs per head (table 18).

On the native rangeland strategy, calf weight gain was 0.59 lbs per day, 4.38 lbs per acre, and accumulated weight gain was 17.73 lbs per head. Cow weight loss was 1.74 lbs per day, 12.90 lbs per acre, and accumulated weight loss was 52.20 lbs per head (table 18).

Cow and calf weight performance on the Altai wildrye strategy was greater than those on the native range strategy. The calf weight gain per day was 208.47% greater, gain per head was 183.93% greater, and gain per acre was 747.49% greater. The cow weight gain per day was 193.10% greater, gain per head was 181.61% greater, and gain per acre was 349.77% greater (table 18).

Pasture costs were 65.58% lower and cost per day were 65.25% lower on the Altai wildrye strategy than those on the native range strategy (table 17). The dollar value captured was greater on the Altai wildrye strategy, pasture weight gain value was 183.96% greater, net return per cow-calf pair was 200.35% greater, and net return per acre was 391.56% greater, while cost per pound of calf gain was 87.94% lower, than those on the native range strategy (table 18).

The biologically effective fall complementary cropland pasture was spring seeded winter cereal. Cow and calf pairs grazed four pastures of spring seeded winter rye with each pasture grazed for one week (replicated two times) at 0.48 ac/AUM for 30 days (0.47 ac/AU) from mid-October to mid-November (table 19).

The traditional fall complementary cropland pasture was cropland aftermath of annual cereal residue of oat and/or barley stubble. Cow and calf pairs grazed one pasture of cereal residue forage (replicated two times) at 6.74 ac/AUM for 30 days (6.63 ac/AU) from mid-October to mid-November (table 19).

The one pasture traditional concept of cropland aftermath provided 270 lbs/ac herbage during the mid-October to mid-November grazing period leaving a residual of 135 lbs/ac, which would indicate a utilization rate of 135 lbs/ac. The nutrient content of stubble from annual cereal harvested for grain is almost nonexistent and lactating cows cannot find forage that meets their crude protein requirements.

The four pasture biologically effective concept of spring seeded winter cereal provided 1908 lbs/ac forage during the mid-October to mid-November grazing period leaving no standing residual vegetation. The livestock had access to one fresh pasture per week with reuse of previous pastures.

On the spring seeded winter cereal strategy, calf weight gain was 2.00 lbs per day, 127.66 lbs per acre, and accumulated weight gain was 60.00 lbs per head. Cow weight gain was 1.05 lbs per day, 67.02 lbs per acre, and accumulated weight gain was 31.50 lbs per head (table 20).

On the cropland aftermath strategy, calf weight gain was 0.42 lbs per day, 1.90 lbs per acre, and accumulated weight gain was 12.57 lbs per head. Cow weight loss was 1.61 lbs per day, 7.27 lbs per acre, and accumulated weight loss was 48.17 lbs per head (table 20).

Cow and calf weight performance on the spring seeded winter cereal strategy was greater than those on the cropland aftermath strategy. The calf weight gain per day was 376.19% greater, gain per head was 377.33% greater, and gain per acre was 6618.95% greater. The cow weight gain per day was 165.22% greater, gain per head was 165.39% greater, and gain per acre was 1021.87% greater (table 20).

Pasture costs were 48.57% greater and cost per day were 50.00% greater on the spring seeded winter cereal strategy than those on the cropland aftermath strategy (table 19). Even though the pasture costs were higher, the dollar value captured was greater on the spring seeded winter cereal strategy, pasture weight gain value was 377.27% greater, net return per cow-calf pair was 600.00% greater, and net return per acre was 7182.09% greater, while cost per pound of calf gain was 68.57% lower, than those on the cropland aftermath strategy (table 20).

Grazing native rangeland after mid October and grazing cropland aftermath of annual cereal residue stubble are old style traditional forage management practices previously used with low-performance livestock that do not work biologically nor economically with modern high-performance livestock. Both practices are deficient at providing adequate forage quality and inefficient at nutrient capture. The cows lose considerable weight and the calf weight gain is diminutive resulting in negative net returns (tables 18 and 20).

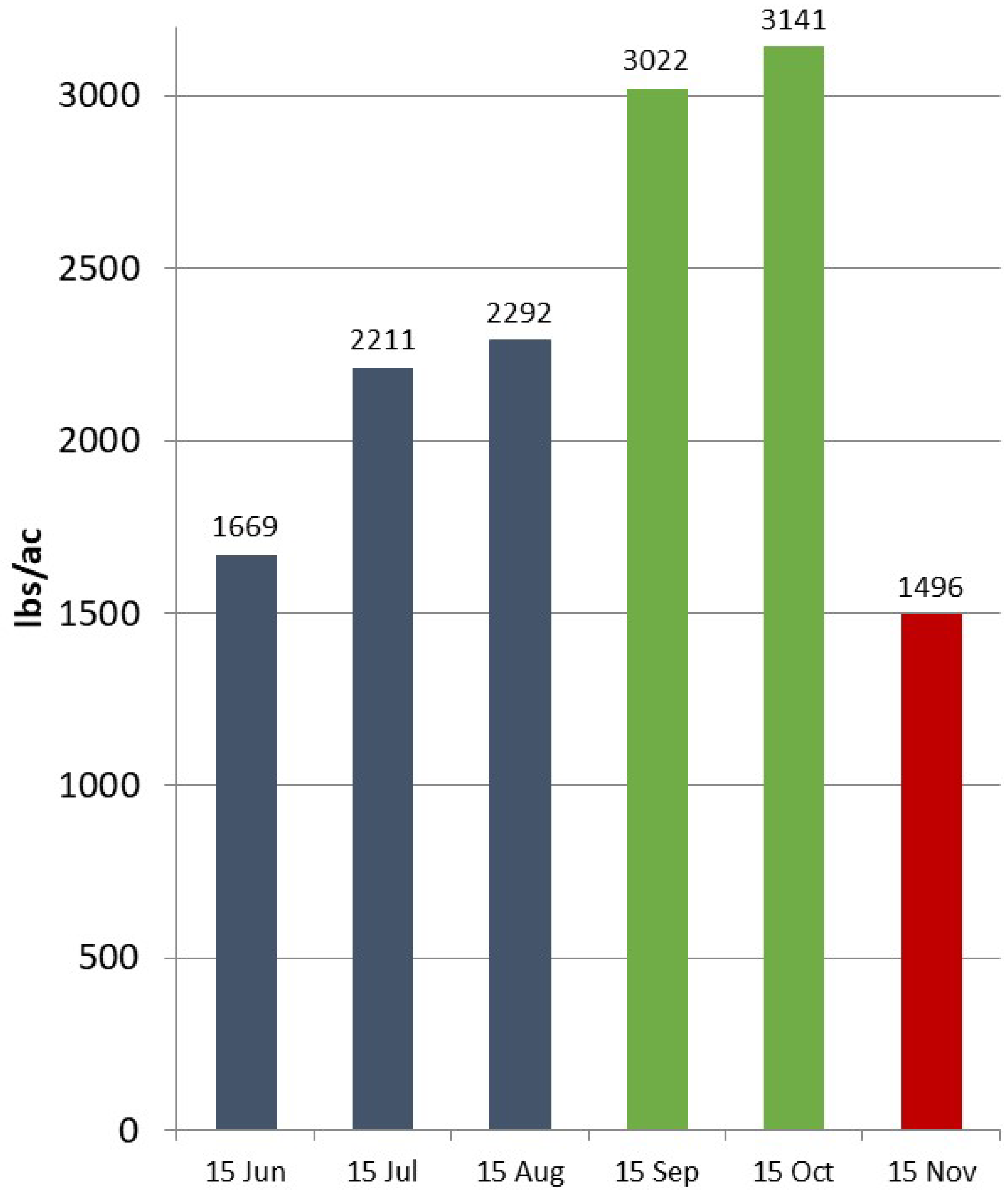


Figure 11. Altai wildrye mean monthly herbage biomass (lbs/ac) on two pastures fall grazed during mid October to mid November, 1984-2002.

Table 16. Conjectural contributions of weight/acre in pounds (lbs) and percentage (%) by the tiller types to total herbage biomass during monthly periods and percent (%) and pounds (lbs) of crude protein from tiller types during the mid October to mid November grazing period.

						Grazing Period	
Tiller Type	Jun	Jul	Aug	Sep	Oct	% CP	lbs CP
Lead Tillers							
lbs/ac	1669	1335	1068	855	684	8%	54.7
%	100.0	60.4	46.6	28.3	21.8		
Secondary Tillers							
lbs/ac		876	1224	1591	1432	10%	143.2
%		39.6	53.4	52.6	45.6		
Fall Tillers							
lbs/ac				576	1025	12%	123.0
%				19.1	32.6		
Total Herbage							
lbs/ac	1669	2211	2292	3022	3141	10.2%	320.9

Table 17. Fall grazing period, stocking rate, and pasture cost on the Biologically Effective concept compared to those on the Traditional concept.

Management Strategy Concept	Grazing Period	# Days	# Months	Acres per C-C pr	Acres per AUM	Pasture Cost $	Cost per day $
Biologically Effective Altai wildrye	14 Oct to 13 Nov	30	0.98	1.39	1.41	12.18	0.41
Traditional Native Rangeland	14 Oct to 13 Nov	30	0.98	4.04	4.11	35.39	1.18
% Difference	same	same	same	-65.59	-65.69	-65.58	-65.25

Table 18. Fall cow and calf weight performance and net returns on the Biologically Effective concept compared to those on the Traditional concept.

Management Strategy Concept	Gain per Head lbs	Gain per Day lbs	Gain per Acre lbs	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Cost/lb Calf Gain $
Biologically Effective							
Calf	50.34	1.82	37.12	35.24	23.06	16.59	0.24
Cow	42.60	1.62	32.22				
Traditional							
Calf	17.73	0.59	4.38	12.41	-22.98	-5.69	1.99
Cow	-52.20	-1.74	-12.90				
% Difference							
Calf	183.93	208.47	747.49	183.96	200.35	391.56	-87.94
Cow	181.61	193.10	349.77				

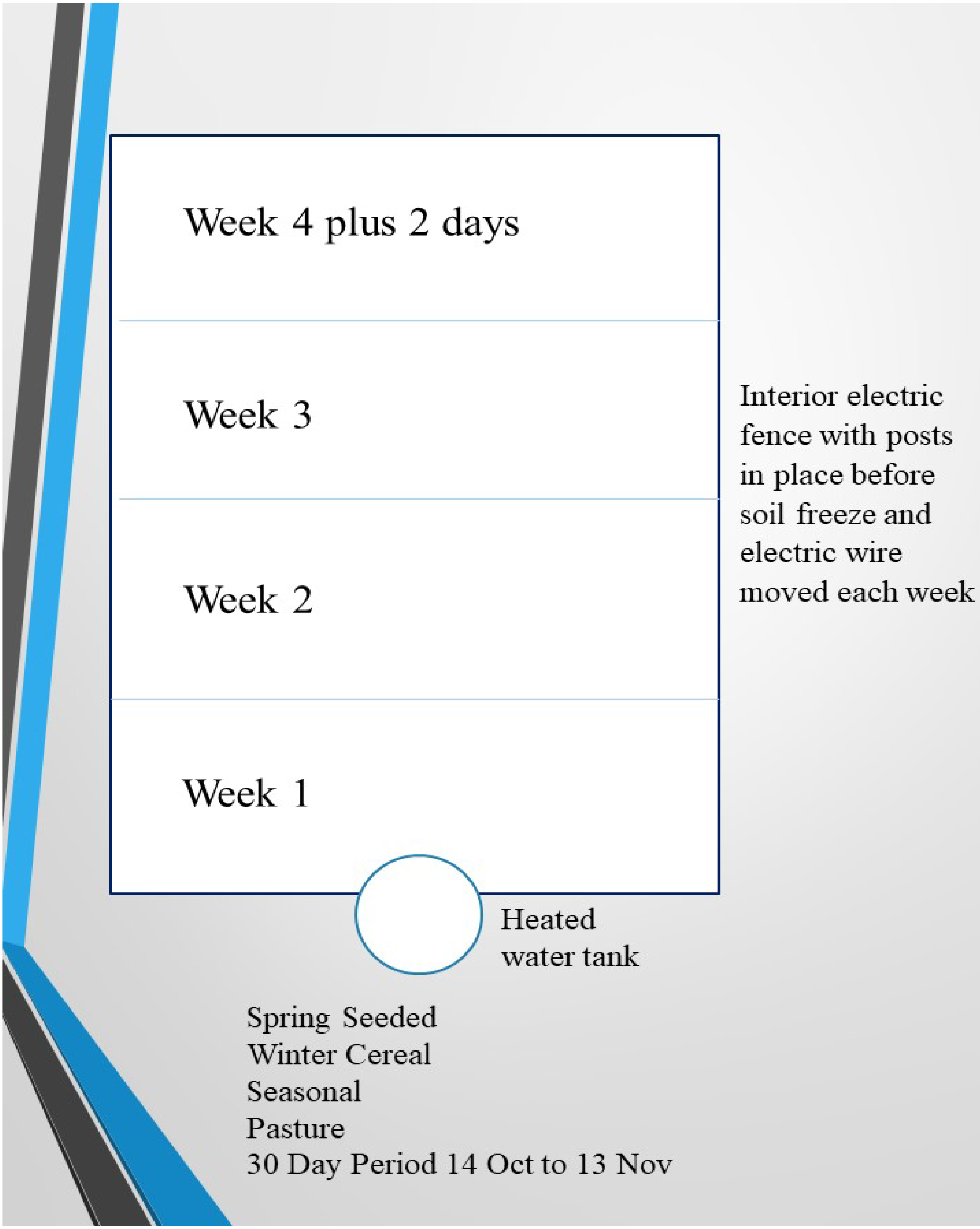
Table 19. Fall grazing period, stocking rate, and pasture cost on the Biologically Effective concept compared to those on the Traditional concept.

Management Strategy Concept	Grazing Period	# Days	# Months	Acres per C-C pr	Acres per AUM	Pasture Cost $	Cost per day $
Biologically Effective Spring Seeded Winter Cereal	14 Oct to 13 Nov	30	0.98	0.47	0.48	19.70	0.66
Traditional Cropland Aftermath	14 Oct to 13 Nov	30	0.98	6.63	6.74	13.26	0.44
% Difference	same	same	same	-92.91	-92.88	48.57	50.00

Table 20. Fall cow and calf weight performance and net returns on the Biologically Effective concept compared to those on the Traditional concept.

Management Strategy Concept	Gain per Head lbs	Gain per Day lbs	Gain per Acre lbs	Pasture Weight Gain Value $	Net Return per C-C pr $	Net Return per Acre $	Cost/lb Calf Gain $
Biologically Effective							
Calf	60.00	2.00	127.66	42.00	22.30	47.45	0.33
Cow	31.50	1.05	67.02				
Traditional							
Calf	12.57	0.42	1.90	8.80	-4.46	-0.67	1.05
Cow	-48.17	-1.61	-7.27				
% Difference							
Calf	377.33	376.19	6618.95	377.27	600.00	7182.09	-68.57
Cow	165.39	165.22	1021.87				

Costs and returns for fall pasture forage types, grazed during 30 day period 14 Oct to 13 Nov.					
		Altai Wildrye Complementary Pasture	Spring Seeded Winter Cereal Seasonal Pasture	Cropland Aftermath Seasonal Pasture	Native Rangeland Fall Pasture
Land Area	ac	1.39	0.47	6.63	4.04
Product Cost	$/ac	8.76	41.75	2.00	8.76
Forage Wt	lb/ac	1645.0	1908.0	135.0	223.0
Forage Cost	$/ton	10.65	43.77	29.63	78.57
Crude Protein	%	10.2	12.2	2.0	4.8
Crude Protein Wt	lb/ac	80.0	233.0	2.70	10.70
Crude Protein	lb/d	3.06	3.66	0.66	1.44
Crude Protein	$/lb	0.11	0.18	0.74	1.18
Total Feed Cost	$	12.18	19.70	13.26	35.39
Cost/day	$	0.41	0.66	0.44	1.18
Acc. Calf Wt	lb	50.34	60.00	12.57	17.73
Return/c-cp	$	38.16	40.30	-0.69	-17.66
Return/ac	$	27.45	85.74	-0.10	-4.37
Calf Wt Gain	$/lb	0.24	0.33	1.05	2.00


Week 4 plus 2 days
Week 3
Week 2
Week 1
Interior electric fence with posts in place before soil freeze and electric wire moved each week
Heated water tank
Spring Seeded Winter Cereal Seasonal Pasture
30 Day Period 14 Oct to 13 Nov

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Determining Soybean Inoculation Strategies in Western North Dakota

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Introduction

Soybean (*Glycine max* L.) production in western North Dakota remains challenging because of the limiting environmental conditions and because the crop is relatively new to the region, and locally validated agronomic recommendations are limited. With soybean acreage in the region having more than doubled over the past decade (USDA-NASS, 2024), the need for region specific inoculation and nitrogen management recommendations become more crucial.

One of the most critical knowledge gaps in supporting soybean expansion into "soybean-virgin" soils is understanding how to effectively use *Bradyrhizobium* inoculants to maximize biological nitrogen fixation (BNF) and reduce dependence on costly nitrogen fertilizers. More than half of soybean nitrogen requirements are typically supplied through symbiosis with *Bradyrhizobium*, with the remainder obtained from soil mineralization or fertilizer inputs (Salvagiotti et al., 2008). For example, a 40 bu/ac soybean crop requires roughly 200 lb N/ac, illustrating the magnitude of nitrogen inputs required for sustainable production (Tamagno et al., 2018).

Farmers currently have access to several inoculation products and application methods, including peat, liquid, and granular formulations. However, limited data exist on which products and rates perform best under the distinct soil and climatic conditions of western North Dakota. Moreover, inoculation effectiveness is known to vary with initial soil nitrogen levels and with the presence—or absence—of native rhizobia populations. In newly cultivated soybean fields, these populations are often low or absent, making inoculation critical for establishing an effective symbiosis.

Therefore, research is needed to determine the most efficient inoculant sources and application rates under varying soil nitrogen conditions.

Material and Methods

To identify the most effective inoculation strategies for maximizing soybean production in western North Dakota, this study evaluated the performance of liquid and granular inoculants derived from different rhizobia strains—*Bradyrhizobium japonicum* (liquid) and *B. elkanii* (granular)—applied at varying rates and in combination with a starter nitrogen fertilizer treatment. This trial was conducted at the Dickinson REC, in a field with no soybean history.

The experiment included the following treatments:

• Three inoculation rates (1×, 2×, and 3× the label recommendation) for both liquid and granular formulations (six treatments total);

• Two treatments combining the 1× inoculation rate (liquid or granular) with 20 lb N/ac starter fertilizer to simulate field starting-nitrogen differences;

• One treatment combining 1× liquid and 1× granular inoculants to evaluate potential strain complementarity;

• Two controls: an untreated control and a control with 20 lb N/ac starter fertilizer.

In total, 11 treatments were evaluated using a randomized complete block design with four replications at each site.

The soybean variety was ND170009GT, treated with a fungicide (Allegiance®). The inoculation treatments were mixed in the seed envelopes prior to planting. All other agronomic management followed the NDSU's soybean production field guide (Kandel & Endres, 2023). Soybean was solid seeded at 145,000 seeds acre^{-1} on May 12 and was harvested on Oct. 3.

Grain yield, oil, and protein content data were determined.

Results

Soybean yield, protein, and oil content were influenced by inoculant type, rate, and the use of starter fertilizer (Table 1). In general, inoculated treatments outperformed the non-inoculated check, confirming the importance of rhizobial inoculation in recently introduced soybean-growing areas such as western North Dakota.

Grain yield ranged from 31.0 to 40.8 bu/ac. The greatest yields were obtained by the 1× Liquid, 3× Liquid, 2x Granular, 3x Granular, and 1× Granular + 20 lbs N/ac treatments, which were statistically similar and significantly greater than the untreated check. These results suggest that both liquid and granular inoculants are effective at improving yield under the study conditions.

Protein content varied from 31.30 to 35.63%, while oil ranged from 16.69 to 17.94%. The 3× Granular treatment had the greatest protein concentration (35.63%). Greater protein levels were often associated with lower oil concentrations, consistent with the typical inverse relationship between these two seed components.

The check and nitrogen-only treatments showed lower protein and moderate-to-high oil content, reinforcing that biological nitrogen fixation contributes more effectively to protein accumulation than small additions of inorganic N.

Table 1. Grain yield, protein content and oil content of soybean treated with different inoculants at varying rates, and the use of a starter fertilizer. Dickinson, ND, 2025.

Treatment	Yield (bu/acre)		Protein (%)		Oil (%)	
1x Liquid	40.6	A	33.44	BCD	17.01	CD
2x Liquid	37.1	AB	32.97	CD	17.59	AB
3x Liquid	40.8	A	33.27	BCD	17.12	BCD
1x Granular	37.3	AB	32.56	DE	17.56	ABC
2x Granular	40.4	A	34.61	AB	16.82	D
3x Granular	40.4	A	35.63	A	16.69	D
1xLq+1xG	39.2	AB	34.15	ABC	16.91	D
1x Liquid + 20 lbs/ac N	36.0	ABC	32.41	DE	17.51	ABC
1x Granular + 20 lbs/ac N	40.7	A	34.13	ABC	16.80	D
20 lbs/ac N	34.5	BC	31.30	E	17.94	A
Check	31.0	C	32.34	DE	17.69	AB

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test.

Conclusions

- Inoculation significantly improved soybean yield compared to the untreated check, confirming the necessity of *Bradyrhizobium* inoculation in western North Dakota soils lacking native rhizobia populations.
- Liquid and granular inoculants performed similarly in yield, though higher granular inoculant rates (3×) tended to enhance protein content, likely offsetting the inhibitory effect of elevated soil nitrate (45 lbs N/ac) on nodulation.
- The study will be replicated at least for one more year to confirm the results, as only one year of the trial is not sufficient to draw impactful conclusions and recommendations.

Acknowledgements

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Emergence and Early Growth of Hard Red Spring Wheat in Acid Soils of Western North Dakota

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Introduction

Acidic acres have been increasing in western North Dakota. Decades of nitrogen fertilizer usage paired with slightly acidic soil parent materials and poorly buffered soils has lowered soil pH below 5.5 on many farmable acres. These areas of strong acidity are adversely impacted by reduced nutrient availability, soil microbial activity, and stunted roots from aluminum (Al) toxicity, ultimately causing yield penalties.

While surface liming can improve these acidic areas, lime availability in western North Dakota remains limited. The Sidney (MT) sugar beet processing plant is one of the few local sources and supplies sugar beet waste lime to the region. However, considering the costs of hauling and application, lime remains a scarce and expensive resource, complicating efforts to address soil acidity effectively.

There is a critical need to help farmers identify alternatives to reduce yield losses on acid-affected soils. For wheat farmers, one potential alternative is variety selection. Yield is determined by three main components: plants per acre, seeds per plant, and seed size. Soil acidity can adversely affect all three components. Specifically, wheat seeds, being small, are typically planted at depths within the stratified acidic soil layer (0-3 inches), exposing them to stress early in their development. This stress can impair emergence, early growth, and overall plant stands.

Previous research conducted in Dickinson, Minot and Lefor looked at wheat variety selection in acidic soils (Buetow, 2022). However, these studies did not account the effects of soil pH on wheat plant stands. Additionally, the author of the study noted that drought conditions during the experimental period introduced high variability, preventing reliable recommendations from being drawn from the dataset (Buetow, 2022).

Because producers in North Dakota are not familiar with the need to lime and infrastructure of lime sources and application equipment in the region are in the early stages and considered costly, many are searching for alternative short-term solutions. This project aims to assess the emergence and early growth of Hard Red Spring Wheat (HRSW) varieties in acidic soils of western North Dakota. By identifying wheat varieties better suited to low soil pH conditions, this research aims to provide short-term solutions for local farmers. The long-term goal is to use the collected data to select the best-performing varieties for future field trials that will also evaluate grain yield and quality.

Material and Methods

The study was conducted in a growth chamber (Conviron GEN1000), under controlled environmental conditions (12 hours of light at 25°C, 12 hours of dark at 20°C) using a completely randomized design with four replications. The assessed varieties were: AP Gunsmoke CL2, Ascend-SD, Brawn-SD, MN Rothsay, MT Carlson, MT Dutton, ND Heron, ND Stampede, ND Thresher, ND Horizon, ND Frohberg, ND Roughrider, and Dagmar. Additionally, the varieties Lanning and SY Soren were included as tolerant and susceptible checks, respectively.

In the spring, acidic soil (pH ≤ 5.5) was collected from a collaborating farmer's field near Lefor, ND. Soil pH characterization was conducted *in situ* using a Veris Cart (Veris Technologies, Inc., Salina, KS). Soil was collected from areas of the field with the lowest pH according to the map generated by the Veris Cart. Furthermore, soil samples were collected at the 0-3 inch depth and analyzed for chemical and physical attributes.

The acidic soil was then ground and placed in plastic trays and planted with ten seeds of each variety per cell. Due to in field variability, prior to experimental setup the batch of soil used in the study was tested again for soil pH using a portable handheld pH meter (MW802 PRO, Milwaukee Instruments, Rocky Mount, NC). The test indicated pH 4.8 for the batch of soil used in the study.

Daily emergence was assessed and the emergence rate index (ERI) was calculated using the formula:

$$ERI = \frac{\sum_{i=1}^{k} Ni}{k}$$

Where:

- k = Total number of time intervals (e.g., days)
- Ni = The number of seeds that emerged in the time interval.

At 10 days after planting, final emergence counts were taken.

Four weeks after planting, whole plants (including roots) were hand-harvested and measured for plant height, root length, culm diameter, phenological stage, and fresh weight. Subsequently, wheat was placed in paper bags and dried in a forced-air circulation oven until constant weight, for dry mass calculation.

Data analysis was performed using the software SAS 9.4 (The SAS Foundation, Cary, NC).

Results

Soil analysis results are shown on Table 1.

Soil Test

	N (Nitrate)	P (Olsen)	K	Cl	S	B	Zn	Fe	Mg	Ca	Na	OM	CCE	Al (Exchangeable)	Soil pH	Buffer pH
	lb/acre	ppm	ppm	lb/acre	lb/acre	ppm	ppm	ppm	ppm	ppm	ppm	(%)	(%)	ppm		
0-3"	12	23	521	2	7	0.5	1.72	89.9	445	1456	13	6.3	0.6	2.90	5.5	6.3

Emergence

The emergence rate index (ERI) varied significantly ($p < 0.05$) among the evaluated HRSW varieties and the variety SD Ascend exhibited the greatest ERI (33.5), indicating the fastest emergence rate (Table 1). A higher ERI reflects a quicker and more uniform emergence, which favors rapid canopy development, improved early-season competition with weeds, and overall better stand establishment.

In contrast, SD Brawn and ND Roughrider recorded the lowest ERI values (17.70 and 13.44, respectively) and where statistically lower than all the other varieties. The lower ERI's observed for these varieties may suggest a greater susceptibility to acidic soil conditions and potential aluminum toxicity.

Despite Lanning's known genetic tolerance to aluminum toxicity and low soil pH, it did not outperform the other varieties in terms of ERI, including those that do not carry the *TaAlmt1* gene responsible for aluminum tolerance. Fordyce et al. (2020) similarly reported that regionally adapted *TaAlmt1* carriers did not outperform adapted noncarriers under field conditions. However, more positive results were observed for Lanning in terms of final emergence, where this variety outperformed the susceptible check and most other varieties.

Final emergence (%) did not differ significantly among varieties, ranging from 80% for ND Roughrider and 100% for SD Ascend. Despite the lack of statistical differences in total emergence, the variation in ERI underscores differences in early seedling vigor and tolerance to acidic soil conditions among the tested varieties.

Table 1. Emergence rate index (ERI) and final emergence rate (%) of 15 wheat varieties grown under acidic soil conditions (pH 4.8).

Variety	Emergence Rate Index		Emergence (%)
AP Gunsmoke	29.58	AB	87.5
Dagmar	28.97	AB	90.0
Lanning (tolerant check)	25.50	B	97.5
MN Rothsay	29.72	AB	97.5
MT Carlson	26.70	AB	87.5
MT Dutton	28.97	AB	95.0
ND Frohberg	24.42	BC	92.5
ND Heron	26.43	AB	97.5
ND Horizon	29.18	AB	97.5
ND Roughrider	13.44	D	80.0
ND Stampede	30.69	AB	97.5
NDThresher	25.88	B	92.5
SD Ascend	33.50	A	100.0
SD Brawn	17.70	CD	85.0
SY Soren (susceptible check)	31.01	AB	90.0

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

Early Growth

Among the evaluated hard red spring wheat (HRSW) varieties, only plant height, root length, and root fresh weight varied significantly ($p < 0.05$) (Table 2). Culm diameter averaged 1.7 mm, tops fresh weight 9.5 g, tops dry matter 1.6 g, root dry matter 2.5 g, and crop growth stage averaged Zadoks 17 across varieties.

Overall, SD Ascend outperformed all other varieties in terms of plant height, root length, and root fresh weight. The superior early growth performance of SD Ascend is consistent with its rapid emergence and likely reflects greater vigor and adaptation to acidic soil conditions.

Aluminum toxicity primarily targets the root apex, where Al exposure inhibits cell elongation and division, resulting in root stunting and impaired water and nutrient uptake (Panda et al., 2009). Consequently, root length is often used as an indicator of Al susceptibility or tolerance. In this study, varieties MT Dutton, ND Frohberg, ND Thresher, and SD Brawn exhibited the shortest roots, suggesting a higher sensitivity to aluminum toxicity. MT Dutton has been described as exhibiting partial/moderate tolerance to aluminum and acidic soils (Cook et al., 2023). However, we observed relatively short root length for MT Dutton under our experimental conditions (pH 4.8), suggesting that its tolerance may be limited under more severe acid stress or may be environment-dependent.

Root fresh weight also differed significantly among varieties ($p < 0.05$). SD Ascend had the greatest root fresh weight, confirming its superior vigor and ability to maintain active root growth under stress. In contrast, ND Frohberg, ND Thresher, and SD Brawn produced the lowest root fresh weights, consistent with their reduced root length.

Lanning also showed low root fresh weight despite showing intermediate root length. This discrepancy suggests that while Lanning was able to sustain primary root elongation under acidic conditions, its overall root biomass accumulation was limited. Such a response could indicate a reduced development of lateral roots or a lower root tissue density, both of which are common adaptive trade-offs observed in aluminum-tolerant genotypes (Kochian et al., 2015). Aluminum exclusion mechanisms, such as those mediated by the *TaALMT1* gene, may protect the root apex but do not necessarily promote biomass accumulation if carbon allocation to roots is constrained under stress. Consequently, Lanning's moderate elongation combined with lower root mass may reflect a tolerance mechanism centered on maintaining root function rather than vigorous root growth under low pH stress.

Root biomass accumulation represents an integrated response to both root elongation and lateral root proliferation. Varieties able to maintain greater root fresh weight under low pH likely possess more efficient carbon allocation to belowground tissues and enhanced physiological resilience against aluminum-induced growth inhibition. Conversely, reduced root biomass may limit nutrient and water uptake capacity, potentially constraining shoot development and yield potential under field conditions (Ofoe et al., 2023).

The variation observed in root fresh weight complements differences in emergence and early growth, highlighting genetic variability in tolerance to soil acidity and aluminum toxicity among the tested HRSW varieties.

Table 2. Plant height (cm), root length (cm), culm diameter (mm), tops fresh weight (g), root fresh weight (g), root dry matter (g), and crop stage (Zadoks) of 15 wheat varieties grown under acidic soil conditions (pH 4.8).

Variety	Plant Height (cm)		Root Length (cm)		Culm Diameter (mm)	Tops Fresh Weight (g)	Root Fresh Weight (g)		Tops Dry Matter (g)	Root Dry Matter (g)	Crop Stage (Zadoks)
AP Gunsmoke	7.5	EF	11.4	BC	1.6	9.0	9.2	BC	1.6	2.0	17
Dagmar	7.0	F	13.4	ABC	1.6	8.4	8.7	BC	1.8	1.9	18
Lanning (tolerant check)	8.0	BCDE	11.3	BC	1.8	11.2	7.8	C	1.7	1.9	15
MN Rothsay	7.5	EF	12.8	BC	1.7	8.7	11.2	BC	1.6	2.8	17
MT Carlson	8.1	BCDE	12.1	BC	1.7	9.8	9.4	BC	1.7	2.1	16
MT Dutton	8.5	BCD	10.3	C	1.8	10.4	10.1	BC	1.8	2.8	18
ND Frohberg	8.6	BCD	10.3	C	1.6	9.8	8.1	C	1.6	1.9	17
ND Heron	8.7	ABC	11.5	BC	1.5	8.7	8.9	BC	1.5	2.3	15
ND Horizon	8.3	BCDE	14.5	AB	1.8	10.1	13.8	BC	2.1	3.7	16
ND Roughrider	8.8	AB	11.3	BC	1.9	8.3	10.3	BC	1.3	3.1	18
ND Stampede	8.4	BCD	10.8	BC	1.6	9.1	9.8	BC	1.5	2.7	16
ND Thresher	7.8	DEF	9.6	C	1.7	9.5	7.0	C	1.5	1.6	15
SD Ascend	9.6	A	16.9	A	1.9	12.3	19.2	A	2.3	4.6	18
SD Brawn	7.8	CDEF	9.9	C	1.6	7.8	6.6	C	1.4	2.4	17
SY Soren (susceptible check)	8.1	BCDE	10.7	BC	2.0	9.0	8.5	BC	1.4	2.1	16

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

Conclusions

- SD Ascend consistently demonstrated superior performance in terms of emergence rate, plant height, root length, and root biomass, indicating strong adaptation and vigor under acidic soil conditions.
- Varieties such as ND Frohberg, ND Thresher, and SD Brawn showed sensitivity to acidic conditions, exhibiting both shorter roots and lower root biomass, implying reduced ability to cope with aluminum stress.
- Variety selection represents a viable short-term management strategy for producers facing acid soils in western North Dakota, offering an immediate alternative while long-term liming solutions remain limited.
- The trial will be repeated one more time to confirm the results, as only one run of the trial is not sufficient to draw impactful conclusions and recommendations.
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Boron Fertilization to Boost Canola Production in Western North Dakota

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Introduction

In recent years, canola acreage has significantly expanded in western North Dakota due to market downturns for small grains and advancements in cultivar traits. However, canola production in North Dakota is significantly impaired by plant nutrient availability, including micronutrients. Boron (B) is a critical nutrient for canola, as the crop is a heavy user of B and is highly sensitive to its deficiency.

Boron deficiency, although rare, typically occurs in sandy areas of fields. This deficiency may be exacerbated by aluminum toxicity to roots, a condition commonly associated with acidic sandy soils—an issue that is becoming increasingly prevalent in western North Dakota. According to AGVISE Laboratories, Inc. (2024), soil samples with soil test boron below 0.4 ppm in 2024 in western North Dakota were between 16-44%.

The current recommendation for boron application in North Dakota is 2 lbs/acre for canola. However, this recommendation is based on data generated in northeast North Dakota, a region characterized by cooler and more humid conditions compared to the semi-arid climate of western North Dakota. While claims of boron fertilization benefits in canola production exist, scientific evidence supporting these claims remains inconclusive, with inconsistent effects observed on yield, protein content, and oil quality.

To address this knowledge gap, the objective of this study is to evaluate the effects of different rates, timings, and modes of boron application on the yield and seed quality of canola in western North Dakota. This research aims to provide region-specific recommendations that optimize canola production and address nutrient management challenges in the area.

Material and Methods

Field experiments were conducted at the Dickinson Research Extension Center and the North Central Research Extension Center (Minot, ND). A randomized complete block design, with four replications was used. Treatments consisted of either three rates of granular B fertilizer (2, 5 and 10 lbs B ac^{-1}) broadcasted after planting, or a foliar B application at 10-20% bloom stage at three different rates (0.25, 0.50 and 1 lbs B ac^{-1}), or the combination of a granular application at planting (1lbs ac^{-1}) and a foliar application at 10-20% bloom (0.25 and 0.50 lbs ac^{-1}) plus a zero B control treatment.

The canola hybrids were InVigor® L345PC in Dickinson and DK400TL in Minot. In both locations, plots were solid seeded with a no-till drill. The seeding rate in Dickinson was 600,000 plants acre^{-1} and Minot it was 450,000 plants acre^{-1}. Prior to planting, soil samples were pulled from the experimental area for soil chemical and physical analysis. Preference was given for fields deficient in Boron (B < 0.5 ppm).

In Dickinson, all plots received a baseline fertilization with 120 lbs. ac^{-1} Nitrogen as Urea and 20 lbs. ac^{-1} Sulfur as ammonium sulfate. In Minot, the plots received 150 lbs. ac^{-1} N (urea plus Anvol™), 50 lbs. ac^{-1} Phosphorus (MAP), and 30 lbs. ac^{-1} Sulfur (ammonium sulfate).

In Dickinson, granular boron at the rate of 0, 1, 2, 5 or 10 lbs B ac^{-1} was broadcasted immediately after seeding in each corresponding experimental plot. In Minot, those same rates of granular boron were placed in furrow. At 10-20% bloom stage, the remainder of the treatments received a foliar spray of Boron (Solubor®, Sodium Borate 20.5%), at 0.25, 0.50 and 1 lbs B ac^{-1}, using a backpack sprayer.

Each experimental unit measured 10 ft x 30 ft (300 ft^2). Local air temperatures and precipitation were quantified using NDAWN weather stations.

At the end of the growing season (after physiological maturity), plants in the central rows of each plot were mechanically harvested and quantified for grain yield, harvest moisture content, test weight, and, seed composition analysis (i.e., seed oil content), due to the importance of seed quality for end users.

Data was analyzed through an analysis of variance using a mixed-model approach (PROC GLIMMIX) in SAS 9.4. Within each site, the fixed factors were be fertilizer rates, timing and modes of application. The random factor was replication.

Results

Soil pH was moderately acidic at Dickinson (5.5) and near neutral at Minot (6.5), which may influence boron availability and uptake (Table 1). Boron concentrations were low and similar between sites (0.35 ppm at Dickinson and 0.44 ppm at Minot). However, boron soil tests are known to be highly variable and often unreliable (Marupaka et al., 2022).

Site	pH	OM %	N (nitrate) lbs. ac^{-1}	P (Olsen) ppm	K ppm	Ca ppm	Mg ppm	S lbs. ac^{-1}	Soluble Salts mmho/cm	B ppm	CEC meq
Dickinson (0-6”)	5.5	4.0	17	19	332	1685	435	10	0.2	0.35	23
Minot (0-6”)	6.5	3.3	10	11	356	2285	395	7	0.2	0.44	18

Source: Agvise

Both in Dickinson and Minot, a large precipitation (>2 inches) was recorded in the days following canola seeding, which resulted in poor plant establishment. In Dickinson, the plant population was 317,462 plants acre^{-1}, equivalent to 53% of the target plant population.

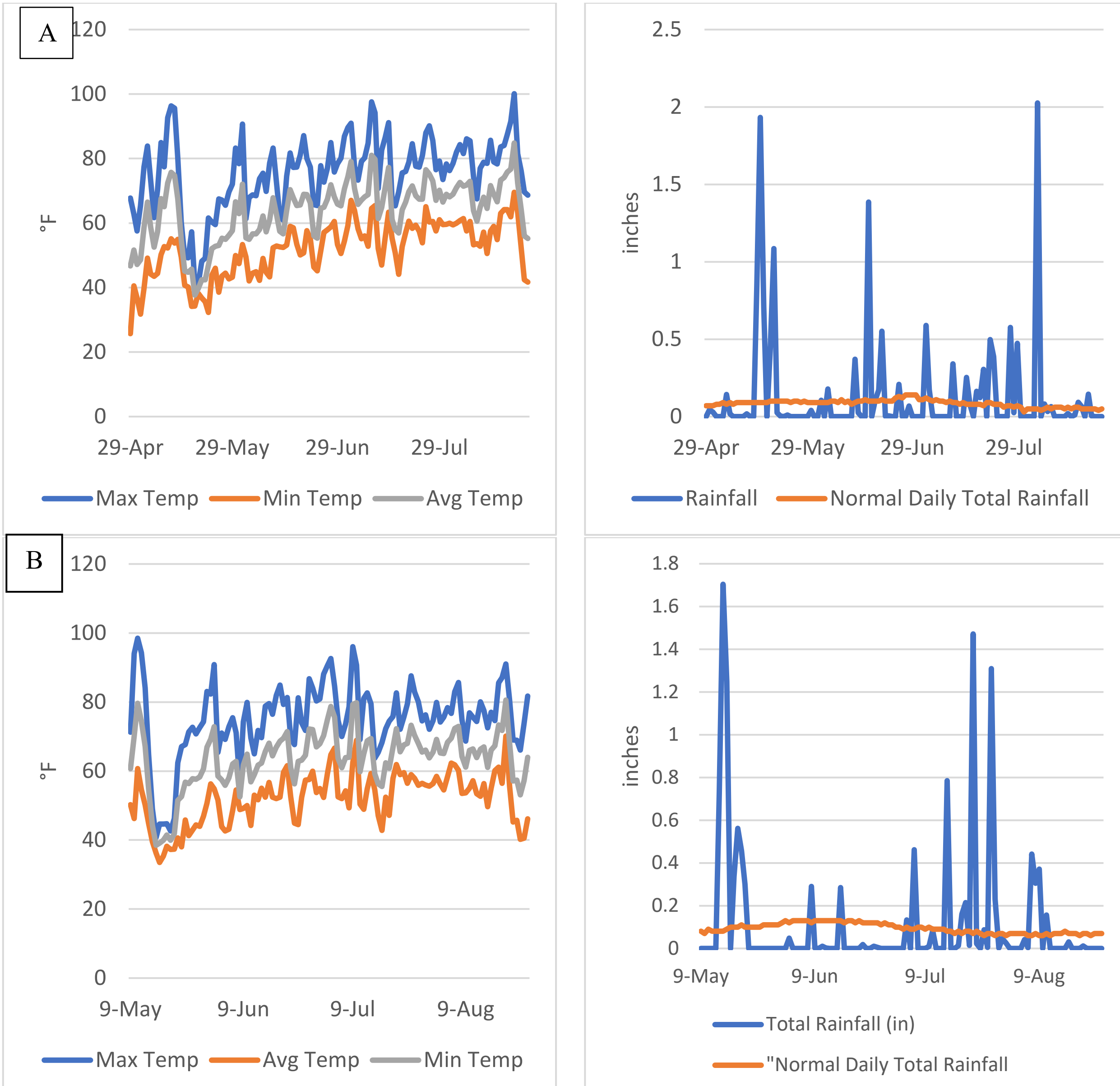

Figure 1. Maximum, minimum and average temperatures and total rainfall in Dickinson, ND (A) and Minot (B) for the duration of the trials. Source: NDAWN

Significant differences in grain yield ($p < 0.05$) were observed only at the Dickinson site (Table 1). Seed oil content was not significant ($p > 0.05$) in any of the locations.

Grain yield at Dickinson responded positively to boron fertilization, with treatments producing higher yields than the untreated check. The combination of granular and foliar boron (1 lb/ac granular + 0.25 lb/ac foliar) resulted in the highest yield (2,351 lbs/ac), significantly outperforming the check (25% yield increase). The lowest rate treatment (0.25 lbs/a foliar) still provided a 14% yield increase in Dickinson.

Treatments with either foliar or granular boron alone generally showed intermediate yield gains. This could be due to the fact that canola plants need a steady supply of boron throughout the growing season, and one single application at planting may not be sufficient to meet the crop needs during the reproductive stages, when the plant's boron demand increases (Ma et al., 2019).

In Minot, while the results were not statistically significant, we could still observe a yield gain trend with the different treatments compared to the control. The treatment consisting of 0.50 lbs B acre^{-1} had the greatest yield overall (2,448 lbs ac^{-1}), with a 14% increase compared to the control treatment.

Overall, the results suggest that low rates and combined application methods tended to be more effective than single-source applications in enhancing canola yield under the conditions at Dickinson.

Table 2. Grain yield (lbs ac^{-1}) and seed oil content (%) of canola as a function of different boron fertilizer sources, rates and application timings in Dickinson, ND and Minot, ND (2025).

	Dickinson		Minot	
Treatment	Yield (lbs/ac)	Oil (%)	Yield (lbs/ac)	Oil (%)
1 lb/ac Granular + 0.25 lb/ac Foliar	2,351 A	43.1	2,405	42.2
1 lb/ac Foliar	2,296 AB	43.0	2,307	42.0
1 lb/ac Granular + 0.50 lb/ac Foliar	2,269 AB	43.0	2,412	41.9
0.25 lb/a Foliar	2,127 ABC	43.5	2,344	42.6
10 lbs/ac Granular	2,088 BCD	43.0	2,328	42.4
2 lbs/ac Granular	2,082 BCD	42.8	2,399	42.7
5 lbs/ac Granular	2,014 CD	43.2	2,337	43.7
0.50 lbs/ac Foliar	1,957 CD	43.2	2,448	42.3
Untreated Check	1,874 D	43.2	2,153	42.7

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

Conclusions

- The effects of Boron fertilization in canola yield seem to be positive.
- The combination of a granular B application at planting plus a foliar B application at 10-20% bloom produced the best results.
- This correlation, however, seems to be location dependent.
- Boron sources, rates and timing of application do not affect seed oil content in canola.
- The study will be conducted again next year to confirm the results and to provide more sound recommendations to canola growers.

Acknowledgments

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Managing Soybean Inoculation in Western North Dakota Acidic Soils

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Summary:
Soybean production in western North Dakota is challenged by the lack of native Rhizobium populations and increasing soil acidity caused by long term no-till associated with ammonia-based fertilizers. Acidic soils reduce Rhizobium survival, limiting nodulation and nitrogen fixation. This study examines the interaction between soil pH and inoculant type to improve soybean establishment and symbiotic performance under low pH soil conditions.

Objective:
Evaluate the performance of three commercial soybean inoculants under varying soil pH conditions to identify Rhizobium strains most tolerant to acidity and suitable for western North Dakota soils.

Methods:
Soybean variety *ND17009GT* was grown in 1-gallon pots under controlled conditions in a growth chamber simulating early-season weather in Stark County. Seeds received one of three inoculant treatments:

- **Granular:** LAL FIX Start (*B. elkanii*)
- **Liquid:** BYSI-N (*B. japonicum*)
- **Peat:** N-Charge Soybean (*B. japonicum*)
  A non-inoculated control was also included.

In the spring, soil from a collaborating farmer field was collected. Soil pH was 5.1. The soil was placed in 1-gallon pots and adjusted to four pH levels (4.7, 5.1, 5.5, 6.0) using either aluminum sulfate to acidify the soil or pelletized lime to increase the soil pH. Emergence, nodulation, and early growth traits were evaluated.

Results

Emergence rate and final emergence were influenced by both inoculant and pH, though not their interaction (Table 1). Inoculated treatments had higher emergence (>85%) than the control (77%). Slightly acidic soils (pH 5.1–5.5) favored faster and more uniform emergence compared to strongly acidic (pH 4.7) or neutral (pH 6.0) soils.

Table 1. Emergence rate index and final emergence of soybean as a function of inoculant products and soil pH.

Inoculant	Emergence Rate Index	pH	Emergence Rate Index	Inoculant	Final Emergence (%)	pH	Final Emergence (%)
Granular	52.71 A	4.7	43.29 B	Granular	93 A	4.7	81 C
Liquid	48.54 A	5.1	51.87 A	Peat	90 A	5.1	93 A
Peat	48.43 A	5.5	51.79 A	Liquid	87 A	5.5	90 AB
UTC	43.12 B	6	45.86 B	UTC	77 B	6	83 BC

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

Soybean early growth was influenced by soil acidity only (Table 2). Plants at pH 4.7 were elongated (etiolated) and had thinner stems, indicating stress and possible aluminum toxicity.

Table 2. Plant height and stem diameter of soybean as a function of soil pH.

pH	Plant Height (cm)	Stem Diameter (mm)
4.7	24.85 A	2.81 B
5.5	21.94 AB	3.15 A
5.1	21.83 AB	3.12 A
6.0	19.05 C	3.24 A

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

The number of nodules per plant and the weight of nodules per plant varied significantly as a function of the interaction between inoculants and pH levels ($p < 0.05$) (Table 4). Overall, it was observed that the granular inoculant produced the greatest number of nodules per plant, followed by the liquid inoculant. Statistically, the peat inoculant was similar to the untreated check in terms of number of nodules.

One possible reason for the superior performance of the granular inoculant is the presence of *Bacillus velezensis* in its formulation. *B. velezensis* is known to promote phosphorus (P) solubilization, increasing the amount of plant-available P in the soil solution. In acidic soils, aluminum (Al^{3+}) readily reacts with phosphate ions, forming insoluble aluminum phosphates and thereby reducing P availability to plants. By solubilizing P, *B. velezensis* may indirectly mitigate Al toxicity's suppression of root growth and nodule formation. This mechanism may help explain the greater nodule numbers observed with the granular inoculant.

Support for this mechanism is found in the work of Buetow (2022), who reported that in furrow-applied phosphorus trials on acid-affected soils (pH < 5.5) in western North Dakota, adding P improved yield responses in a susceptible hard red spring wheat variety, suggesting P availability can alleviate some of the constraints imposed by low pH and Al toxicity. Similarly, a report from Oklahoma State University showed that in acid Oklahoma soils (pH < 5.5) banding P fertilizer significantly reduced Al toxicity and improved root performance in winter wheat.

In terms of weight of nodules, it was observed a linear growth for the granular inoculant that followed the pH increase. For the liquid inoculant, the weight of nodules at pH 5.1 was the greatest across all treatments. The peat inoculant had low nodule weight, being for the most part similar to the untreated check.

Table 3. Number and weight of nodules per plant as a function of inoculant and soil pH.

Inoculant	pH	Number of nodules per plant		Weight of nodules per plant (g)	
Granular	4.7	3.87	D	0.0344	CDE
	5.1	19.47	A	0.0825	BCD
	5.5	15.20	B	0.0964	BC
	6.0	19.33	A	0.1030	B
Liquid	4.7	0.20	DE	0.0023	E
	5.1	10.00	C	0.1711	A
	5.5	8.67	C	0.0788	BCD
	6.0	2.93	DE	0.0302	DE
Peat	4.7	0.00	E	0.0000	E
	5.1	2.07	DE	0.0361	CDE
	5.5	1.40	DE	0.0058	E
	6.0	0.73	DE	0.0125	DE
UTC	4.7	0.07	E	0.0005	E
	5.1	0.47	DE	0.0063	E
	5.5	0.47	DE	0.0038	E
	6.0	0.52	DE	0.0094	DE

Means followed by the same letter within a column are not significantly different according to the least significant difference (LSD) test at 5%.

Conclusions

- Inoculant type and soil pH significantly affect soybean emergence and nodulation.
- The granular inoculant (*B. elkanii*) performed best in acidic soils, producing more nodules.
- Extremely acidic conditions (pH 4.7) impaired plant growth, suggesting aluminum toxicity.
- Slightly acidic soils (pH 5.1–5.5) supported better plant emergence.
- A second experimental run is underway to confirm these results before developing grower recommendations.

Acknowledgements

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Sulfur Fertilizer for Spring Wheat Production in Western North Dakota-Year 3

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Introduction

Sulfur fertilization has gained increasing attention as sulfur deficiencies become more frequent across western North Dakota. Although plants require sulfur in relatively small amounts, it is essential for chlorophyll formation and overall growth. Historically, soils supplied most of the sulfur needed by crops, but sulfur availability is strongly influenced by environmental conditions that control mineralization. As a result, sulfur deficiencies have become more common, especially in sandy soils or soils with less than 2% organic matter, which often respond to sulfur fertilizer application (Franzen and Grant, 2008). Managing sulfur can be challenging. Sulfate-based fertilizers such as ammonium sulfate are generally the most dependable sources because they are immediately plant available. In contrast, elemental sulfur requires biological oxidation before becoming available, a process that may be too slow to meet the early-season demands of short-season crops like wheat. To address the limited information on sulfur requirements for hard red spring wheat in western North Dakota, this project aims to (1) evaluate the effects of various sulfur fertilizer sources and application rates on spring wheat yield and quality in western North Dakota, and (2) assess how these sulfur sources and rates interact with different nitrogen management strategies to influence spring wheat performance in the region.

Materials and Methods

This research has been conducted at three different locations in western North Dakota: Dickinson, Minot, and Hettinger since 2023. In 2025 trial, spring wheat was planted at 1.1 million pure live seeds/ac in early May, and all fertilizer treatments were broadcast immediately after planting. The study evaluated three fertilizer treatments: (1) sulfur sources (ammonium sulfate, gypsum and elemental sulfur); (2) sulfur application rates (0, 5, 10, 15 and 20 lb S/ac); and (3) nitrogen application rates (0 and 125 lb N/ac). The 0 lb N/ac treatment received nitrogen equivalent to 30 lb/ac of ammonium sulfate, supplemented with urea to balance N levels. Treatments were arranged in a randomized complete block design with a split-split-plot structure and four replications. Plot sizes were 30 × 10 ft in Dickinson and Minot, and 22 × 5.33 ft in Hettinger. At physiological maturity, the center 5 ft of each plot was harvested using a plot combine to measure seed yield and protein content. Seed moisture and test weight were determined with a commercial grain tester, and grain yield was adjusted to the standard 13.5% moisture.

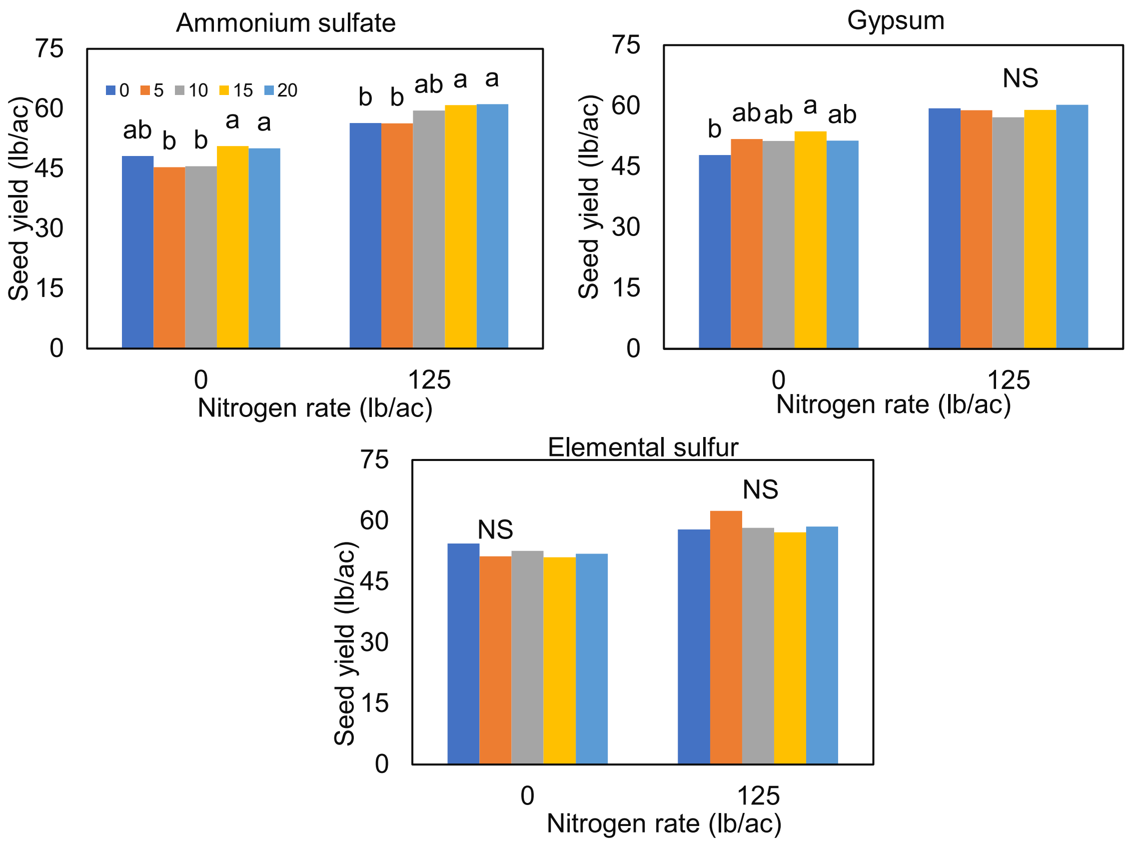
Results

Our results in 2025 trial showed that 15 and 20 lb/ac sulfur produced the top spring wheat seed yield when ammonium sulfate was used as sulfur source (Fig. 1). When gypsum was used, again 15 lb/ac was one of the top seed yield producing sulfur rate particularly when no nitrogen was applied. With 125 lb/ac nitrogen application, no difference was observed for seed yield among different sulfur rates when gypsum was used as a sulfur source. Similarly, no differences were observed among different sulfur rates when applying elemental sulfur as sulfur source in both 0 and 125 lb/ac nitrogen rates.

Conclusions and recommendations to producers

With continuous three years of research on sulfur fertilizer management in spring wheat, we found that 15 lb/ac sulfur with ammonium sulfate as a sulfur source improves spring wheat yield in western North Dakota. When broadcasting sulfur fertilizer in spring before planting, producers are encouraged to apply ammonium sulfate as sulfur source as no yield gains were consistently observed with other sources such as gypsum and elemental sulfur. Yield gains with ammonium sulfate sulfur fertilizer application may be limited when weather becomes severe like extreme drought and heat. Additional research comparing spring versus fall application timings are still needed to develop stronger region-specific sulfur recommendations for spring wheat in western North Dakota.

Fig. 1. Spring wheat seed yield affected by different sulfur rates (0, 5, 10, 15 and 20 lb/ac), sulfur fertilizer sources (Ammonium sulfate, gypsum and elemental sulfur) and nitrogen rates (0 and 125 lb/ac) in 2025. Columns marked with same letter are not significantly different at P ≤ 0.05.



Reference

Franzen, D.W., and C.A. Grant. 2008. Sulfur response based on crop, source, and landscape position. Agron. Mono. pg. 105-116. Am. Soc. Agron. Madison, WI. DOI:10.2134/agormonogr50

Acknowledgements: We would like to thank North Dakota Wheat Commission for funding support and entire research crew for help.

Soil Amendments and Inoculum to Improve Corn Production Under Soil Acidity and No-Till Dryland System in Western North Dakota

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Introduction

Dryland corn production is steadily expanding in the semi-arid western region of North Dakota due to the availability of early-maturing hybrids and widespread adoption of no-till systems. Corn helps diversify small-grain–dominated rotations and supports long-term soil health and pest management. However, precipitation in this region is low and highly variable, making drought a recurring challenge. In 2023, nearly 20% of corn acres in North Dakota were affected by moderate to exceptional drought, with the greatest impact occurring in the west (USDA-NASS, 2023). Because this region is semi-arid, moderate drought events occur periodically, and in 2025 the crop experienced combined moisture stress and soil-acidity stress.

A growing concern in no-till dryland corn systems is the accumulation of surface soil acidity due to long-term use of ammonium-based nitrogen fertilizers without soil mixing. Corn is moderately sensitive to low pH, and increased acidity can intensify drought effects by restricting nutrient availability, reducing root growth, and limiting water uptake. Soil amendments such as biochar, lime, and arbuscular mycorrhizal fungi (AMF) inoculum have the potential to alleviate acidity and improve soil water retention and nutrient uptake. Biochar can enhance cation exchange capacity and moisture storage, lime supplies base cations that neutralize acidity, and AMF increases effective root area and improves nutrient and water acquisition. When combined, these amendments may offer complementary or synergistic benefits that help corn tolerate the combined stresses of acidity and moisture limitation.

The objective of this study was to evaluate the effects of single and combined applications of lime, biochar, and AMF inoculum on corn growth and yield under no-till dryland conditions at the Dickinson Research Extension Center (DREC) in western North Dakota.

Materials and Methods

Field Operations and Treatments

This field experiment was conducted at the Dickinson Research Extension Center, North Dakota, in 2025 under no-till dryland conditions. Eight soil-amendment treatments were evaluated in a Randomized Complete Block Design (RCBD) with four replications. Each plot measured 30 ft × 10 ft. The treatments included AMF, AMF + Biochar, Biochar, Control (no amendment), Lime, Lime + AMF, Lime + AMF + Biochar, and Lime + Biochar.

Field operations began with application of pelletized lime at 6.9 tons/acre, a commercial AMF inoculant containing 300 propagules g^{-1} of *Rhizophagus intraradices* applied at 8 lb/acre, and commercial biochar applied at 1% of soil weight in the surface 6-inch layer (Genesis Biochar). Biochar was split-applied before planting this year. A mixture of all three amendments at their single rates and a no-amendment control were also included.

Biochar and lime were applied on April 30, 2025, followed by pre-emergence herbicide application. Urea fertilizer was applied at 190 lb N/acre on May 1, and corn was planted on May 8 targeting ~40,000 plants/acre (≈292 seeds per 300 ft^2, assuming 95% germination).

Data Collection and Analysis

Three subsamples were collected from each plot to assess plant growth. Leaf Area Index (LAI) was measured on September 9, 2025. Grain weight (lb) and moisture (%) were recorded on October 10, 2025, and grain yields were adjusted to the standard corn moisture content of 15.5% following established procedures (Hicks & Thomison, 2020). The moisture-adjusted yields were then converted to bushels per acre (bu/acre) by dividing the values (lb/acre) by 56, the standard test weight for corn at 15.5% moisture.

Statistical analysis was conducted using ANOVA for RCBD, and treatment means were separated using Fisher's LSD at $\alpha = 0.05$. All analyses and graphing were performed in RStudio version 4.5.1, and results are reported as mean ± standard deviation (SD).

Results

Leaf Area Index (LAI)

LAI showed significant treatment effects ($P < 0.05$). From figure 1, AMF alone (Treatment A) produced the highest LAI (0.62), significantly greater than most other treatments. Treatments with combined lime, biochar, and AMF generally produced intermediate LAI values. The lowest LAI values were observed in AMF+Biochar (B) and Control (D), indicating that AMF effectiveness may be influenced by amendment combinations.

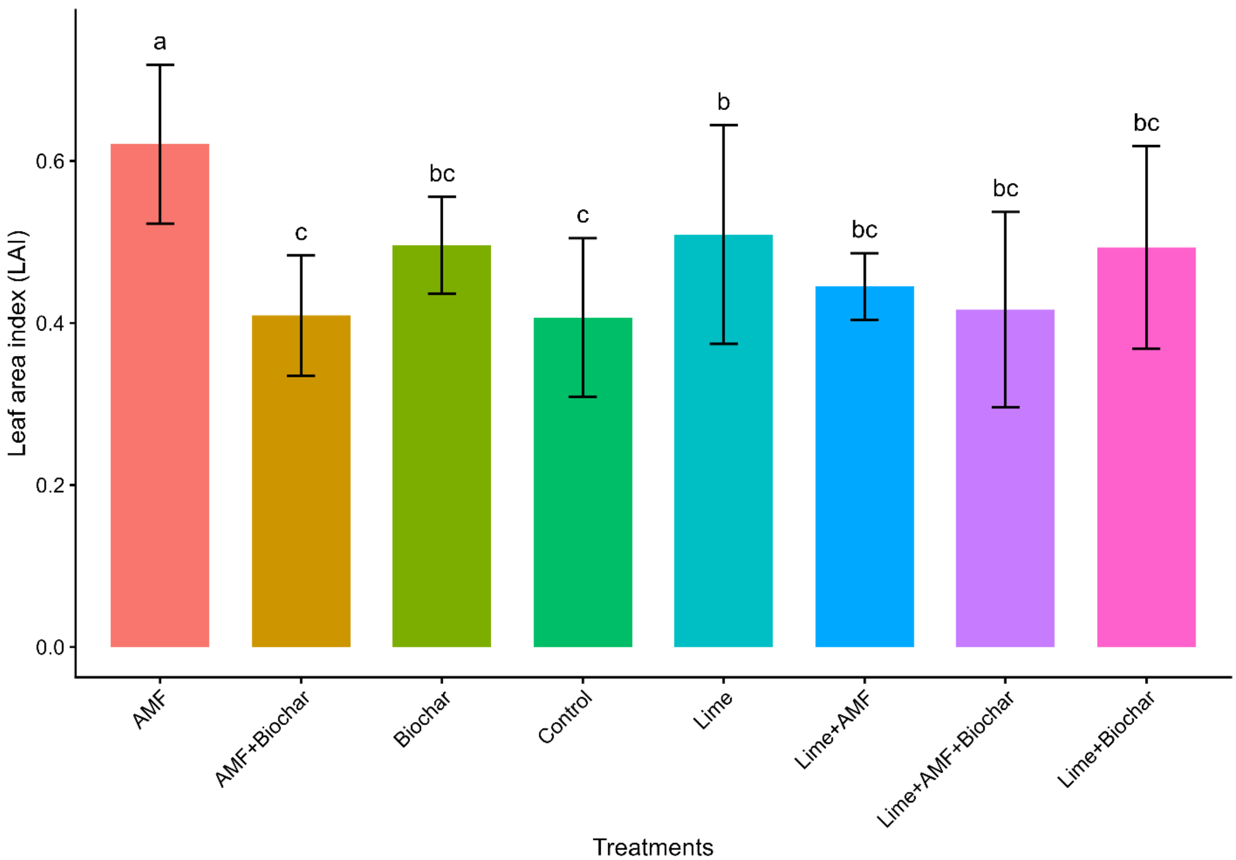

Fig. 1. Leaf Area Index (LAI) on 9/9/2025 across eight soil amendment treatments. Bars represent mean ± SD. Letters indicate significant differences at P ≤ 0.05 (LSD).

Grain Yield (Bu/acre)

Yield response differed significantly among treatments (Fig. 2). The Lime + AMF + Biochar treatment produced the highest yield at ≈142 bu/acre, followed closely by Lime + AMF and Lime, which also showed relatively high yields (≈135–138 bu/acre). In contrast, Control and Lime + Biochar resulted in the lowest yields (≈122–128 bu/acre).

Overall, treatments that included lime—especially when combined with AMF—tended to improve corn productivity under dryland acidic soil conditions.

ANOVA detected a statistically significant treatment effect on grain yield ($P = 0.0217$). Based on Fisher's LSD ($\alpha = 0.05$), the Lime + AMF + Biochar treatment was significantly higher than Lime + Biochar and AMF + Biochar, whereas most other treatments were statistically similar.

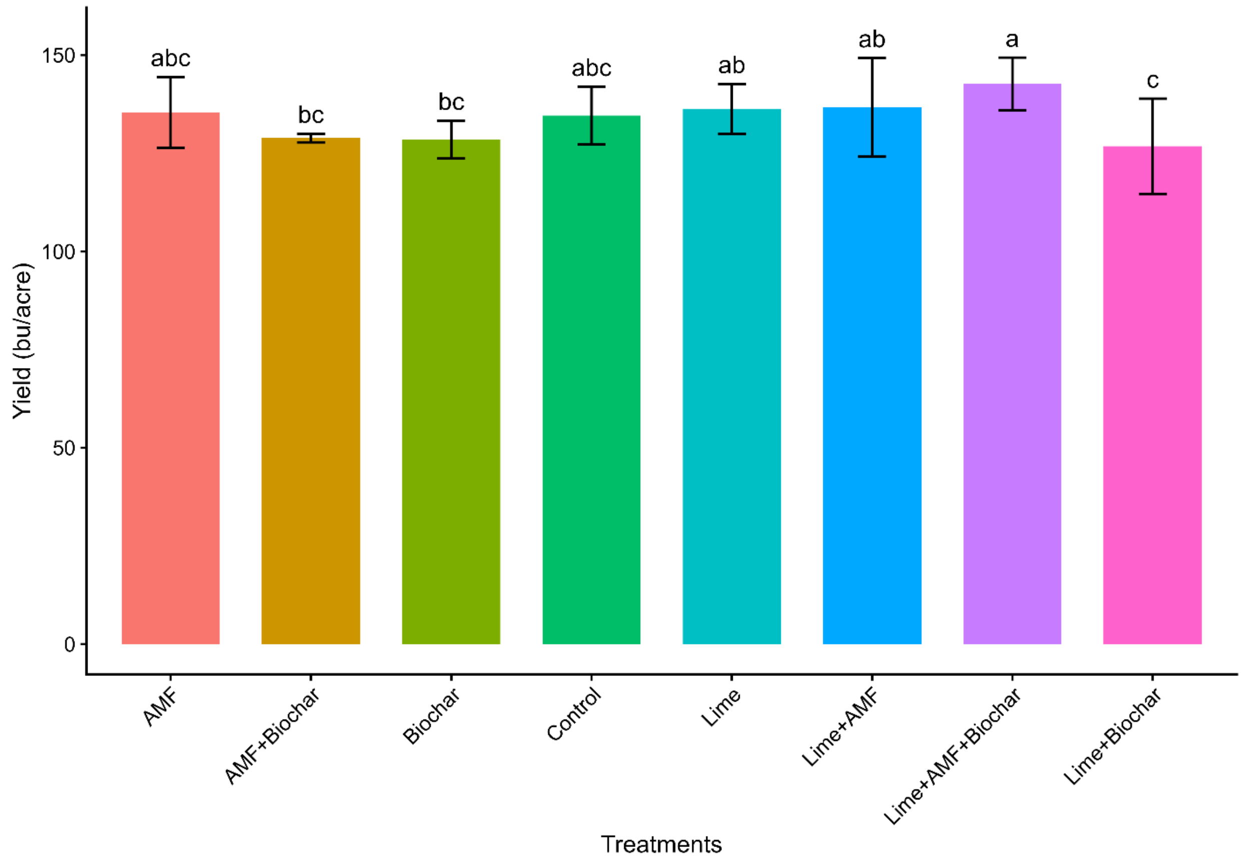

Fig. 2. Corn grain yield (bu/acre) across eight soil amendment treatments. Bars represent mean ± SD. Letters indicate significant differences at P ≤ 0.05 (LSD).

Conclusion

The 2025 dryland corn trial at DREC showed measurable effects of soil amendments and AMF inoculation on plant growth and yield. AMF alone significantly increased LAI, indicating enhanced vegetative growth. For yield, lime-containing treatments—particularly Lime + AMF + Biochar—consistently produced superior performance. These results suggest that combining lime and AMF may help mitigate surface soil acidity commonly observed under long-term no-till and ammonium-based fertilization, thereby improving corn performance under moisture-limited conditions.

However, year-to-year variability and environmental interactions are expected in dryland systems. Additional multi-year data will strengthen conclusions and support development of region-specific soil amendment recommendations for improving dryland corn productivity in western North Dakota.

References

Hicks, D. R., & Thomison, P. R. (2020). *Procedure for calculating grain yields of agronomic crops*. Ohio State University Extension.

USDA National Agricultural Statistics Service. (2023). *Crop progress & condition reports and drought impact summaries*. U.S. Department of Agriculture.

Lime Impacts on Spring Wheat Yield

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Introduction

Acidic soils (pH below 5.5) limit nutrient availability and can suppress biological activity. Soil acidity has increased in North Dakota largely due to fertilizer applications. During nitrification, hydrogen ions are released as nitrogen is converted to plant-available nitrate; these hydrogen ions drive acidity and add to the soil's acidity pool. Lime (calcium carbonate) is an amendment that neutralizes acidity by reacting with hydrogen ions to raise soil pH. The Dickinson Research Extension Center has been researching and developing lime recommendations for North Dakota soils (Augustin, 2023).

Materials and Methods

The initial soil pH at the research site was 5.3. Half of the site was limed on April 16–17, 2025, using 98G pelletized lime from Calcium Products (2025) at a rate of 6.8 tons calcium carbonate equivalent per acre. The lime rate was based on Augustin (2024), which reported a 0–3 inch soil buffer pH of 6.6. Lime was surface-applied with a pendulum spreader and not incorporated. The remaining half of the site received no lime.

Plots measured 540 ft^2, and each treatment had three replications. Roughrider spring wheat was planted on May 6, 2025, at 1.1 million live seeds per acre using a no-till drill. The crop was managed for weeds and other pests as needed. Initial soil tests showed 40 lbs N/ac, 18 ppm P, and 402 ppm K. Urea was applied at 50 lbs N/ac. Plots were harvested with a small-plot combine to determine yield.

Results

The untreated check spring wheat yielded 34.3 bu/ac. Whereas, the limed spring wheat yield was 39.8 bu/ac (figure 1). The lime treatment did increase the soil pH (figure 1). This area will be transitioned into a rotational study to see the impacts of different crop rotations and fertilizer practices on soil pH where agri-nomics will be accounted for.

Table 1. Yield and soil pH impacts from lime treatments.

Treatment	Wheat Yield -bu/ac-	Soil pH -0-3in depth-
Lime	39.8	7.5
Check	34.3	5.5
p-value	0.05	0.04

Works Cited

Augustin, C.L. 2023. Surface applied lime impacts on North Dakota no-till soils. p. 63-4 *In* Dickinson Research Extension Center 2023 Annual Report. NDSU Dickinson Research Extension Center, Dickinson, ND. https://www.ndsu.edu/agriculture/sites/default/files/2024-04/2023%20Annual%20Report%20for%20Print_0.pdf

Calcium Products. 2025. 98G pelletized lime. ISU Research Park, 2520 N Loop Dr, #7100. Ames, IA. https://www.calciumproducts.com/

Sugarbeet Waste Lime Impacts on Field Pea Aphanomyces

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Introduction

Aphanomyces root rot—caused by *Aphanomyces euteiches*—poses a major threat to field pea production. Effective management strategies are urgently needed. Sugarbeet waste lime a by-product of sugar processing has been found to reduce Aphanomyces in sugarbeets (Bresnahan et al., 2003).

Materials and Methods

Lime was hand applied after field pea planting at rates of 0, 2.25, 4.5, and 9 tons calcium carbonate per acre. Additionally, soils were inoculated with Aphanomyces with treatments of 0 and 4.5 tons calcium carbonate per acre. The plots were 265 ft^2 with five replications. Plots were harvested with a small plot combine to determine crop yield.

Results

Treatments did not impact field pea yield (p-value 0.41) or quality (0.33). The average yield was 29 bu/ac. A similar study conducted at the Williston Research Extension Center observed similar results. However, nodule counts appeared to be positively correlated with lime treatments at the previous year WREC trial.

Works Cited

Bresnahan, G.A., A.G. Dexter, C.E. Windels, J.R. Branter, and J.L. Luecke. 2003. The effect of spent lime on sugarbeet yield and *Aphanomyces cochlioides* suppression. Sugarbeet Res. Ext. Rept. 33:273-276.

Aphanomyces and Sugarbeet Waste Lime Impacts on The Subsequent Spring Wheat Crop

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Introduction

A study was initiated in 2024 to observe impacts of sugarbeet waste lime treatments on field pea and Aphanomyces. Sugarbeet waste lime a by-product of sugar processing has been found to reduce Aphanomyces in sugarbeets (Bresnahan et al., 2003). Lime treatments in 2024 did not impact field pea yield or quality. Spring wheat was planted in these plots 2025 to determine if there was a yield improvement the subsequent year.

Materials and Methods

In the spring of 2024, lime was hand applied after field pea planting at rates of 0, 2.25, 4.5, and 9 tons calcium carbonate per acre. Additionally, soils were inoculated with Aphanomyces with treatments of 0 and 4.5 tons calcium carbonate per acre. The plots were 190 ft^2 with five replications. Roughrider spring wheat was planted at 1.1 million live seeds per acre using a no-till drill. Plots were harvested with a small plot combine to determine crop yield.

Results

Treatments did not impact spring wheat yield (p-value 0.11) or quality (0.93). The average yield was 21.5 bu/ac.

Works Cited

Bresnahan, G.A., A.G. Dexter, C.E. Windels, J.R. Branter, and J.L. Luecke. 2003. The effect of spent lime on sugarbeet yield and *Aphanomyces cochlioides* suppression. Sugarbeet Res. Ext. Rept. 33:273-276.

Integrated Crop-Livestock System Research Publications: Past, Present and Future

Douglas Landblom

Long-term integrated crop-livestock system research was initiated in 2010 when winter triticale/hairy vetch was planted following spring wheat harvest. All other crops in the diverse crop rotation were planted the following spring 2011. Experimentally, spring wheat grown continuously year-after-year in the same experimental fields served as the control (HRSW-CTL) and was compared to spring wheat grown in a five-crop rotation (HRSW-ROT). The diverse rotation consisted of spring wheat, dual cover crop (fall seeded winter triticale-hairy vetch harvested for hay followed by planting a multi-specie cover crop), forage corn, field pea-forage barley mix, and sunflower. Beef cattle steers were used as the grazing animal for the earlier grazing research projects and later grazing research evaluated replacement heifer pregnancy using fixed-time artificial insemination comparing heifers in confinement to heifers grazing integrated system forages.

Past Publications:

Songul Senturklu, Douglas G. Landblom, Robert Maddock, Tim Petry, Cheryl J. Wachenheim, and Steve I. Paisley. Effect of yearling steer sequence grazing of perennial and annual forages in an integrated crop and livestock system on grazing performance, delayed feedlot entry, finishing performance, carcass measurements, and systems economics. J. Anim. Sci. 2018. 96:2204-2218. https://doi.org/10.1093/jas/sky150.

Songul Senturklu, Douglas Landblom, Steven Paisley, Cheryl Wachenheim, and Robert Maddock. Frame score, grazing and delayed feedlot entry effect on performance and economics of beef steers from small- and large-framed cows in an integrated crop-livestock system. Animals 2021, 11, 3270. https://doi.org/10.3390/ani11113270.

Songul Senturklu, Douglas Landblom, and Steve Paisley. Effect of bale grazing following annual forage grazing on steer grazing and feedlot performance, muscling ratio, carcass measurements, and carcass value. In Dickinson Research Extension Center 2019 Annual Report. https://www.ndsu.edu/agriculture/sites/ default/files/2022-10/34.%202019%20Steer-Bale%20Grazing_Annual%20Rpt_Senturklu-Landblom_5-14-19.pdf.

Abstract:

Ninety-six yearling steers of similar frame score were randomly assigned to an extended grazing study to compare grazing native range (NR) or a sequence of NR and annual forages (ANN: field pea-barley, corn, cover crop) to evaluate the effect of further extending the grazing season feeding cover crop bales (bale grazing) on steer performance and economics. At the end of bale grazing, the steers were finished at the University of Wyoming, Sustainable Agriculture Research and Extension Center (SAREC), Lingle, Wyoming, and slaughtered at the Cargill Meat Solutions plant, Ft. Morgan, Colorado. Compared to previous research, bale grazing cover crop bales extended the grazing season from 180 days to an average 218.5 days. Forage sequence grazing combined with cover crop bale grazing supported ADG of 2.13 lb/day for steers that grazed a combination of NR and ANN forage compared to 1.74 lb/day for steers that grazed NR for the entire period ($P = 0.01$). The ANN steers were 87.2 lbs. heavier at the end of grazing ($P = 0.001$). For comparison, animal muscling is expressed as the ratio of hot carcass weight (HCW) per 100 pounds to square inches of ribeye area measured between the 12th and 13th ribs. Steers that grazed NR had greater ribeye area per 100 pounds of carcass weight than ANN (REA:CWT = NR 0.91; ANN 0.88, $P = 0.04$); however, ANN steer percent intramuscular fat (IMF) was greater ($P = 0.01$), but ANN system marbling score did not differ. One of the research questions addressed in this investigation was to determine the effect of extended NR and ANN for grazing on subsequent steer finishing performance (Table 2) and carcass measurements (Table 4). Steers that grazed the sequence of NR and ANN forage grew at a faster rate of gain and ended the grazing season heavier ($P = 0.01$) than the NR steers. Entering the feedlot heavier, the ANN steer growth was numerically slower than the NR steers ($P = 0.30$); however, the ANN steer shrunk ending weight was 63 pounds heavier at the end of the finishing period. For carcass measurements (Table 4), ANN steer HCW averaged 49.0 lbs. heavier than NR steers, but did not differ ($P = 0.11$). Carcass yield expressed as dressing percent ($P = 0.01$) and USDA Yield Grade ($P = 0.01$) were greater for the ANN steers. Nonetheless, the REA:HCW ratio was greater for the NR

steers (P = 0.02). The two-year carcass quality grade was 97.9% Choice or better. Gross carcass value for the NR and ANN steers was nearly the same after two years ($1,959.88 vs. 2,019.86). By the end of the finishing period, ending weight margins did not change appreciably from starting weight margins resulting in gross carcass returns that were. Weight margins among groups entering the feedlot do not change appreciably by the end of the finishing period and gross carcass value is routinely greater and more profitable for steers grazing ANN forages before feedlot entry compared to NR.

Current Publication:
Songul Senturklu, Douglas Landblom, Larry Cihacek. Effect of long-term integrated multi-crop rotation and cattle grazing on no-till hard red spring wheat (Triticum aestivum L.) production, soil health, and economics. Manuscript submitted to Agriculture 2025 for Open Access. The manuscript is currently being reviewed.

Abstract:
A long-term 12-year integrated systems study evaluated spring wheat grown (HRSW-CTRL) continuously on the same land resource when compared to spring wheat (HRSW-ROT) grown in a five-crop rotation: 1) spring wheat, 2) 7-specie cover crop, 3) forage corn, 4) field pea/forage barley mix, and 5) sunflower. Yearling beef cattle steers grazed the field pea/forage barley mix, unharvested corn, and 7-specie cover crop. Spring wheat and sunflowers were marketed as cash crops. The hypothesis was that the supply of nitrogen (N) and crop nutrients from multiple sources (legumes, livestock manure, and decaying roots) would result in similar grain and oilseed yields, but greater net return due to lower input expenses. Twelve-year spring wheat yield was numerically greater for the rotation (ROT) yield (10.75 vs. 11.41 Mt Ha^{-1}, P=0.15), similar for test weight (136.55 vs. 135.70 kg, P=0.62), and greater percent protein (12.94 vs. 13.18%, P=0.18), however, differences were not significant. Economically, HRSW-ROT input cost Ha^{-1} was less (p = <0.001), however, gross return Ha^{-1} (p = 0.55) and net return Ha^{-1} (p = 0.43) were numerically greater, but not significantly greater. Although, nearly all criterion measured were numerically greater for the HRSW-ROT, annual variability (p = <0.001) resulted in no significant difference between the two production management methods.

Future Publications:
Songul Senturklu and Douglas Landblom. Effect of reducing beef cow wintering expense grazing cover crop, corn, and sunflower residues, and stockpiled tame grass pastures on calving performance and economics. The manuscript is being prepared and will be submitted to Agriculture for Open Access early 2026.

Douglas Landblom, Songul Senturklu, Lauren Hanna, Byron Parman, George A. Perry, Steve Paisley. Effect of non-traditional beef heifer management on fixed-time AI and delayed feedlot entry of non-pregnant heifers. The manuscript will be prepared and submitted to Animals in early 2026.

Drought Effects on Soil Microbial Activity, pH and Plant Nutrient Activity

Douglas Landblom, Songul Senturklu, and Larry Cihacek

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[2]Canakkale Onsekiz Mart Universiteis, Canakkale, Turkey
[3]School of Natural Resource Sciences, North Dakota State University, Fargo, ND

Abstract

Drought negatively impacts soil pH, microbial biomass, and soil derived nutrients. Long-term integrated crop, beef, and soil health research at the Dickinson Research Extension Center is designed around a no-till diverse multi-crop rotation (spring wheat, cover crop, corn, pea-barley, sunflower). In the study, beef cattle graze pea-barley, corn, and a 13-specie cover crop to document microbial, fungal, and nutrient change. Precipitation during years 1-5 were normal to slightly above normal. Years 6-10 were drier than normal. Reduced precipitation contributed to reduced SOM content and nitrogen mineralization. For most of the rotation crops, the percent of microbial active carbon, organic C:N ratio, and organic N:inorganic N ratio declined. Ward Lab Haney Test results for 24-hour microbial respiration provide measurements of microbial community and organismal diversity. Mean microbial biomass under drought conditions (2017), in the crop rotation, was 1,637 ng/g of soil. Return to normal precipitation (2019) soil microbial biomass was 4,804 ng/g of soil; a 193.5% increase. With return to precipitation in 2019, mycorrhizal fungi (AMF) did not re-establish among the crops due to excessive precipitation (8-10 in.) during Aug-Sept of 2019. At pH levels less than 5 (strongly acidic), aluminum availability becomes toxic to plants. Drought effected soil pH in this integrated systems research declined 9.5% to a mean crop pH value of 5.95, which at this pH level aluminum is sufficiently hydrated to be non-toxic. Return to normal precipitation (2019) increased the crop rotation pH mean to 6.58.

Introduction

Drought resulting from extended periods of limited precipitation have a substantial impact on soil pH, microbial biomass, and soil derived nutrients for plant growth. A long-term integrated crop, beef, and soil health research project at the Dickinson Research Extension Center is designed around a no-till diverse multi-crop rotation (spring wheat, cover crop, corn, pea-barley, sunflower). In this crop and animal production system, beef cattle graze the pea-barley, corn, and 13-specie cover crop to document microbial, fungal, and nutrient change over time and space. Precipitation during the first five-year crop rotation was normal to slightly above normal. However, the second five-year rotation was drier than normal resulting in nutrient concentration, reduced microbial biomass, and pH decline.

Discussion

The 2016-2020 diverse crop rotation was drier than normal resulting in soil nutrient concentration, reduced microbial and fungal biomass, and pH decline. Potential nitrogen mineralization of soil organic matter (SOM) in the crop rotation suggests that 8.4 mg N/kg of soil are mineralized for each 1.0% increase in SOM. The mean SOM content of soils in the study is 3.97%.

- Periods of reduced precipitation inhibit soil nutrient solubilization and translocation: negatively impacting soil microbial respiration, fungal activity, plant nutrient supply, crop yield, and animal grazing days.
- With drying, soil pH declined as soluble salt became more concentrated resulting in a more acidic soil condition.
- Reduced precipitation contributes to minimized plant and root growth, reduced SOM content and nitrogen mineralization.
- For most of the crops in the diverse crop rotation, the percent of microbial active carbon, organic C:N ratio, and organic N:inorganic N ratios declined.
- 24-hour microbial respiration (Haney Test) provided measurements of microbial community and organismal diversity.
- Mean drought microbial biomass (2017) was 1,637 ng/g of soil.
- Microbial biomass with normal precipitation (2019) was 4,804 ng/g of soil; a 193.5% increase.
- Arbuscular Mycorrhizal fungi (AMF) did not re-establish among the crops due to excessive precipitation (8-10 in.) during Aug-Sept of 2019.
- Declining soil pH approaching 5 or less reduces copper, manganese, zinc, and aluminum availability. At pH levels less than 5 (strongly acidic), unhydrated aluminum(Al^{3+}) is toxic to plants.
- Mean drought effected soil pH declined 9.5% to a mean crop pH value of 5.95, which at this pH level aluminum is sufficiently hydrated to be non-toxic.
- Normal precipitation (2019) increased the crop rotation pH mean to 6.58.
- Sunflower and corn have the potential to bring cations to the soil surface to support pH buffering.

Extending the Breeding Season: Managing for Increased Profit

Douglas Landblom[1] and Songul Senturklu[1,2]

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[2]Department of Animal Science, Canakkale Onsekiz Mart University, Canakkale, Turkey

Profitability drivers in the beef cattle industry can be partitioned into several categories some of which include breeding/crossbreeding, feed resources, calving date/weaning date, and the impact modifying the breeding season length can have on potential profit. Good breeding management defines a specific date to begin breeding heifers and cows and a specific date to end the breeding period. Common breeding season lengths range from 45- to 60-days. Removing herd sires from breeding groups on a predetermined date results in late cycling cows being identified as "open" or not pregnant.

Ultrasound is powerful technology available for pregnancy determination by the local veterinarian. Because ultrasound technology is readily available, there is no reason to remove bulls at a predetermined time. Leaving herd sires with cows for an extended period of time followed by ultrasound pregnancy determination allows the producer to identify late calving cows that are pregnant instead of being identified as "open". Although late calving cows in a given ranch are outside of a predetermined calving window, those same cows may fit perfectly at another ranch that has a different calving window.

The difference in cow value between "open" and "bred" can be significantly large and is related to cow age. As cows age, their productive life shortens, which is reflected in the amount cow buyers are willing to pay. Figure 1, shows the average cow value for various cow ages from a bred heifer to short-term broken mouth cows and the margin or difference between the bred cow value and an open cow. Young 3-year-old cows have the greatest margin of $1,396 compared to an open cow and there is a stepwise margin decline as cows age settling at an average margin of $400 between a short-term bred cow compared to an open cow. These bred cow values illustrate that there is a financial advantage for not removing bulls according to a predetermined breeding period, but rather sorting cows into the predetermined breeding period using ultrasound during the fall pregnancy check. Allowing bulls to remain with breeding groups also reduces labor and resources needed to gather cattle, sort, and haul bulls to a set aside pasture.

Figure 1. Bred cow values and the margin between bred and open cows at various ages.

Outreach List 2025

Name	Topic	Location	Date
Chris Augustin	West River 4-H	Dickinson, ND	Throughout year
Chris Augustin	Lead Slinger's .40.45 4-H Air Rifle Club	Dickinson, ND	Throughout year
Chris Augustin	City of Dickinson Tree Board	Dickinson, ND	1-023-2025
Victor Gomes	DREC Crop Production Research Update - Mercer County Crops Day	Beulah	1-28-2025
Victor Gomes	DREC Crop Production Research Update - Making Cent$ in 2025	Golva	2-4-2025
Victor Gomes	DREC Soil Acidity Research Update - 2025 Crop Update: Soil Management	Belfield	2-5-2025
Victor Gomes	DREC Crop Production Research Update - Hettinger County Crop & Livestock Improvement Association Annual Meeting	Regent	2-6-2025
Victor Gomes & Chandler Gruener	Soybean fertility management – Western Soybean School	Minot	2-18-2025
Victor Gomes & Chandler Gruener	Soybean fertility management – Western Soybean School	Dickinson	2-19-2025
Llewellyn Manske	Grazing Management Workshop	Winner, SD	4-6-Feb-2025
Victor Gomes & Ana Carcedo	Crop Staging and Abiotic Stress ID – Western Crop & Pest Management School	Bismarck	3-5-2025
Chris Augustin	Soil Acidity Management – Western Crop Scout School	Bismarck, ND	3-6-2025
Chris Augustin	Soil Science Panel – Western Crop Scout School	Bismarck, ND	3-6-2025
Victor Gomes	Weed ID Tools – Pesticide Recertification Training	Halliday	3-11-2025
Victor Gomes	Weed ID Tools – Pesticide Recertification Training	Manning	3-20-2025
Rutendo, Nyamusamba, Chris Augustin, Lindsay Malone, Victor Gomes, Brady Goettl, Chandler Gruener, Carlos Pires, Sergio & Leiva Cabello	Cover Crop Summit	Virtual-In-person Hybrid	3-26-2025
Chris Augustin	Southwest CTE Advisory Board	Dickinson, ND	4-3-2025
Douglas Landblom	DREC Ranch Field Day	DREC Ranch HQ	4-16-2025
Victor Gomes	Monitoring and Managing Soil Health - NDSU Extension ANR Basic Training	Online (ZOOM)	5-21-2025
Victor Gomes	Small Grain Staging - IPM Scout Training	Online (ZOOM)	6-2-2025
Llewellyn Manske	Carbon Sequestration in Grasslands	Dickinson, ND	6-10-2025
Douglas Landblom	DREC Advisory Board Meeting	Dickinson	6-10-2025
Victor Gomes	DREC Soil Acidity Research Update - 2025 Froid Research Farm Field Day	Froid, MT	6-18-2025
Chris Augustin	Soil Sample No-till Acid Soils at the 0-7cm Depth (Poster at NACAA AM-PIC; National Finalist)	Billings, MT	7-1-2025
Douglas Landblom	Am. Soc. Anim. Sci. Annual Meeting - Abst	Hollywood, FL	7-6-9-2025

Llewellyn Manske	Low Mineral Nitrogen in Rangelands	Near Manning, ND	7-16-2025
Victor Gomes	DREC Crop Research Update - 2025 DREC Agronomy Field Day	Dickinson	7-17-2025
Krishna Katuwal	Optimize corn production in drought and surface soil acidity (DREC field day-Agronomy)	Dickinson	07-17-25
Victor Gomes & Douglas Landblom	Western Cooperative Credit Union – DREC Crop Tour	Dickinson	7-23-2025
Chris Augustin	Acid Soil Management in North Dakota (Canadian Soil Science Society)	Winnipeg, MB	7-23-2025
Victor Gomes	Southwest North Dakota Soybean Inoculation Insights & Soybean Research Update - NDSC Shop Talk	Elgin	8-5-2025
Llewellyn Manske	Association of National Grasslands Annual Meeting Biologically Effective Grazing	Badlands near Amidon, ND	8-11-2025
Victor Gomes & Ana Carcedo	Crop Staging and Abiotic Stress ID – NDSU ANR Agent In-Service Training	Langdon	8-14-2025
Victor Gomes	Sunflower Survey Training	Dickinson	8-27-2025
Victor Gomes	Soil Acidity Management – Soil Health Workshop	Manning	9-17-2025
Douglas Landblom	DREC Soil Health Workshop	Dickinson/Manning	9-17-2025
Victor Gomes & Ana Carcedo	Differentiating Abiotic Stressors in Soybeans and Wheat – NDSU All Ag Conference	Bismarck	10-28-2025
Victor Gomes	Boron Fertilization to Boost Canola Production – International Canola and Wheat-Durum Outlook Forum	Minot	11-05-2025
Krishna Katuwal	Sulfur fertilizer management in spring canola (canola/wheat outlook & International durum forum)	Minot	11-05-25
Victor Gomes	Boron Fertilization Boosts Canola Production in Western North Dakota – Tri-Society Meeting (Poster)	Salt Lake City, UT	11-11-2025
Victor Gomes	Determining Soybean Inoculation Strategies in Western North Dakota – Tri-Society Meeting (Oral)	Salt Lake City, UT	11-12-2025
Douglas Landblom	DREC Beef Reproductive Strategies	Dickinson	11-13-2025
Krishna Katuwal	Sulfur fertilizer management in spring canola (Northern Canola Grower Association conference)	Via zoom	12-09-25
Victor Gomes	Agronomy Meetings	Dickinson	March-July
Victor Gomes	Western Bi-weekly Crop Calls	Online (ZOOM)	April-September

Outreach Collaborators and Grants 2025

Collaborators	Grant Title	Granting Agency	Amount ($)
Carlos Pires, Chandler Gruener, Victor Gomes, Joao Paulo Flores & Brady Goettl.	Dynamic Soil Properties Assessment and Digital Mapping Across Diverse Land Uses in the Northern Great Plains	Natural Resources Conservation Service	404,929
Richard Wade Webster, Hope Renfroe Becton, Lindsay Malone, Michael Wunsch, Edson Ncube, Victor Gomes, Leandro Bortolon, Janet Knodel, Ana Julia Paula Carcedo, Febina Matthew	Investigating Soybean Seed Treatments and their Integration into Cropping Systems for Management of Soybean Seedling Diseases in North Dakota	ND Soybean Council	69,355
Leandro Bortolon, Chris Augustin, & John Rickertsen	Corn Response to Sulfur Application in Central and Western North Dakota	ND Corn Utilization Council	$65,820
Joseph Ikley, Caleb Dalley & Victor Gomes	Evaluating Metribuzin and Sulfentrazone Rates for Crop Injury and Weed Control Across North Dakota - Year 2	ND Soybean Council	60,500
Victor Gomes, Leandro Bortolon, Edson Ncube, John Rickertsen & Ana Julia Paula Carcedo	Determining Soybean Inoculation Strategies in Western North Dakota	ND Soybean Council	55,208
Victor Gomes, Chris Augustin, Krishna Katuwal & Leandro Bortolon	Boron Fertilization to Boost Canola Production in Western North Dakota	Northern Canola Growers Association	32,869
Lindsay Malone & Victor Gomes	Boots on the Ground 2: AI-Driven Tools for Maximizing Soybean Yield and Profitability	North Central Soybean Research Program	30,000
Leandro Bortolon & Chris Augustin	Variability of Corn Yield Related to Soil Acidity in Western North Dakota	ND Corn Utilization Council	$24,704
Janet Knodel, Patrick Beauzay & Victor Gomes	Red Sunflower Seed Weevil - Insecticide Testing	National Sunflower Association	14,340
Victor Gomes & Chris Augustin	Emergence and Early Growth of Hard Red Spring Wheat in Acidic Soils of Western North Dakota	ND Wheat Commission	10,450
Victor Gomes & Chris Augustin	Managing Soybean Inoculation in Western North Dakota Acidic Soils	ND Soybean Council	4,450
Ana Julia Paula Carcedo, Victor Gomes & Febina Matthew	2025 Sunflower Crop Survey	National Sunflower Association	2,875

2025 Weekly Updates

Name	Topic	Date
Victor Gomes	2025 Land & Livestock Forum set for January 15th in Dickinson	7-Jan-25
Doug Landblom	Hay feeding Method: Effects on Performance, Waste, and Economics	14-Jan-25
Chris Augustin	Cover Crop Summit Scheduled in Bismarck on March 25-26	21-Jan-25
Llewellyn L. Manske	Prairie Junegrass Tiller Growth	28-Jan-25
Victor Gomes	2025 Crop update: Soil Management Days set for Feb. 4-6	4-Feb-25
Doug Landblom	Cattle Price Remains High	11-Feb-25
Llewellyn L. Manske	Green Sage Autecology	26-Feb-25
Victor Gomes	Crop Management Considerations for a Potentially Coler and Drier Spring in 2025	4-Mar-25
Doug Landblom	Reducing Winter Cow Feed Cost	11-Mar-25
Rutendo Nyamusmba	Cover Crop Summit	18-Mar-25
Rutendo Nyamusmba	Cover Crop Summit	25-Mar-25
Llewellyn L. Manske	White Sage Autecology	1-Apr-25
Victor Gomes	Early-Season Considerations for Winter Wheat Management	8-Apr-25
Doug Landblom	What if the Drought in Western North Dakota Continues: Is Early Weaning an Option?	15-Apr-25
Chris Augustin	Liming Improves Soil Acidity	22-Apr-25
Llewellyn L. Manske	Fringed Sage Autecology	29-Apr-25
Victor Gomes	Spring 2025 Kicked Off Early: Make it Count with Stand Checks and Seed Quality Checks	6-May-25
Doug Landblom	Integrated Crop and Livestock Systems Research Summary	13-May-25
Chris Augustin	Much Needed Precipitation and Field Days	20-May-25
Llewellyn L. Manske	Blue Wild Lettuce Autecology	27-May-25
Victor Gomes	IPM Crop Survey Program Launches This Week	3-Jun-25
Doug Landblom	Fly Control Methods for Beef Cattle	10-Jun-25
Chris Augustin	Crop Nutrient Deficiencies	17-Jun-25
Llewellyn L. Manske	The Problem of Low Mineral Nitrogen in Grasslands	24-Jun-25
Chris Augustin Victor Gomes	2025 Field Days Set for Wednesday, July 16 and Thursday, July 17	1-Ju1-25
Chris Augustin Victor Gomes	2025 Field Days Set for Wednesday, July 16 and Thursday, July 17	9-Ju1-25
Chris Augustin Victor Gomes	2025 Field Days Set for Wednesday, July 16 and Thursday, July 17	15-Ju1-25
Doug Landblom	Integrated Systems Heifer Development and Profitability	22-Jul-25
Llewellyn L. Manske	Bastard Toadflax Autecology	5-Aug-25
Victor Gomes	2025 Soil Health Workshop to Highlight Practices for Healthy Farms and Ecosystms	12-Aug-25
Doug Landblom Victor Gomes	Soil Health Workshop is Coming in September	19-Aug-25
Krishna Katuwal	Harvest Season	26-Aug-25
Chris Augustin	Fall is a Great Time to Soil Test	3-Sep-25

Llewellyn L. Manske	Curlycup Gumweed Autecology	9-Sep-25
Victor Gomes	Early September Frost Poses a Challenge for Row Crop Protection in Western North Dakota	16-Sep-25
Douglas Landblom	New World Screwworm NWS Awareness	23-Sep-25
Krishna Katuwal	Crop Diversification and Importance	30-Sep-25
Chris Augustin	Greetings from Pembina County!	7-Oct-25
Llewellyn L. Manske	Crested Wheatgrass Growth and Development	14-Oct-25
Doug Landblom	Will Your Cows be Ready to Re-Breed Next Spring?	21-Oct-25
Victor Gomes	End of Growing Season Soil Fertility Tips	28-Oct-25
Doug Landblom	Reproductive Strategies Workshop Scheduled for November 13	4-Nov-25
Chris Augustin	Soil Compaction	12-Nov-25
Llewellyn L. Manske	Altai Wildrye Growth and Behavior	18-Nov-25
Victor Gomes	NDSU Extension Western Soybean Days set for Feb. 18 and 19	25-Nov-25
Doug Landblom	Extending the Breeding Season: Managing the Increased Profit	2-Dec-25

Manning Weather Summary

	Max Temp			Monthly Avg. Temp		
Month	2025	2024	2023	2025	2024	2023
Jan	24.5	22.0	26.9	14.2	13.6	19.1
Feb	16.4	38.0	30.2	6.4	28.4	20.7
Mar	50.2	37.5	25.2	36.6	25.5	16.7
Apr	56.0	58.1	48.2	43.2	44.9	37.4
May	68.3	66.4	71.6	55.1	52.6	57.8
Jun	76.7	74.9	80.8	63.6	62.1	67.5
Jul	80.1	86.5	81.5	67.6	72.1	68.5
Aug	80.0	80.8	81.0	67.7	68.2	68.2
Sep	76.4	82.9	75.8	63.2	65.9	62.0
Oct	60.6	65.5	53.6	48.5	49.7	42.6
Nov		38.5	43.5		28.5	32.6
Dec		31.5	39.6		23.1	30.3

Precipitation

Month	2025	2024	2023
Jan	0.17	0.23	0.33
Feb	0.54	0.29	0.25
Mar	0.09	0.57	1.78
Apr	1.08	1.35	0.30
May	4.64	2.35	2.69
Jun	2.92	2.75	1.91
Jul	4.99	0.88	2.21
Aug	1.70	1.28	3.25
Sep	0.72	0.12	1.32
Oct	3.46	0.00	1.24
Nov		0.15	0.02
Dec		0.92	0.12
Total	20.31	10.89	15.42

Dickinson Weather Summary

	Max Temp			Monthly Avg. Temp		
Month	2025	2024	2023	2025	2024	2023
Jan	23.0	25.0	26.0	13.0	16.0	18.0
Feb	17.0	38.0	31.0	7.0	29.0	21.0
Mar	50.0	36.0	25.0	37.0	26.0	17.0
Apr	56.0	58.0	50.0	43.0	45.0	39.0
May	68.0	67.0	72.0	56.0	54.0	60.0
Jun	75.0	75.0	79.0	63.0	62.0	68.0
Jul	81.0	86.0	81.0	69.0	73.0	68.0
Aug	81.0	80.0	81.0	68.0	68.0	68.0
Sep	78.0	83.0	75.0	64.0	66.0	62.0
Oct	61.0	66.0	53.0	49.0	51.0	43.0
Nov	44.0	40.0	45.0	33.0	30.0	34.0
Dec		31.0	41.0		24.0	31.0

Precipitation

Month	2025	2024	2023
Jan	0.24	0.30	0.15
Feb	0.80	0.63	0.77
Mar	0.19	1.31	1.37
Apr	1.63	1.21	0.18
May	5.32	2.77	2.58
Jun	3.18	3.17	2.77
Jul	3.99	0.36	1.32
Aug	2.54	2.65	3.70
Sep	1.56	0.47	1.73
Oct	2.37	0.07	1.89
Nov	1.12	0.36	0.11
Dec		0.23	0.33
Total	22.94	13.53	16.90

Dickinson Research Extension Center
Field Days
2025


FIELD DAY

NDSU Dickinson Research Extension Center

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