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PLANTS FOR THE WEST

Forage and Range Research Team

- 8 Geneticists, 1 Ecologist, 1 vacant SY

To develop plant materials and applications to improve weed- and fire-resistance of rangelands, pasture productivity, and turf

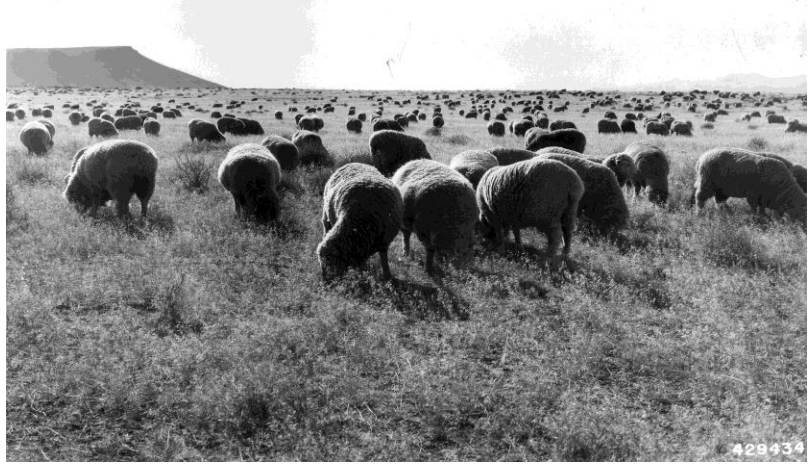
EARLY CONCERNS

In addition to increased homesteading in the west, there were other concerns being raised:

1898 – H.L. Bentley expressed alarm over range injury resulting from overgrazing in Central Texas.

1899 – Jared Smith reported grazing problems in the Southwest.

1903 – Public lands commission reported that 1400 stockmen in 16 states .. present range conditions .. greater portion of the public grazing land is not supporting the number of stock they formally did.



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Rangeland Research - Problem

Wildfire

Over Grazing

Mining Activities

Mechanical Disturbance

Cheatgrass can take over a landscape and result in increased wildfires, loss of soil structure, perennial plant cover etc.

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Research Challenges

- Low precipitation ~ 7 to 11 inches a year – mostly in the form of snow
- Shallow soils often saline

- Presence of invasive annual weeds (cheatgrass, medusahead, halogeton)

Plant characteristics needed:

1. Establishment
2. Persistence
3. Ability to compete against invasive annual weeds (cheatgrass, medusdahead, halogeton)
4. Defoliation tolerance

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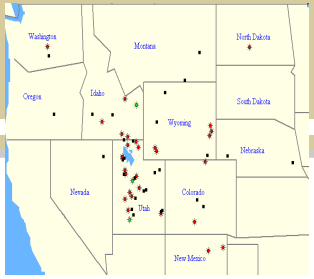
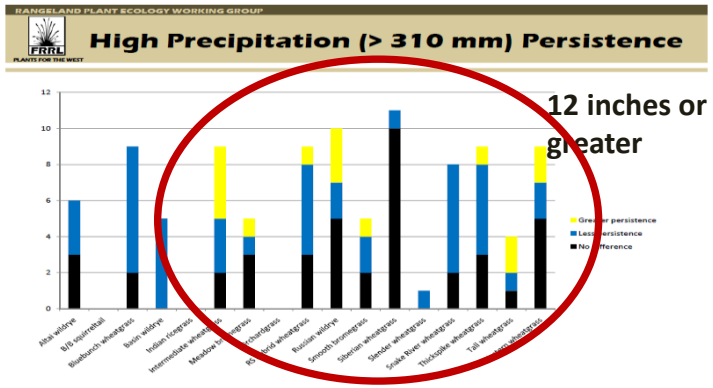
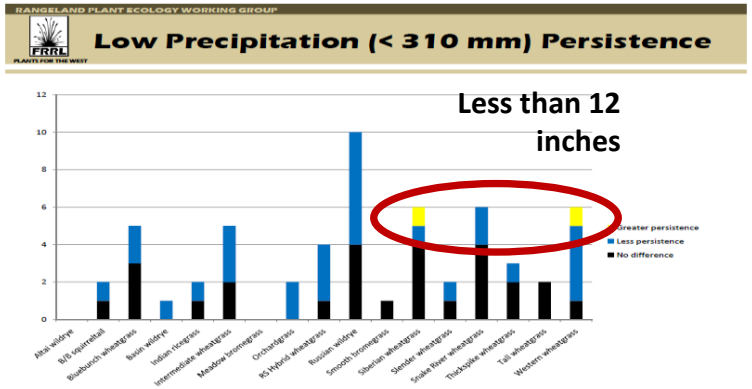
Rangeland – Understanding Problem



- **Annual precipitation is most critical.**
  - **Amount of available water (when)**
  - **Soil Type (Loam, Clay, Sand)**
  - **Summer Temperatures**
  - **Winter Temperatures**
  - **Snow Depth**





Winnemucca, NV below 12 inches

Beaver, UT above 12 inches

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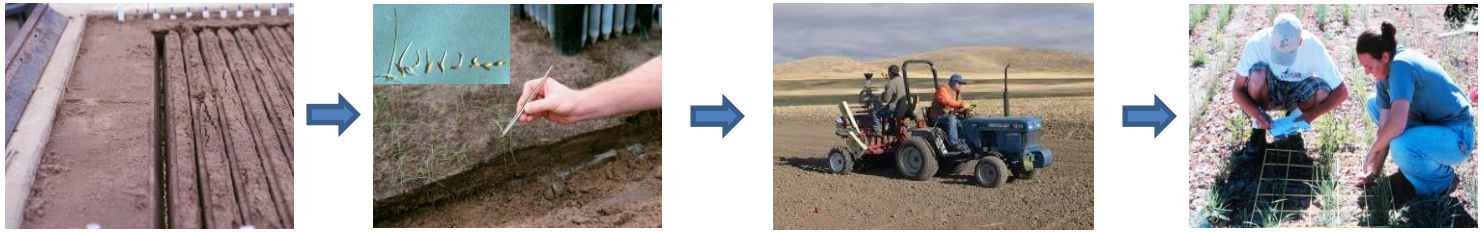
Rangeland Research - Traits

Increased

- Seed germination and seedling emergence on dry disturbed rangelands



- Increased stand persistence/plant vigor under weed competition

Perennial plant community (grass)

Annual plant community (cheatgrass)

- soil erosion ↓
- soil structure ↓
- fire frequency ↓
- overall use by insects, wildlife, and livestock ↑

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Dryland Dry-Matter Yield

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Study Locations

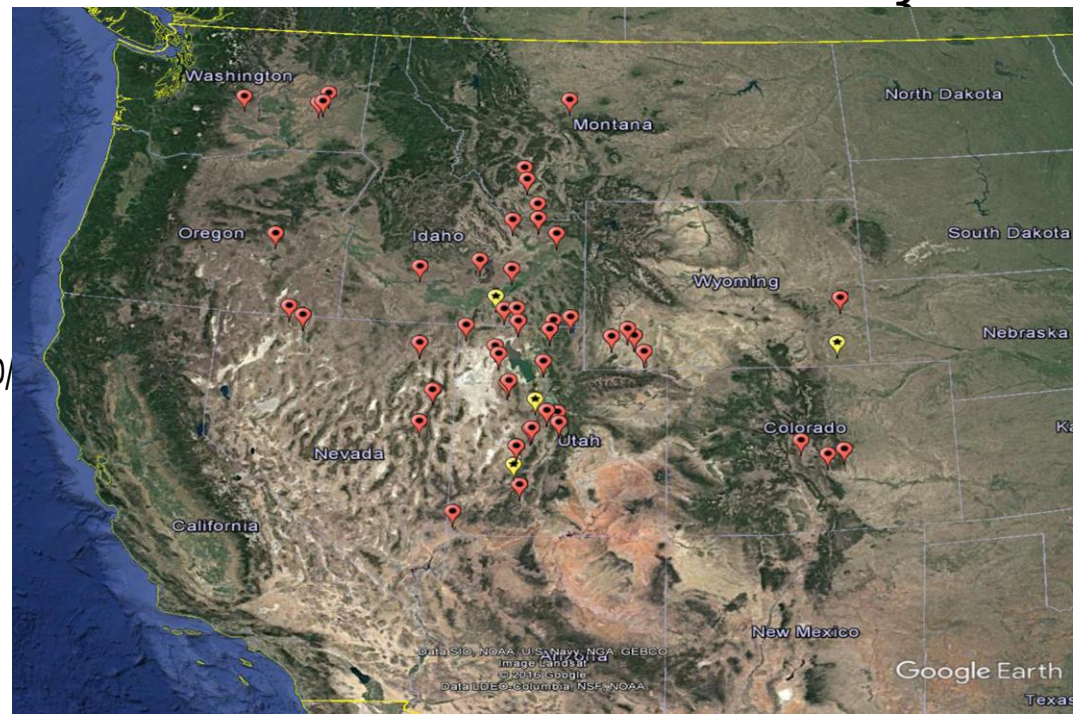
Location	Year Planted	County	ST	El. (m)	Precip. (mm)	Soil Type	Ecoregion Level IV	Precip. (inches)
Beaver	2006	Beaver	UT	1981	365	Murdock Silt Loam, 1-3% slopes	Woodland- and Shrub-Covered Low Mountains	14.
Cheyenne	2009	Laramie	WY	1901	397	Altvan loam, 0 to 6 percent slopes	Moderate Relief Rangeland	15.
Malta	2004	Cassia	ID	1481	292	Declo Silt Loam, 1-3% Slope	Saltbush-Dominated Valleys	11.
Tintic	2009	Juab	UT	1789	415	Doyce Silt Loam, 2-4% Slope	Sagebrush Basins and Slopes	16.

Elevation, google earth, https://earth.google.com/

Precipitation, Prism Climate Group, http://prism.oregonstate.edu

Soil type, USDA-NRCS, websoilsurvey.nrcs.usda.gov/app/

Ecoregions U. S. EPA, http://archive.epa.gov/wed/ecoregions/web/



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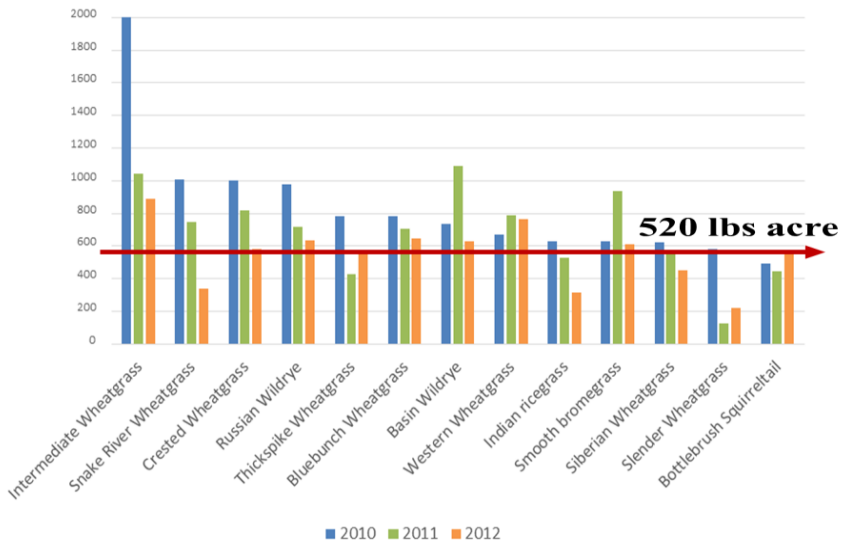
Dry Matter Yield Beaver, UT
Mean kg ha^{-1} (x 0.893 = lbs acre)

Species	2010	2011	2012
Intermediate Wheatgrass	2029 a	1045 ab	887 a
Snake River Wheatgrass	1009 bc	746 bcd	339 def
Crested Wheatgrass	1003 b	817 b	584 abcd
Russian Wildrye	976 bc	715 bcd	637 abc
Thickspike Wheatgrass	783 bcd	430 f	563 bcd
Bluebunch Wheatgrass	782 bcd	707 bcde	648 abc
Basin Wildrye	735 cde	1088 a	628 abc
Western Wheatgrass	672 de	790 bc	765 ab
Indian ricegrass	630 de	526 def	314 ef
Smooth bromegrass	628 de	938 ab	609 abcd
Siberian Wheatgrass	624 de	555 cdef	451 cdef
Slender Wheatgrass	583 de	123 g	222 f
Bottlebrush Squirreltail	493 e	444 ef	560 bcde



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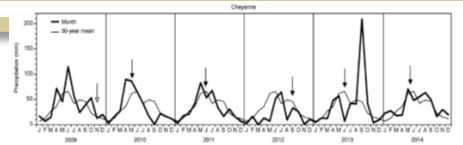
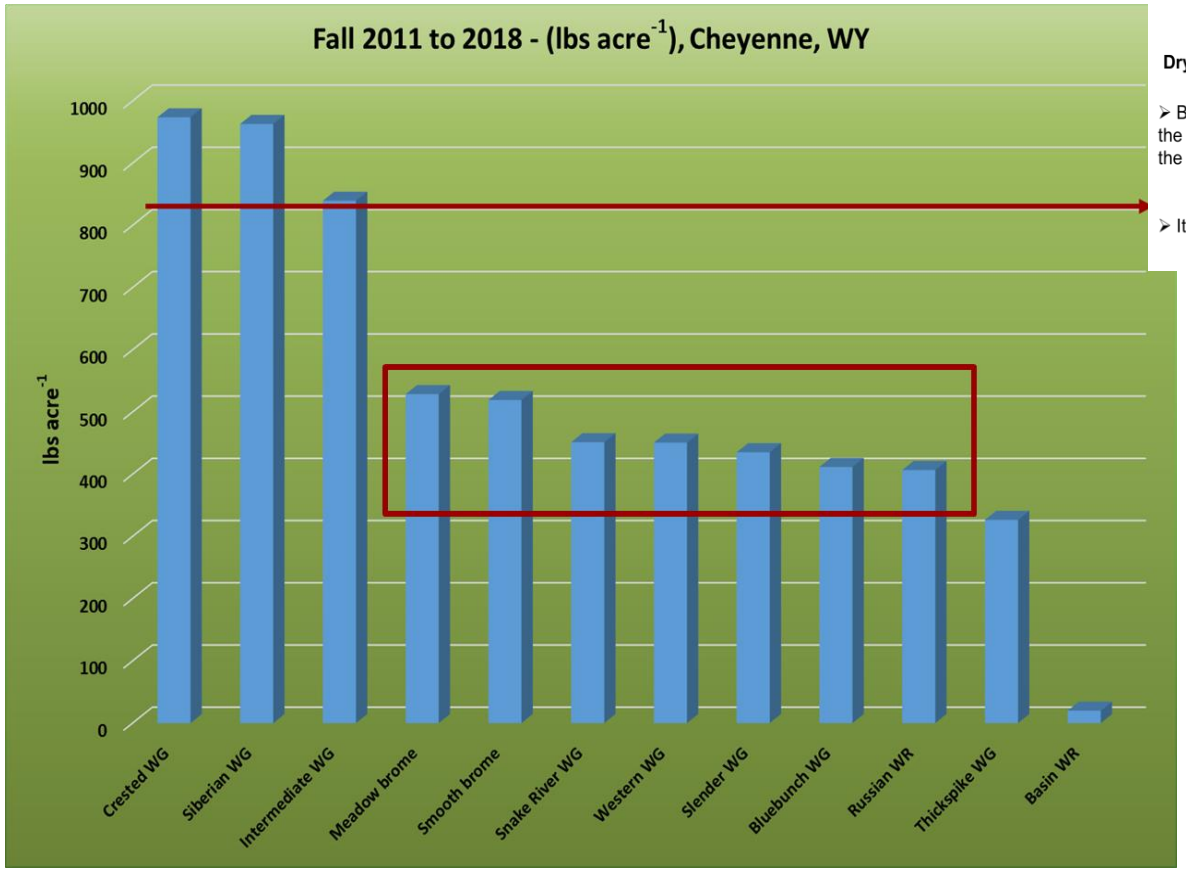
Forage yield data – Cheyenne, WY





Dryland

- Based on our data it does not appear that under dryland conditions that the range grasses will re-grow sufficiently to support a fall grazing. 70% of the forage is produced in the spring.

- It may require to set aside land to stockpile forage for this period. I would include forage kochia in this planting.

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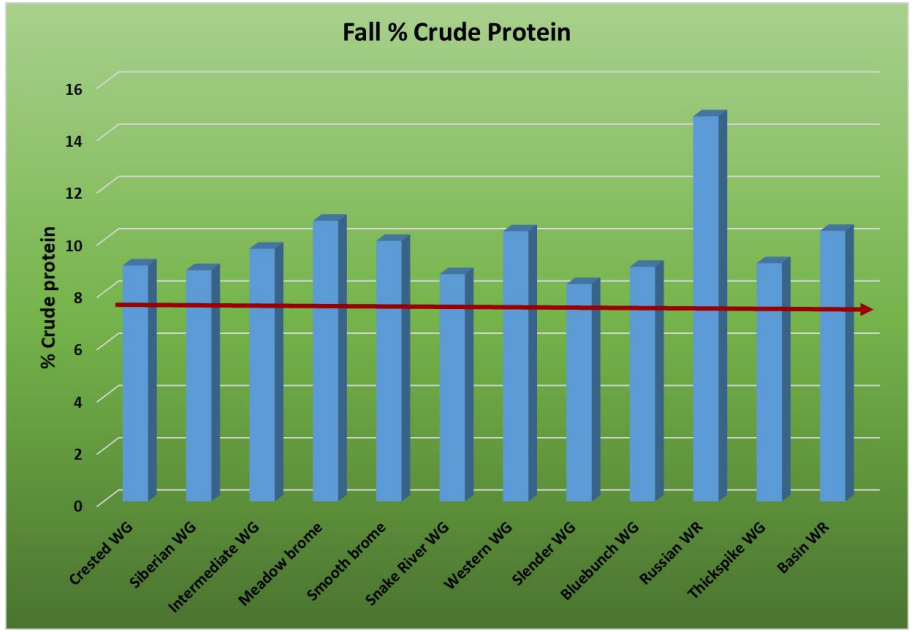
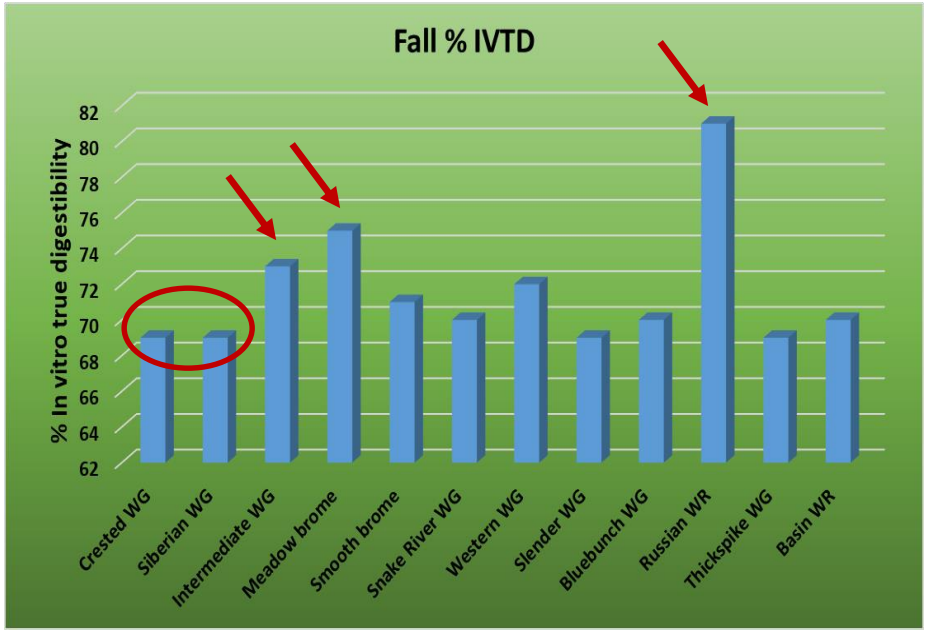
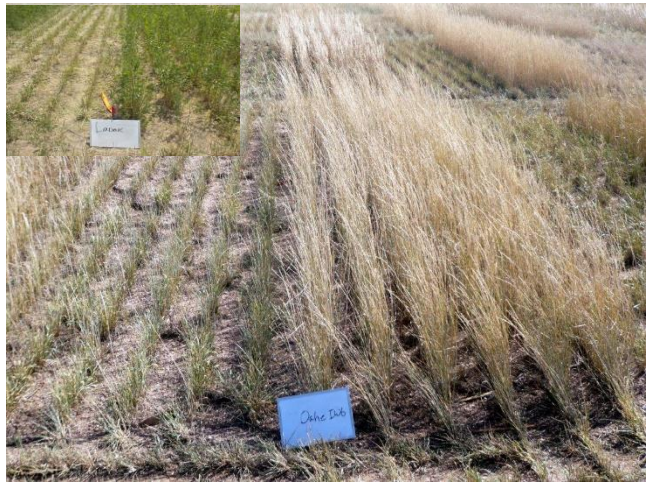
Forage quality – Cheyenne, WY







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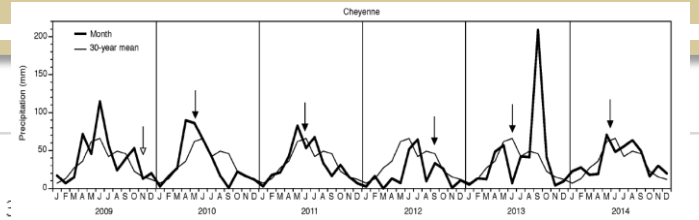
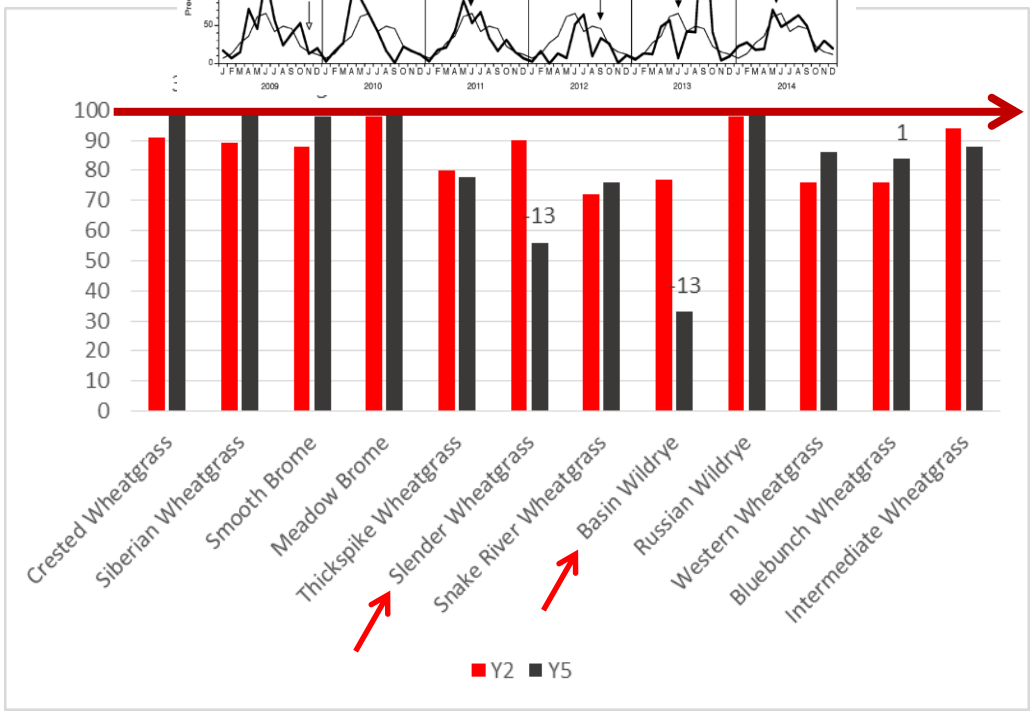
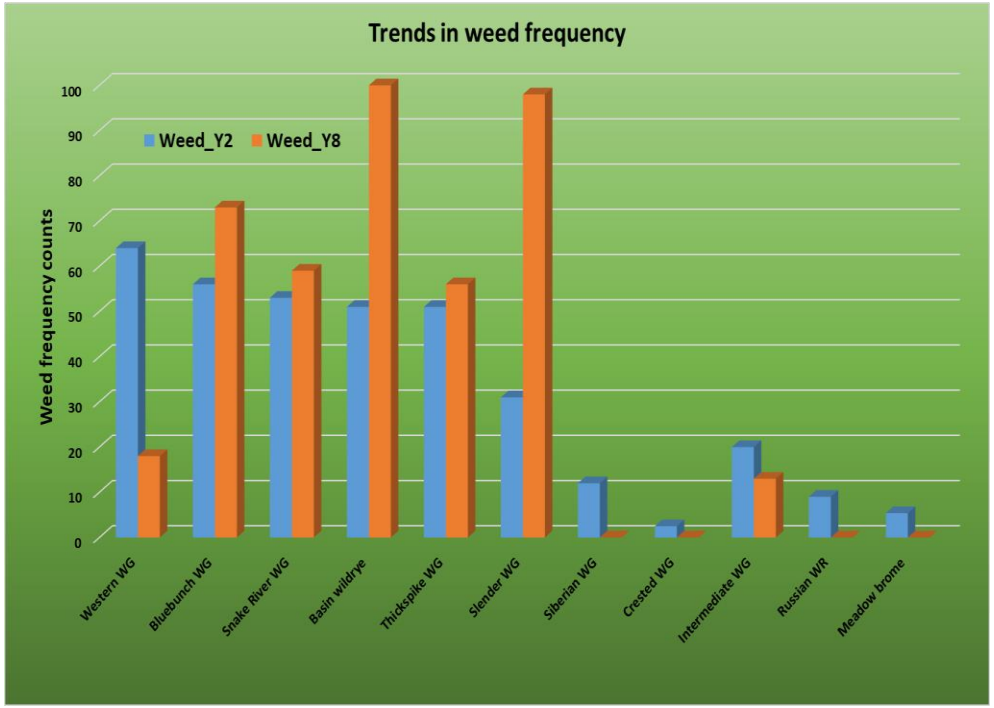
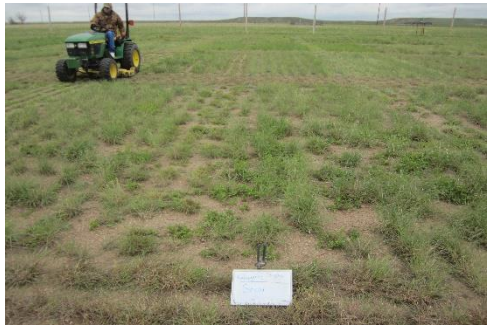
Year Two to Eight Trends – Cheyenne, WY









Crested Wheatgrass (*Agropyron cristatum*)

- Easy to establish in harsh environments, widely adapted
- Does well on clay, clay-loam soils
- Withstands heavy use
- High palatability in Spring and Fall
- Hycrest II (2008)
- Best seedling vigor of any crested wheatgrass

Winter Forage Study – Cheyenne, WY

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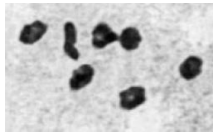
Capitalizing on genetic diversity



2x

colchicine

4x

Induced tetraploid

Hybridize

4x

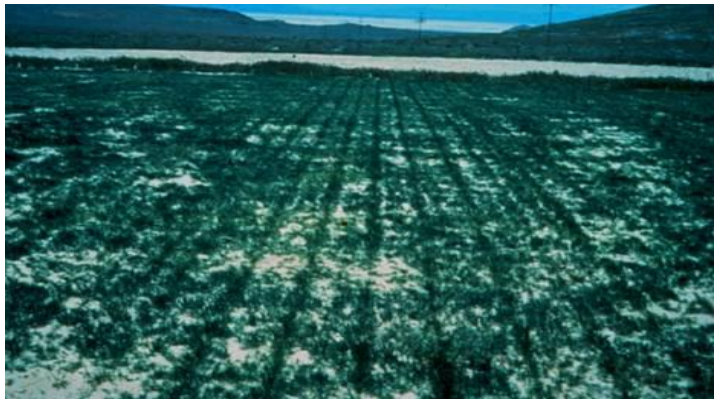
Natural tetraploid

Hycrest

3-cycles of selection for increased seedling establishment under harsh dry environments

Fairway | Hycrest

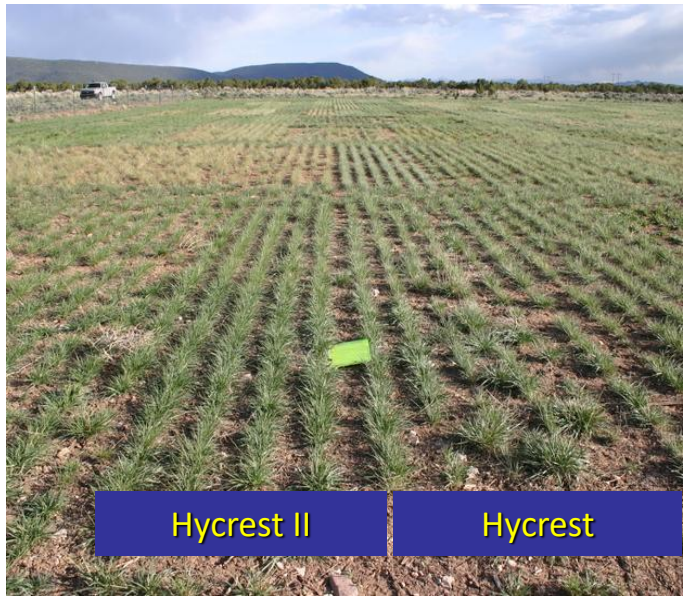
Nordan | Hycrest

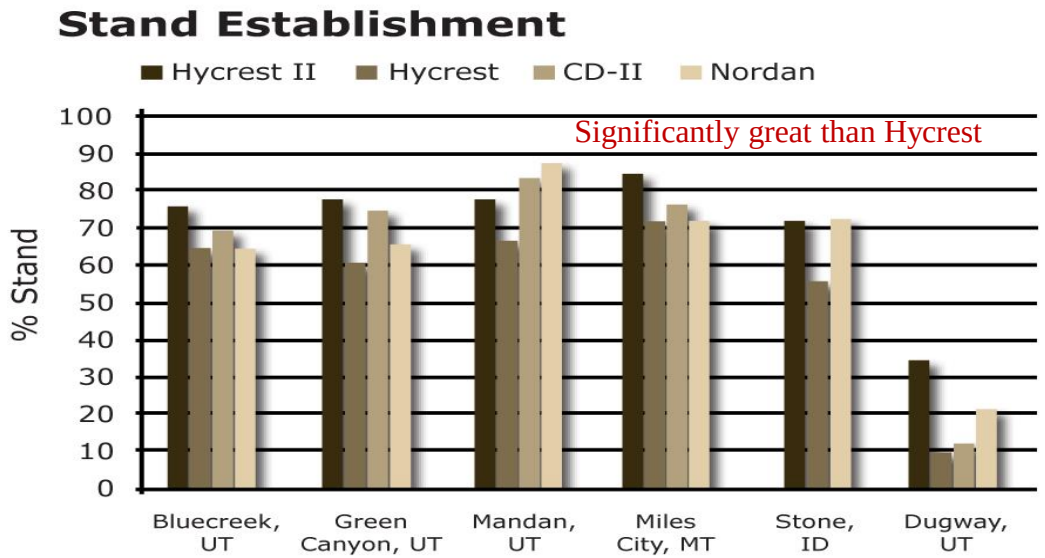


Capitalizing on generated diversity

'Hycrest II'…. (*A. cristatum-4x*) … USDA-ARS….One of the original parents to Hycrest….Increased seedling establishment.

2x —colchicine→ **4x**





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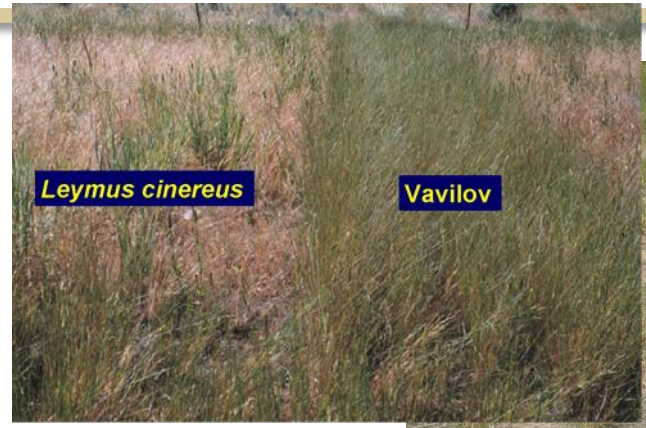
Siberian Wheatgrass (*Agropyron fragile*)

- Drought tolerant 7-8” ppt
- Prefers sandy soils
- Selected for vigor, persistence and establishment
- Withstands heavy use
- High palatability in Spring and Fall



Winter Forage Study – Cheyenne, WY

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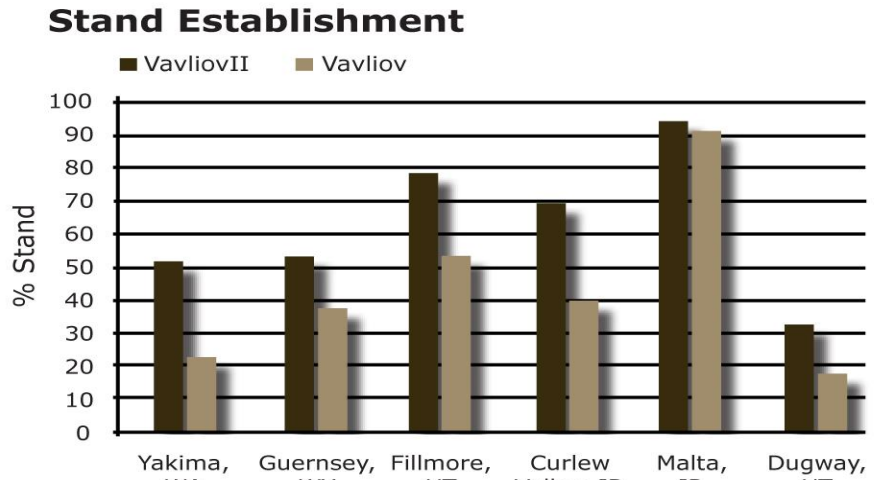
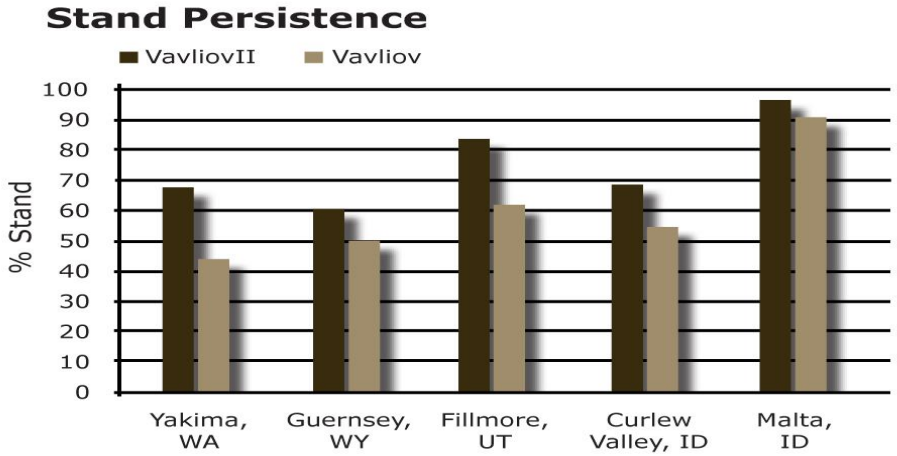
Siberian wheatgrass

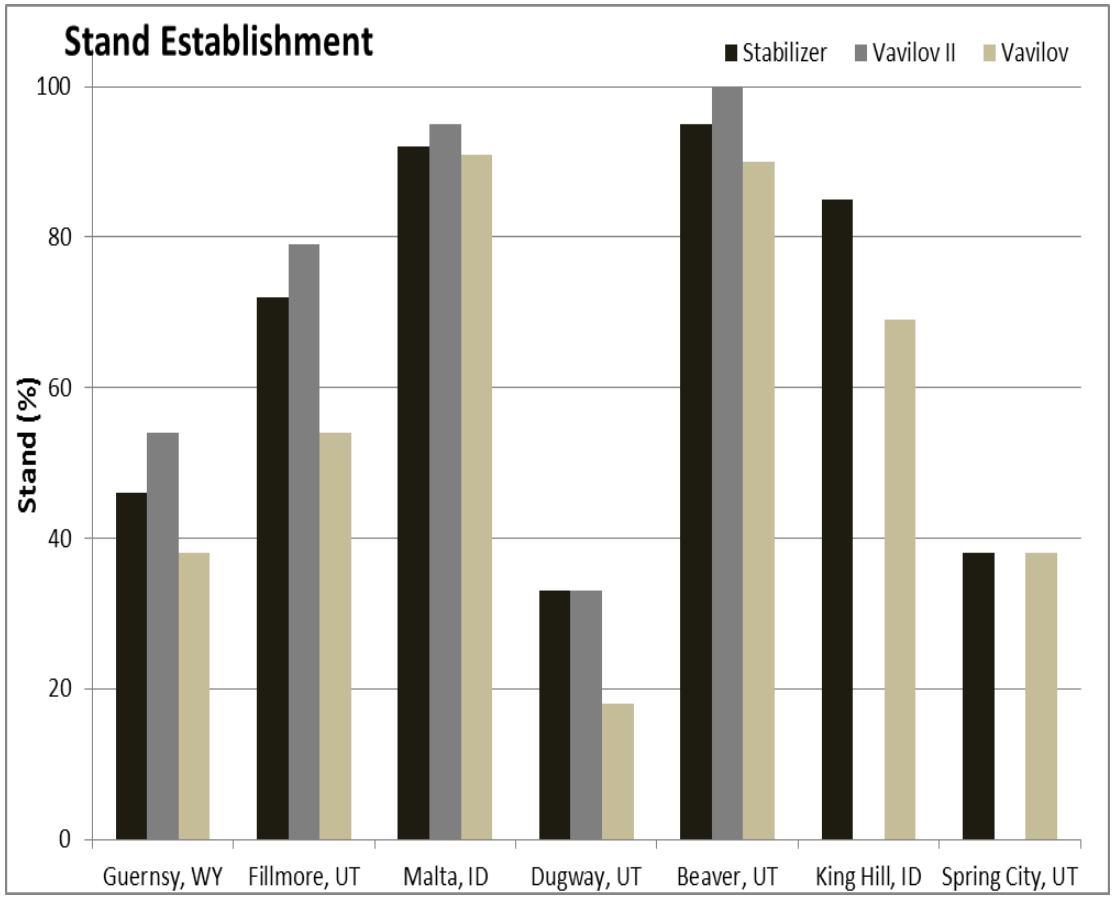
'Vavilov II'…. 2008 …. 70% derived from the cultivar Vavilov (plants selected under extreme drought) and 30% from collections made in 1988 in Kazakhstan…Increased seedling germination, establishment and persistence over Vavilov.





Winter Forage Study – Cheyenne, WY

Stabilizer Siberian wheatgrass



12 inch annual precipitation

- Originated from collections made in Kazakhstan in 1989 from regions receiving less than 5 inches of annual precipiation.
- Only true Siberian wheatgrass cultivar

Siberian Wheatgrass

Species/Entry	Frequency Percentage 2009	2010	2011
Siberian Wheatgrass	97 A	97 A	93 AB
Vavilov	95 b	95 b	85 a
Vavilov II	97 ab	100 a	95 a
Stabilizer	99 a	98 ab	98 a

Species/Entry	DMY (kg ha^{-1}) 2010	2011	2012
Siberian Wheatgrass			
Vavilov	812 a	604 ab	590 a
Vavilov II	719 a	727 a	453 ab
Stabilizer	341 b	333 b	310 b

Crested/Siberian wheatgrass – Nutritional Quality

Spring Traits:

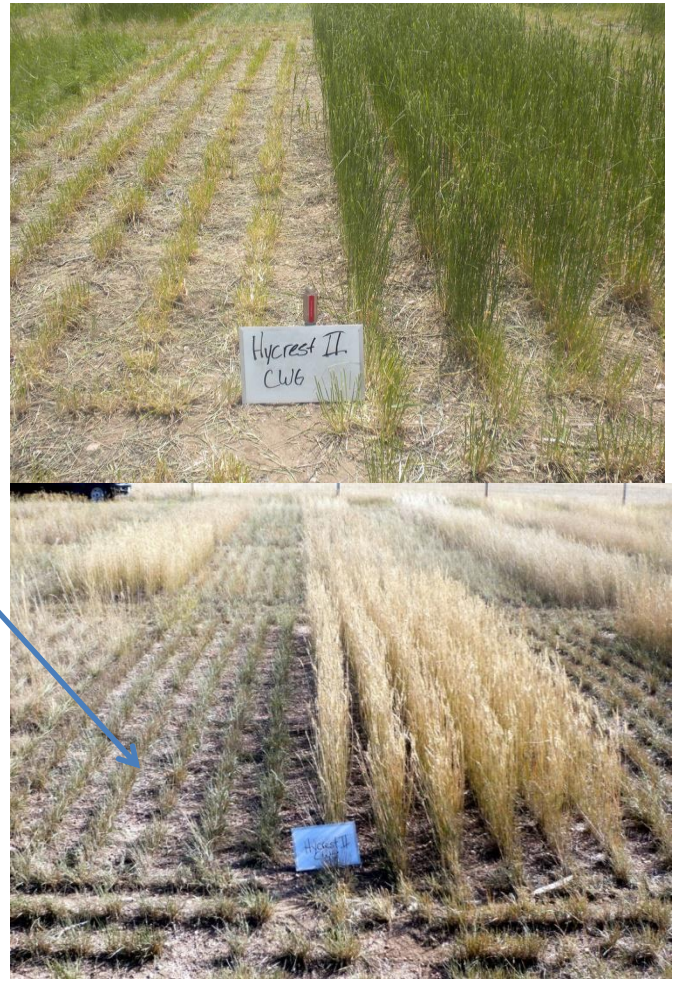
- 849 lbs ac^{-1} (May – dryland)
- CP 12.6%; Digestibility 81%;
- NDF 54.7%

Regrowth Traits - October:

- 255 lbs ac^{-1}
- CP 15.6%; Digestibility 83%;
- NDF 54%

Fall Traits:

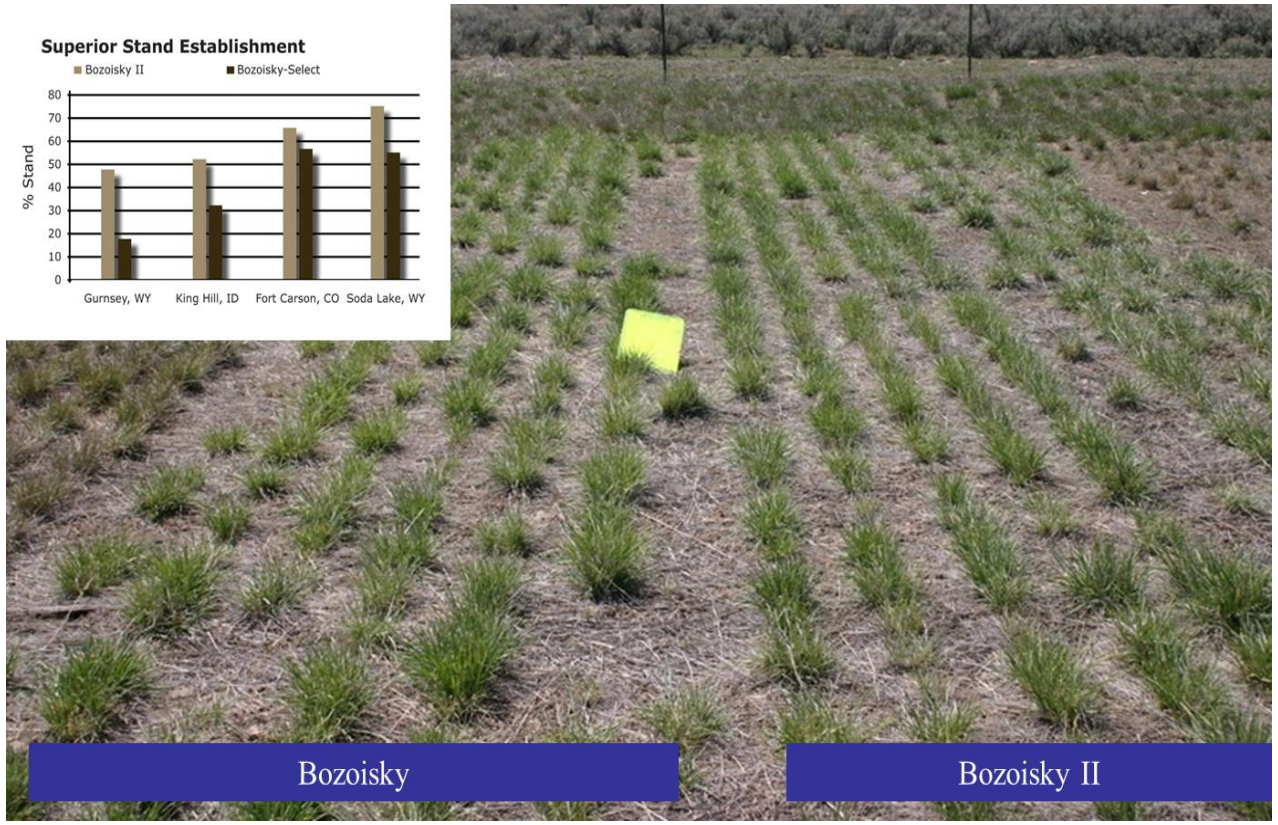
- 974 lbs ac^{-1} (Oct. - stockpiled)
- CP 9.0%; Digestibility 69%;
- NDF 61.9%



Winter Forage Study – Cheyenne, WY

Russian Wildrye (*Psathyrostachys juncea*)

- Can withstand heavy use, extreme persistence
- Low palatability in Spring, high in the Fall
- Less seedling vigor than crested wheatgrass
- More tolerant of saline and alkaline soils than crested wheatgrass
- Bozoisky II (2005)



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Russian wildrye – Nutritional Quality

Spring Traits:

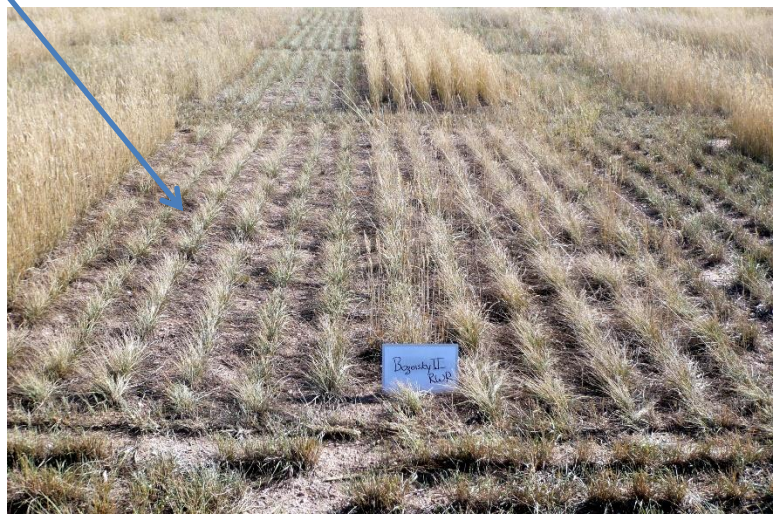
- 385 lbs ac^{-1} (May – dryland)
- CP 15.3%; Digestibility 88%;
- NDF 49.0%

Regrowth Traits - November:

- 157 lbs ac^{-1}
- CP 18.1%; Digestibility 88%;
- NDF 53.9%

Fall Traits:

- 375 lbs ac^{-1} (Oct. - stockpiled)
- CP 14.7%; Digestibility 81%;
- NDF 58.7%



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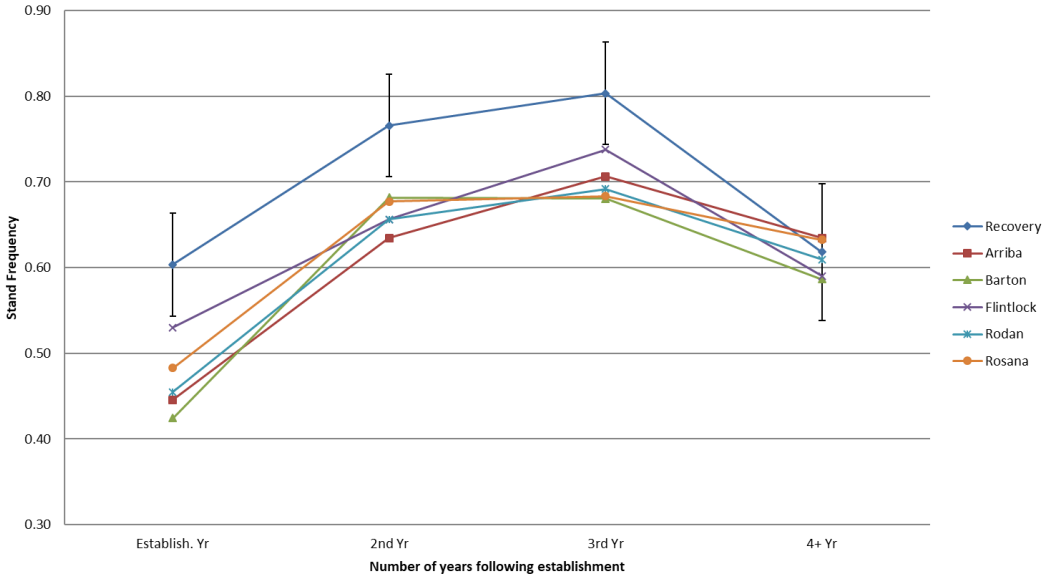
Recovery Western Wheatgrass (2010)

Adaptations

- 14 inches (350 mm of precipitation)
- Rhizomatous
- Withstands heavy grazing
- Research for increased germination and seedling vigor for better stands



Winter Forage Study – Cheyenne, WY

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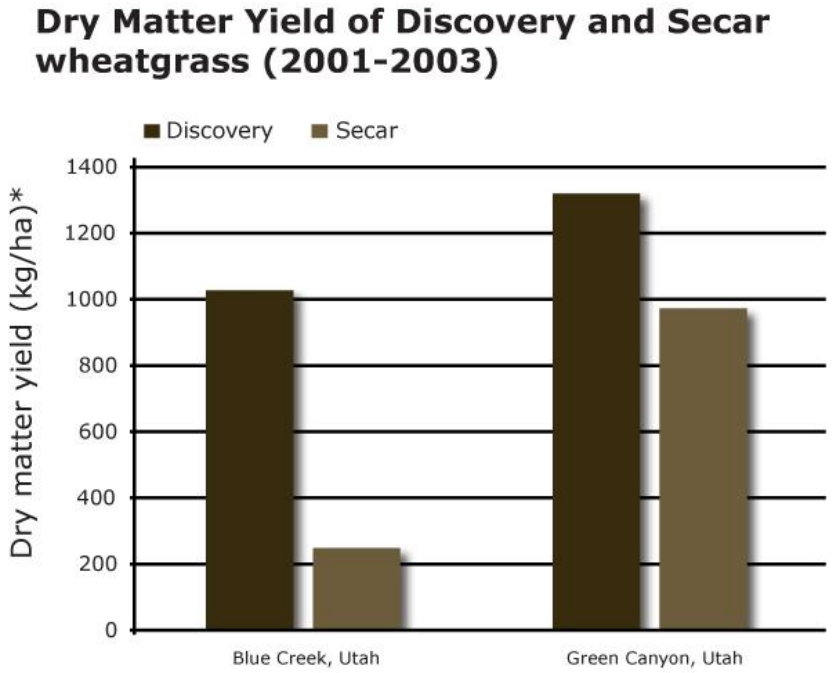
Discovery - Snake River Wheatgrass



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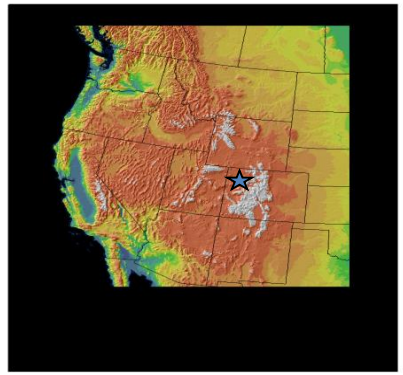
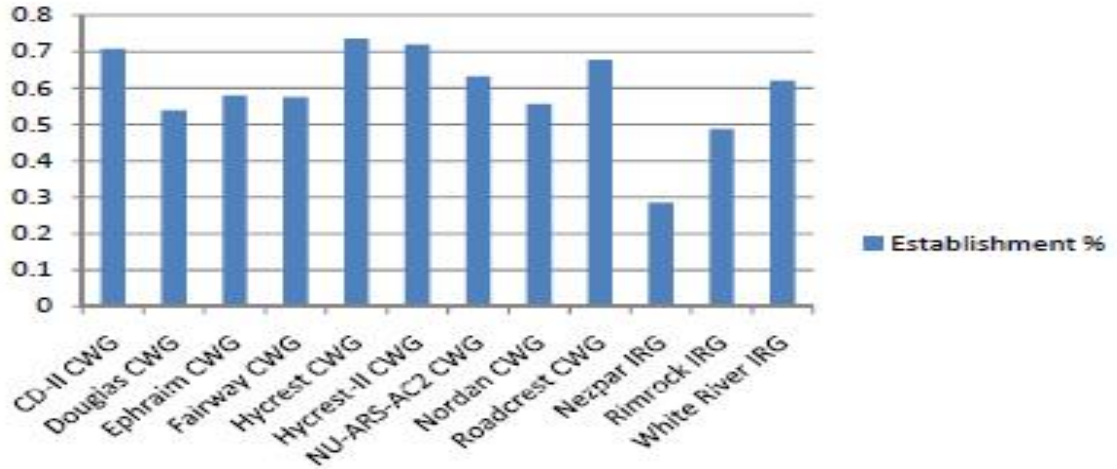
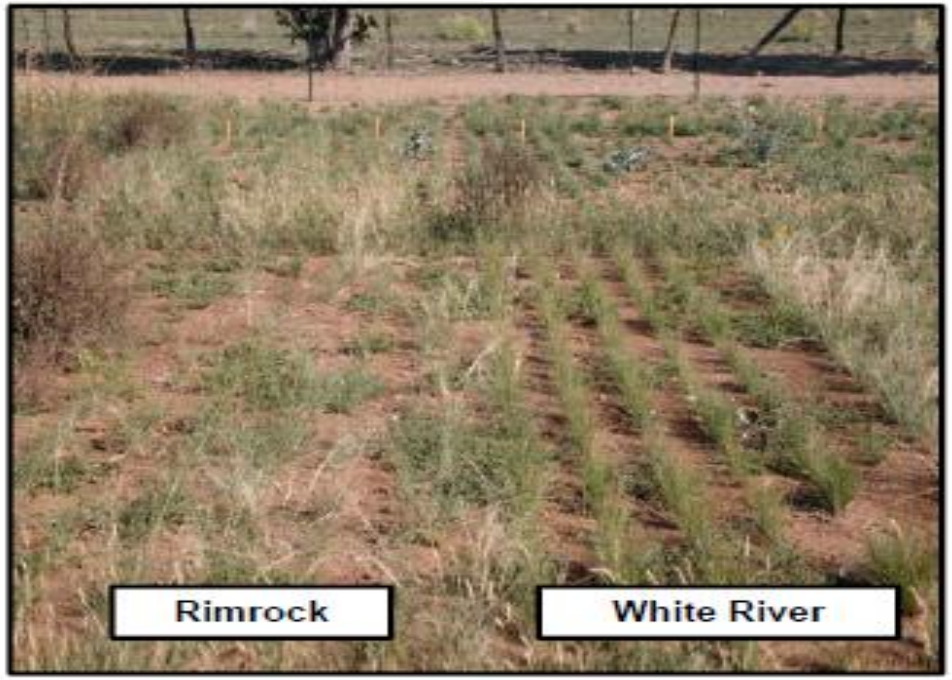
Indian Ricegrass





Screened for decreased seed dormancy



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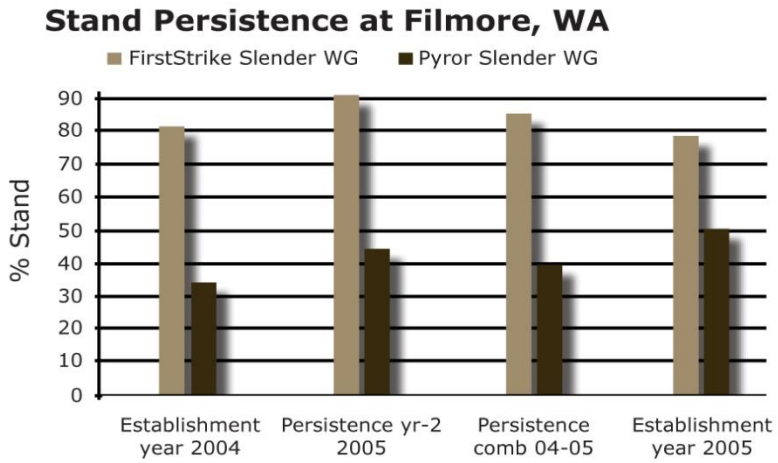
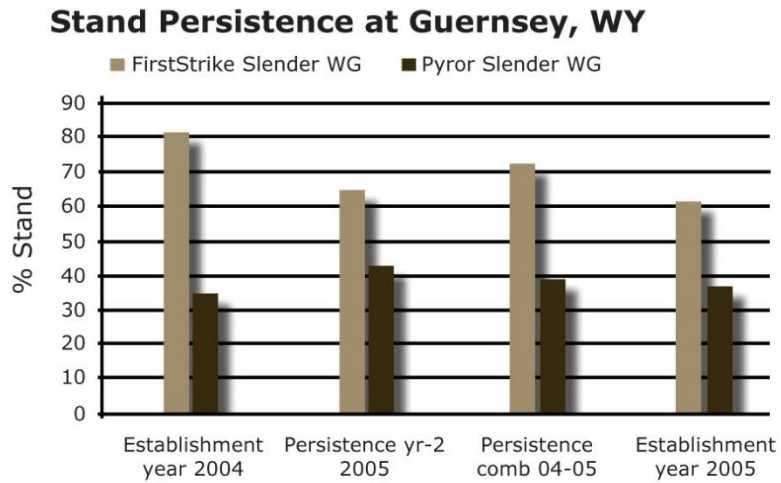
FirstStrike - slender Wheatgrass (2006)

Selected for rapid emergence and establishment





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Research Challenges

- Low precipitation ~ 7 to 11 inches a year – mostly in the form of snow
- Shallow soils often saline

- Presence of invasive annual weeds (cheatgrass, medusahead, halogeton)

Plant characteristics needed:

1. Establishment
2. Persistence
3. Ability to compete against invasive annual weeds (cheatgrass, medusdahead, halogeton)
4. Defoliation tolerance

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Why Fall and Winter Forage?

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Forage Availability – Challenges?

April – early June **-** Transition period between winter grazing pastures and summer pastures .. forage quality is critical because of possible calving.

September – October - Transition period between summer grazing and winter pastures.

November – March **-** Maintenance period through the winter - generally less productive land used.

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Economics of winter feed

Simonds (1990) concluded that hay costs accounted for 70% of the total livestock costs.

He further concluded that those expenses could be reduced by almost 50% with the use of alternative feed sources.

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Challenge – Forage Quality?

Literature reports that a CP level of 7 to 8% is needed to maintain a pregnant cow throughout the winter (Turner & Raleigh, 1985)

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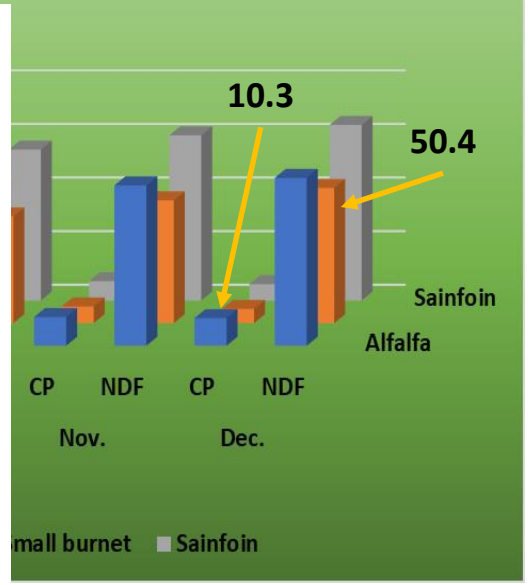
Forage Quality – Legume?

- Alfalfa

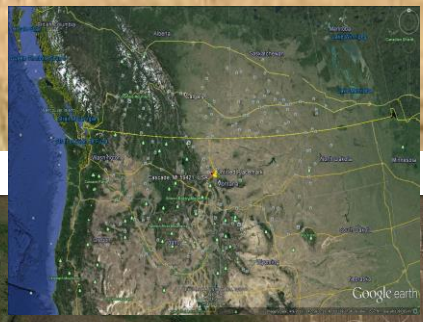


- Small burnet

Noticed Deer grazing the day prior to picture taken.

Winter – Forage Study

Sieben Land and Livestock – Cascade, MT



Questions:

- Graze in May (lightly) and then return in the winter?
- Identify species & mixes with increased forage DMY and nutritional quality during the winter.
- Can species and mixtures withstand intensive short duration grazing?

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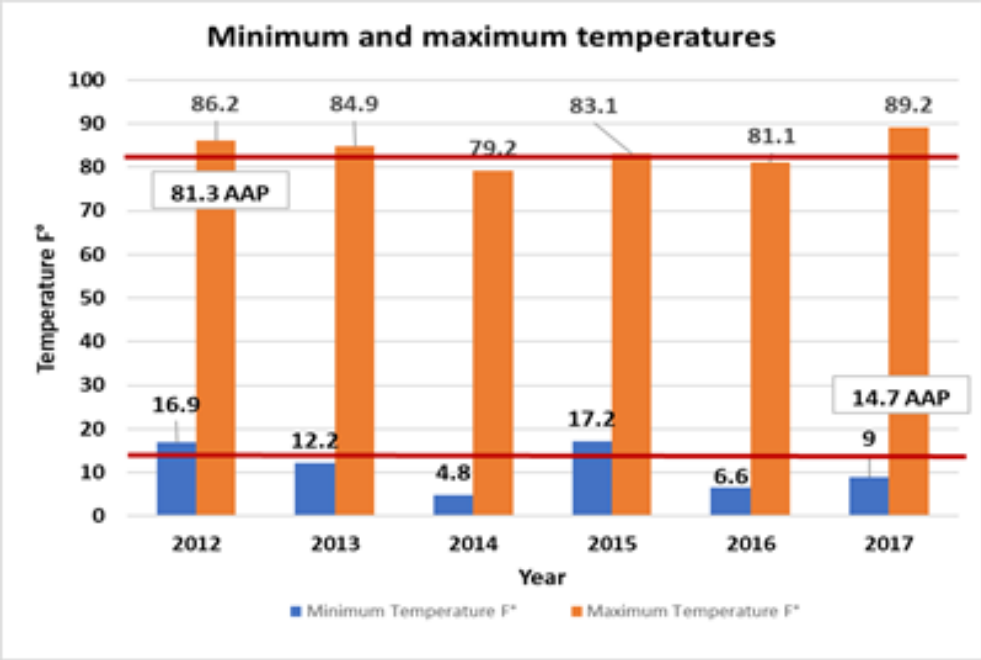
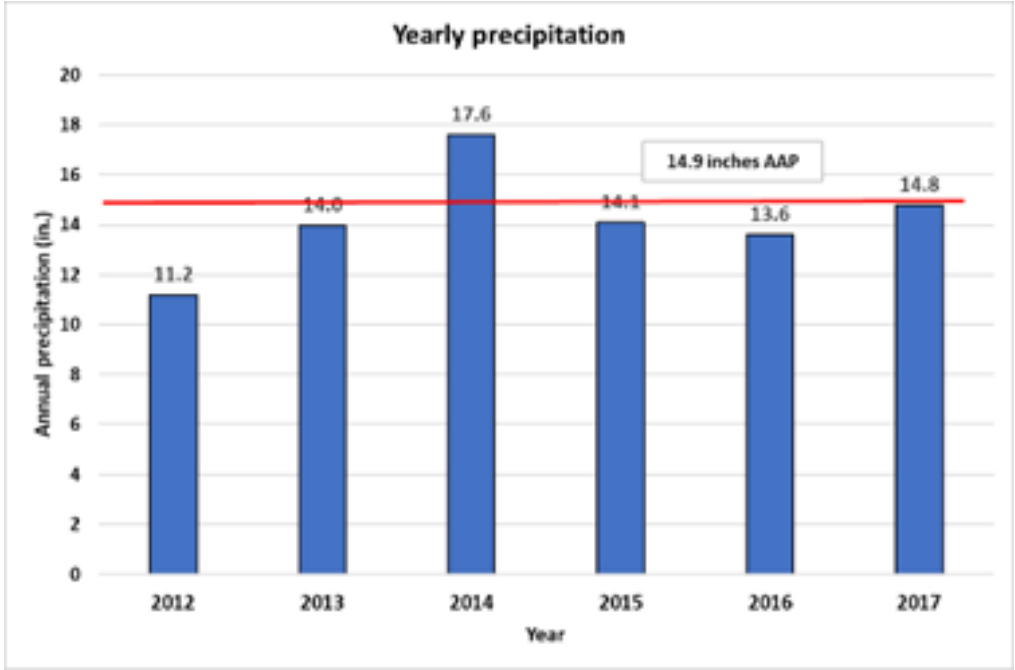
Weather Data





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Seiben Study

- **Plant Materials/Field Design:**

Treatment 1 = Meadow brome (15 lbs)

Treatment 2 = Intermediate wheatgrass (15 lbs)

Treatment 3 = Tall fescue (12 lbs)

Treatment 4 = Crested wheatgrass (12 lbs)

Treatment 5 = Orchardgrass (12 lbs)

Treatment 6 = Meadow brome (7 lbs) + Intermediate WG (7 lbs) + Alfalfa (2 lbs)

Treatment 7 = Meadow brome (7 lbs) + Intermediate WG (7 lbs) + Sanfoin (3 lbs)

Treatment 8 = Meadow brome (7 lbs) + Intermediate WG (7 lbs) + Small Burnet (2 lbs)

Treatment 9 = Meadow brome (7 lbs) + tall fescue (5 lbs) + Alfalfa (2 lbs)

Treatment 10 = Meadow brome (7 lbs) + tall fescue (5 lbs) + Sanfoin (3 lbs)

Treatment 11 = Orchardgrass (12 lbs) + Alfalfa (2lbs)

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Plant Establishment - Data

Plant establishment

- **Seedling Frequency**

x		x		x x		x
		x x				x
		x		x x		
x x						x x
x x		x				x
x		x x		x		x x
x				x x		
x		x		x x		
x		x		x		x x
x		x x		x x		x x
x x		x x		x x		
		x		x		x x

- **Seedling counts (grasses & legumes)**

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Plant - Establishment

November 2013

Sig.		Percent Grass Establishment	Entries
	A	99.750	Orchardgrass
B	A	97.000	OG_Alfalfa
B	A	93.667	Intermediate_WG
B	C	90.000	MB_IWG_Alfalfa
B	C	89.750	MB_IWG_Sanfoin
B	C	89.750	MB_TF_Alfalfa
B	C	89.500	MB_IWG_Small_burnet
B	C	89.250	MB_TF_Sanfoin
B	C	89.250	Tall_fescue
B	C	88.250	Meadow_brome
	C	82.000	Crested_WG

Sig.	Percent Legume Establishment	Entries
A	39.500	MB_TF_Alfalfa
A	35.000	OG_Alfalfa
A	34.250	MB_IWG_Alfalfa
B	13.500	MB_IWG_Sanfoin
B	8.000	MB_TF_Sanfoin
B	6.500	MB_IWG_Small_burnet

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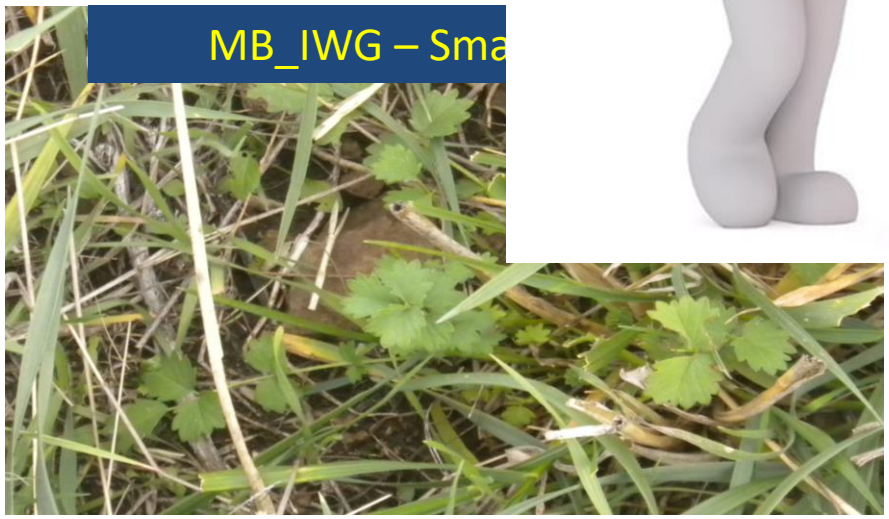
Legume - Persistence

Legume	# Legume plants acer^{-1} (201
OG+Alfalfa	36,84
MB+IWG+Alfalfa	46,96
MB+TF+Alfalfa	59,51
MB+IWG+Small burnet	14,57
MB+IWG+Sainfoin	6,07
MB+TF+Sainfoin	5,66

Where did the legumes go?

Alfalfa - Orchardgrass

MB_IWG – Sma



MB_IWG - Sainfoin

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Treatments - Data

- Dry-matter yield (Fall – November)

- Forage nutritional characteristics (Just prior to winter grazing)
- Grazing
  - ✓2015 – Feb (1009 – cows)
  - ✓2016 – April (1117 – cows)
  - ✓2017 – Early graze – (962 cows)

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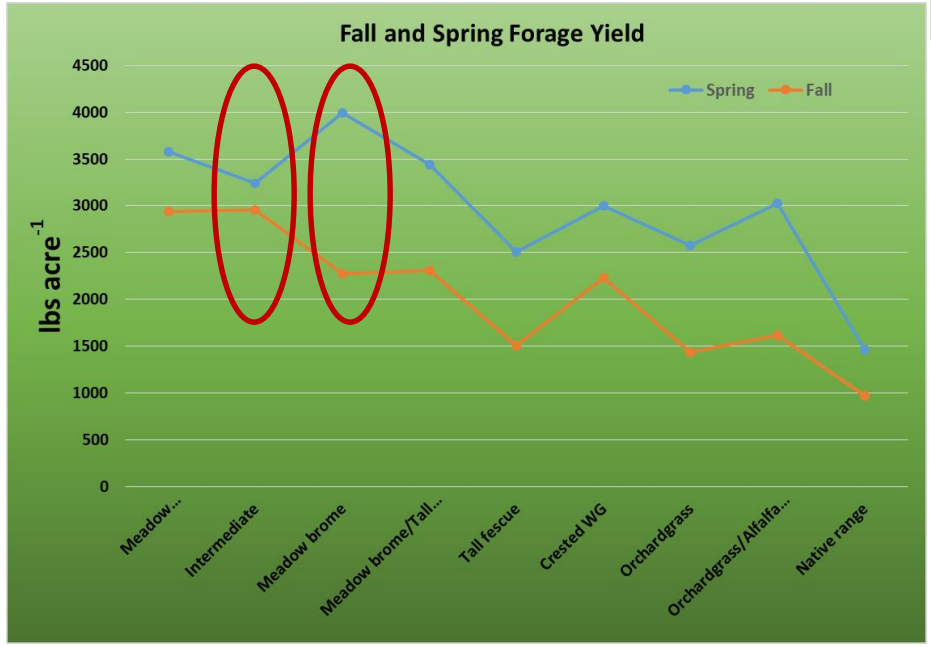
Spring Yields – lbs acre^{-1} 2014-17



Seed Mix	June Spring DM lbs acre^{-1} (2014-17)	
Meadow brome/Intermediate WG	3575	ab$^{-\mp}$
MB-Int_small burnet	3429	abc
MB_Int_alfalfa	3724	ab
MB_Int_sainfoin	3572	abc
Intermediate	3241	bc
Meadow brome	3995	a
Meadow brome/Tall fescue	3441	bc
MB_TF_sainfoin	3410	abc
MB_TF_alfalfa	3473	abc
Tall fescue	2510	d
Crested WG	2998	cd
Orchardgrass	2579	d
Orchardgrass/Alfalfa (control)	3024	cd
Native range	1459	e

24%

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Fall Yields – lbs acre^{-1} 2014-17

Seed Mix	Oct-November Fall DM lbs acre^{-1} (2014-17) November	
Meadow brome/Intermediate WG	2935	a
MB-Int_small burnet	3010	a
MB_Int_alfalfa	2961	a
MB_Int_sainfoin	2833	a
Intermediate	2954	a
Meadow brome	2273	b
Meadow brome/Tall fescue	2306	b
MB_TF_sainfoin	2247	b
MB_TF_alfalfa	2365	b
Tall fescue	1502	c
Crested WG	2229	b
Orchardgrass	1436	c
Orchardgrass/Alfalfa (control)	1617	c
Native range	973	d

45%

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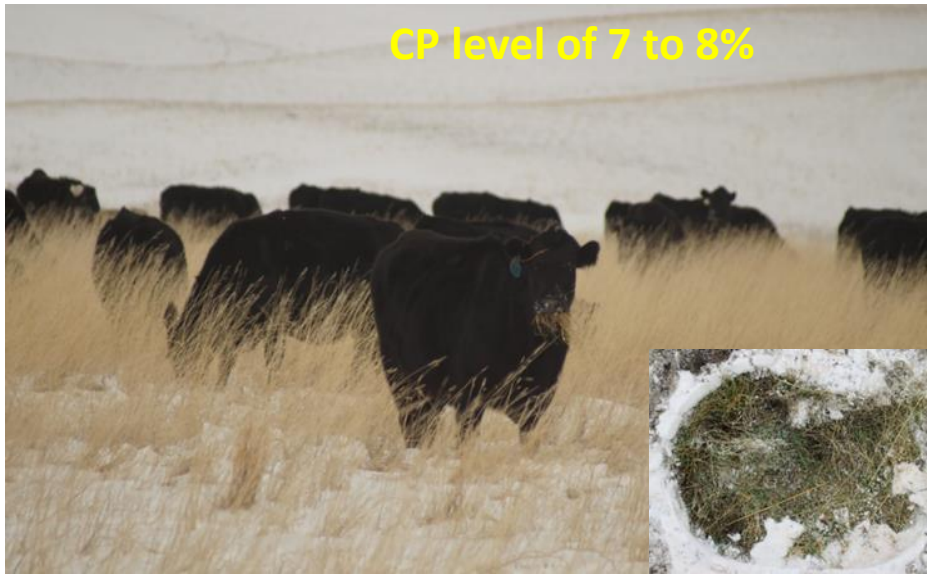
Winter Quality – 2014-17



	Winter forage quality				
Seed Mix	% CP	% NDF	% dNDF48	% WSC	RFQ
Meadow brome/Intermediate WG	6.5	80	35	0.9	43
MB-Int_small burnet	5.6	82	36	0.8	38
MB_Int_alfalfa	7.5	81	35	1.3	48
MB_Int_sainfoin	6.3	79	32	0.7	44
Intermediate	7.0	79	35	1.8	53
Meadow brome	6.1	82	32	0.0	31
Meadow brome/Tall fescue	7.1	80	33	0.6	35
MB_TF_sainfoin	7.1	80	32	0.5	36
MB_TF_alfalfa	7.0	81	34	0.8	34
Tall fescue	8.3	76	38	3.7	54
Crested WG	6.0	81	31	1.5	44
Orchardgrass	7.0	76	39	1.8	61
Orchardgrass/Alfalfa (control)	6.9	77	42	2.6	58
Native range	5.3	80	33	1.5	48
LSD $_{(0.05)}$	2.1	4.1	4.0	1.4	14

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Estimated stocking rates

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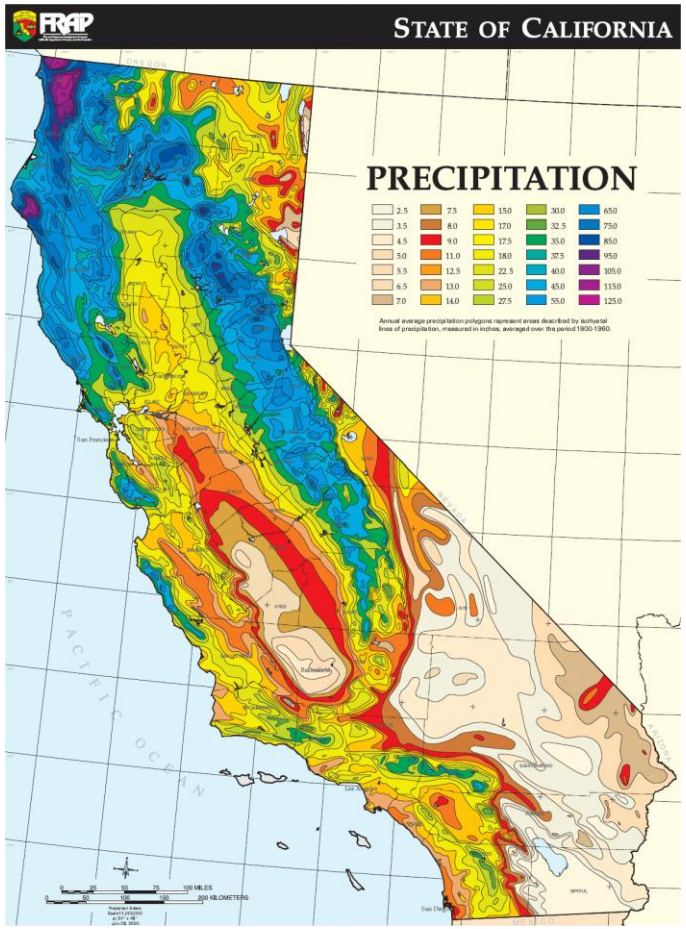
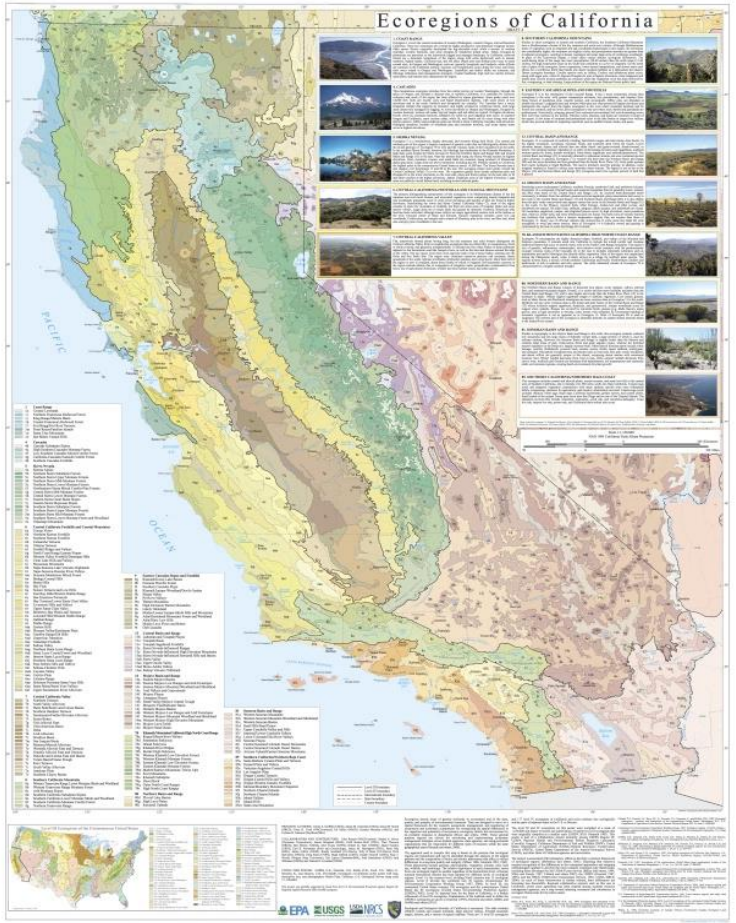
What did we learn?

- Grasses and legumes established
- Grasses persisted but sainfoin and small burnet were gone
- 2018, alfalfa increased
- Forage production maintained consistent 2015-2018
- Increased forage production over traditional range and orchardgrass/alfalfa mix
- Still looking for a good source of CP in plant materials

Challenges

Diversity of environments





One shoe does not fit all situations

Challenges/Choices

What species do I use

- Amount of available water (when)
- Soil Type (Loam, Clay, Sand)

Example 1: If plants use 1/4 inch per day, on Sandy Soil -- Then {1.25 inches/0.25 inches per day = 5 days between irrigations}

Example 2: If the plants use 1/4 inch per day, on Loamy Soil -- Then {2.50 inches/0.25 inches per day = 10 days between irrigations}

- Summer/Winter Temperatures
- Intended Use

Management

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Challenges/Choices

Invasive annual grasslands

- No real cost (outlay) to the farmer/rancher each year.
- Very environment dependent – fluctuating DMY.
- Often increases frequency and magnitude of fires.
- Persistent over years and environments.
- In some cases the nutritional quality is better than the perennials.

Perennial grasslands

- Cost of establishing the perennial grass/irrigation etc.
- Question as to how long will it persist and be productive (cool-season grasses)
- Reduces invasive weeds
- Usually provides forage longer in the growing season

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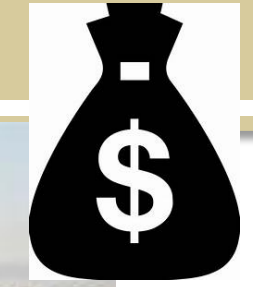
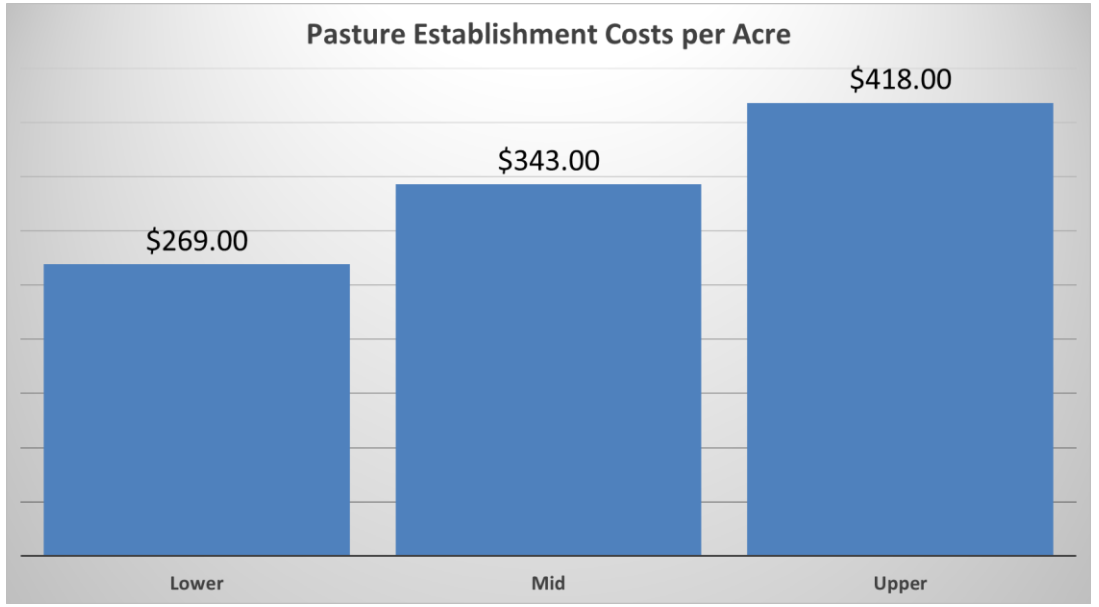
Challenges/Choices



➢ To renovate or not

UC COOPERATIVE EXTENSION
TABLE 1. SUMMARY OF COSTS FOR ALFALFA- PER ACRE OVER YEARS
SACRAMENTO VALLEY & NORTHERN SAN JOAQUIN VALLEY-2015

Operations	Establishment-Year	Year-1	Years-2	Year-3	Year-4
Pre-Plant:					
Land Prep (Combined)	95				
TOTAL PRE-PLANT COSTS	99				
Cultural:					
Soil Sample	4				
Plant-Roll-Cover Seed	222				
Irrigate-Sprinkler2X	106				
Irrigate-Flood7X		315	315	315	315
Irrigation Labor	27	122	122	122	122
Ditch/tail drain		31	31	31	31
Weed Control	7	7	7	65	14
Insect Control		61	61	61	61
Tissue Samples			11		
Fertilizer	119			85	
Farm Trucks	35	37	37	37	37
TOTAL CULTURAL COSTS	615	573	583	715	580
Harvest:					
Harvest (All operations)		270	270	270	270
TOTAL HARVEST COSTS		270	270	270	270
Interest on Operating Capital at 5.75%	3	13	13	19	13
TOTAL OPERATING COSTS/ACRE	619	855	866	1,004	862
CASH OVERHEAD COSTS/ACRE	203	208	208	208	208
TOTAL CASH COSTS/ACRE	822	1,063	1,073	1,212	1,070
NON-CASH OVERHEAD COSTS/ACRE	424	751	751	751	751
TOTAL COSTS/ACRE	1,255	1,814	1,824	1,963	1,821
TOTAL COSTS/TON		259	261	280	260



Based on 7 ton/acre

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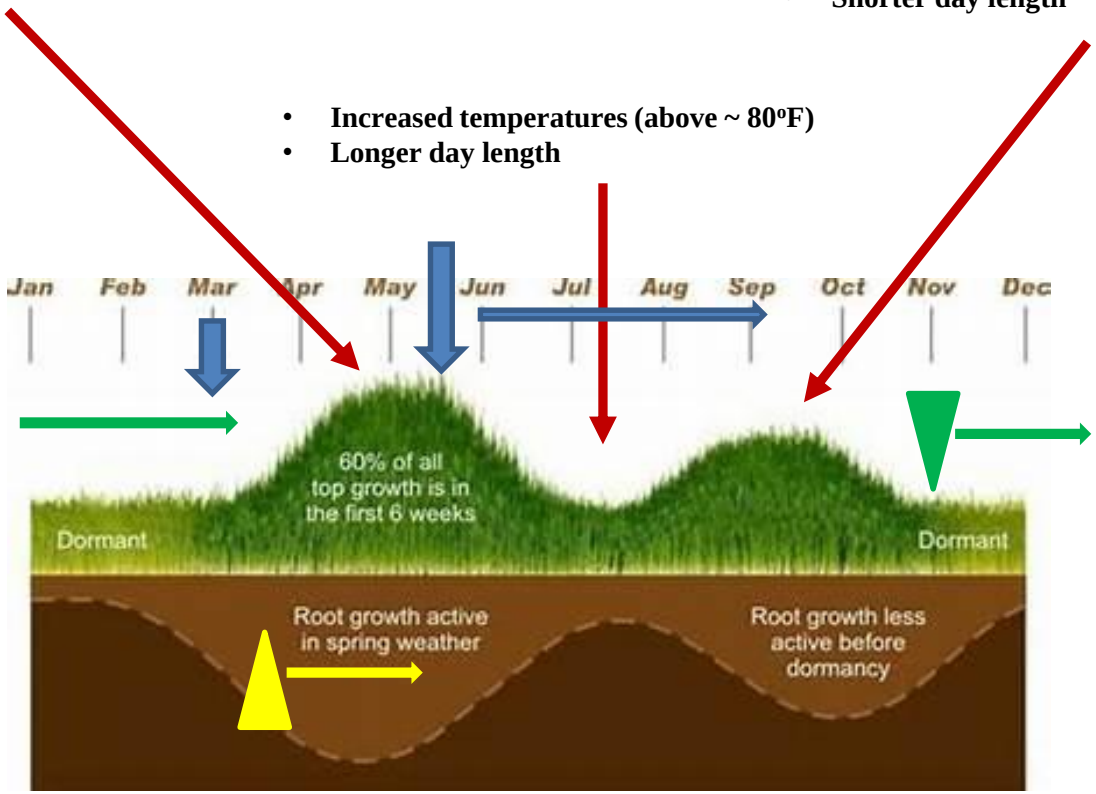
What are we asking perennial cool-season grasses to do?

- Longer day length
- Cool temperatures (up to ~ 80°F)

- Decreasing temperatures (below ~ 80°F)
- Shorter day length

- Increased temperatures (above ~ 80°F)
- Longer day length

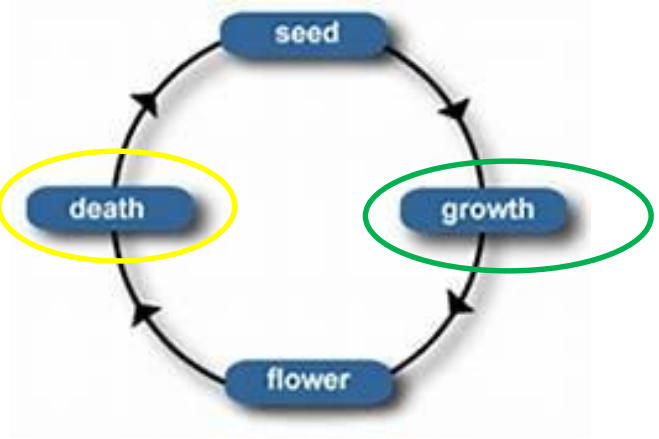


What affect does drought have?

Regions of California

- When day lengths are long enough to initiate growth, temperatures may be above the threshold for growth?
- Cool-season grasses want to be going dormant?

Annual life cycle



Tall Fescue

Summer dormant – growth habit

These grass ecotypes possess a summer dormancy trait that allows them to survive six months without precipitation, in blistering heat

- ‘Flecha’ (Grasslands Innovation)
- ‘Prosper’ (Barenbrug USA)
- ‘Chisholm’ (Noble Research Institute)

- **Chisholm is capable of producing high-quality forage from autumn through spring suitable for grazing livestock before entering summer-dormancy.**
- **After four years of grazing Chisholm pastures on our research farms, cattle had similar average daily and total live-weight gains compared to cattle on graze-out wheat pasture.**
- **The net return per acre on Chisholm was also similar to the graze-out wheat system.**
- **Other potential benefits of this perennial forage include the reduction of soil erosion and the improvement of soil health.**

Tall Fescue

Agronomic Traits

- ***Of all the pasture grasses, it is perhaps the most widely adapted across many different environments.***
- ***Forage yield (excellent) and quality (ok)***

Different irrigation levels

Species	Water Level (inches/week) 2.00	1.66	1.30	1.10	0.60
Meadow brome (1)	8.7	8.4	7.8	7.0	6.1
Orchardgrass (9)	8.9	8.3	7.4	6.3	4.6
Tall fescue (10)	**9.7**	**9.8**	**9.7**	**8.9**	**7.3**
Perennial ryegrass (9)	6.2	5.5	5.0	4.0	3.1
Smooth brome (1)	6.2	5.9	6.1	4.9	4.0
RS-Hybrid (1)	6.3	6.2	6.0	5.0	4.4

Cool-season grasses	Mean DMY lbs/Ac
Irrigated	
Perennial ryegrass	2957
Orchardgrass	5400
Timothy	5691
Creeping meadow foxtail	3405
Tall fescue	5549
Kentucky bluegrass	1804
§Meadow brome	6119

Cool-season grasses	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC
	..... g kg^{-1}						
Irrigated							
Perennial ryegrass	90.7	14.7	78.8	40.3	20.4	9.4	22.4
Orchardgrass	88.1	15.2	75.5	45.0	13.3	8.0	15.2
Timothy	87.9	14.4	75.2	43.0	17.0	10.6	19.0
Creeping meadow foxtail	86.8	13.7	73.0	47.3	14.5	10.3	16.4
Tall fescue	85.2	12.7	68.9	46.9	14.3	9.2	15.9
Kentucky bluegrass	84.3	13.6	69.0	48.8	13.7	8.0	15.1
§Meadow brome	84.2	14.2	70.6	49.2	10.8	7.2	12.4

Tall Fescue

Comparative forage yields and quality

Environmental variation

Dry matter yield performance of Chisholm tall fescue compared with summer-active and summer-dormant tall fescue cultivars over 3 yr at two locations in Oklahoma and one in Texas.

Entry	Type†	Ardmore, OK				Vashti, TX				Woodward, OK			
		Total			3-yr avg.	Total			3-yr avg.	Total			3-yr avg.
		2012‡	2013§	2014‡		2012‡	2013¶	2014‡		2012‡	2013‡	2014‡	
		kg ha^{-1}											
Chisholm	SD	4466	4317	1946	3576	5827	2617	3192	3878	3852	1818	2001	2557
Flecha	SD	5039	4079	1138	3418	5874	2483	2513	3623	4280	2154	1891	2775
Prosper	SD	4130	4114	856	3033	5113	3167	2381	3553	3854	1297	1230	2127
Kentucky 31	SA	6140	3900	2505	4182	6607	-#	-	-	4042	1478	867	2129
Texoma MaxQ II	SA	7104	2853	2792	4249	6857	-	-	-	4413	1298	1139	2283
Mean		5375	3853	1848	3692	6055	2755	2695	3685	4088	1609	1426	2374
CV %		24	14	10	9	16	22	16	15	20	39	44	19
LSD (0.05)		2465	1058	375	650	ns††	Ns	505	ns	ns	ns	974	ns

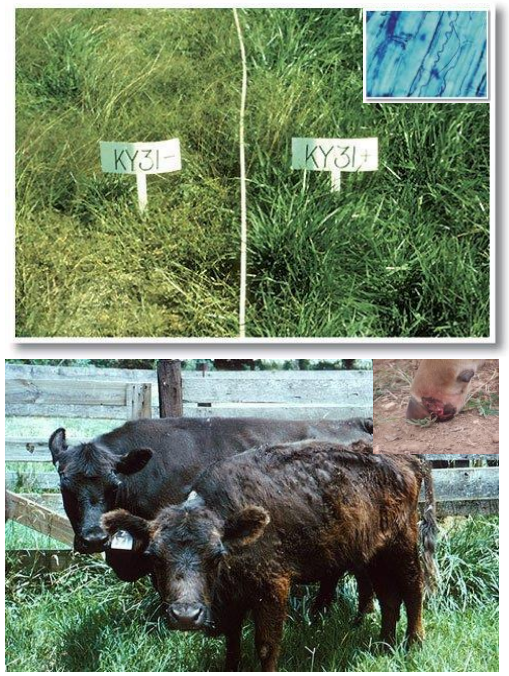
Crude protein concentration and in vitro true dry matter digestibility (IVTDMD) with summer-active and summer-dormant tall fescue cultivars. Data are the average of 12 harvests from three sites across Oklahoma and Texas, 2012–2014.

Entry	Type†	3-yr average	
		Crude protein	IVTDMD
		g kg^{-1}	g kg^{-1}
Chisholm	SD	150	736
Flecha	SD	130	727
Prosper	SD	140	737
Kentucky 31	SA	140	739
Texoma MaxQ II	SA	130	744
Mean		140	737
CV %		7	2
LSD (0.05)		10	ns‡

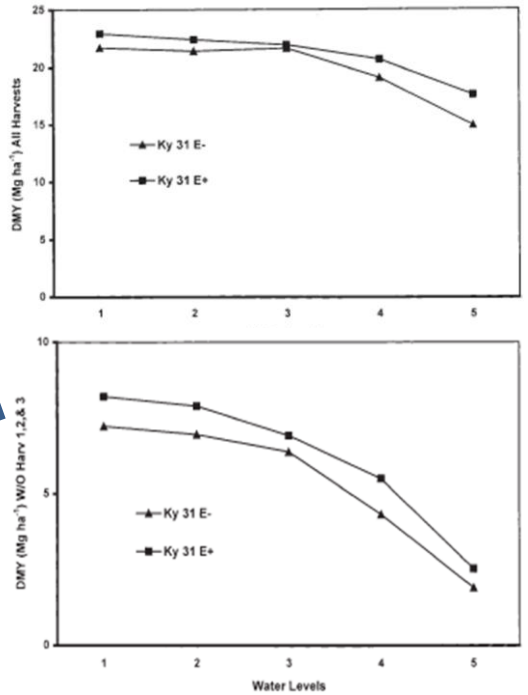
Tall Fescue

Limitations

- The presence of the fungal endophyte (reduced weight gain/or milk production, rapid breathing, and increased body temperatures) - why use endophyte free cultivars.



Advantage under hot temperatures



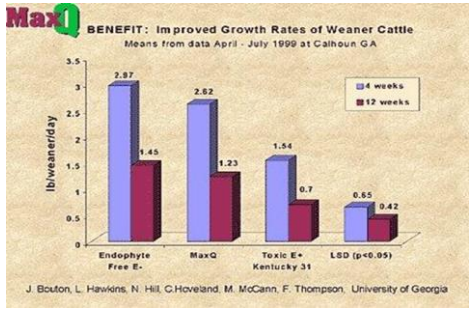
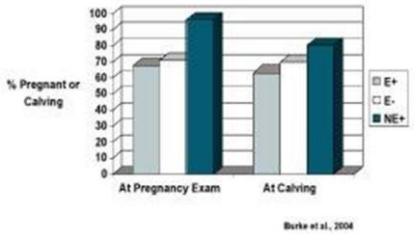


Figure 2. Effect of Fescue Type on Reproduction in Beef Cows



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Tall Fescue/Univ. of WY – Powell WY

Variety	7/14	10/7	Total (T/ac)	% of Ranger
Maximize	3.02	2.40	5.42	113
Fawn	2.69	2.16	4.85	97
Barolex	2.50	1.93	4.43	93
LSD (0.05)	0.74	0.38	0.97	

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Seasonal Trends in Tall Fescue

	Spring	Summer	Fall
Sugars, %	9.5	8.5	19
Crude Protein %	22	18	19
DDM %	69	66	74

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Other Pasture Grasses

(Adequate Water)

Perennial ryegrass
Orchardgrass
Meadow brome**
Timothy

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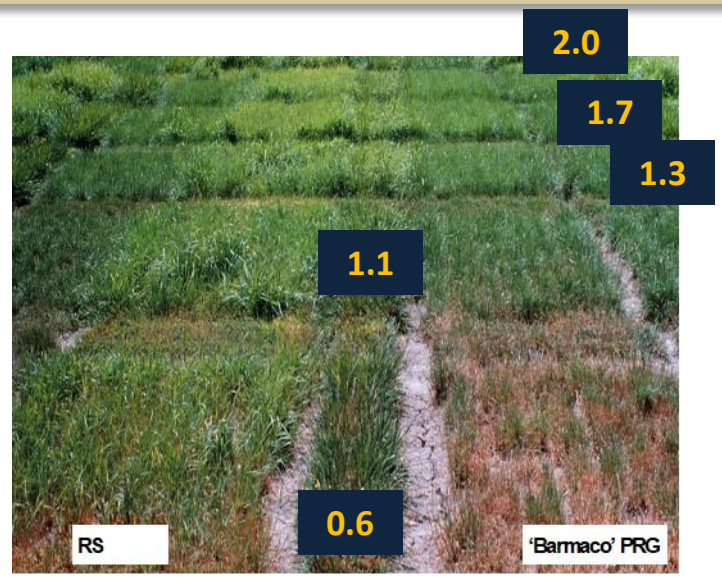
Perennial Ryegrass

Adaptations

- Best adapted to regions with 30- 50 inches of rainfall
- Adapted to a wide range of soils (pH between 5-8)
- Easy to establish
- Rapid establishment during first year (45-60 days)
- Excellent forage quality



	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC
Cool-season grasses	..... g kg^{-1}						
Irrigated							
Perennial ryegrass	90.7	14.7	78.8	40.3	20.4	9.4	22.4
Orchardgrass	88.1	15.2	75.5	45.0	13.3	8.0	15.2
Timothy	87.9	14.4	75.2	43.0	17.0	10.6	19.0
Creeping meadow foxtail	86.8	13.7	73.0	47.3	14.5	10.3	16.4
Tall fescue	85.2	12.7	68.9	46.9	14.3	9.2	15.9
Kentucky bluegrass	84.3	13.6	69.0	48.8	13.7	8.0	15.1
[§]Meadow brome	84.2	14.2	70.6	49.2	10.8	7.2	12.4

Perennial Ryegrass

Limitations

- Due to a shallow root system, not adapted to periods of heat or drought resistance
- Reduced forage production - visible mid summer slump - due to increased temperatures (above 80 F)

	Water Level (inches/week)				
Species	2.00	1.66	1.30	1.10	0.60
Meadow brome (1)	8.7	8.4	7.8	7.0	6.1
Orchardgrass (9)	8.9	8.3	7.4	6.3	4.6
Tall fescue (10)	9.7	9.8	9.7	8.9	7.3
Perennial ryegrass (9)	**6.2**	**5.5**	**5.0**	**4.0**	**3.1**
Smooth brome (1)	6.2	5.9	6.1	4.9	4.0
RS-Hybrid (1)	6.3	6.2	6.0	5.0	4.4

Cool-season grasses	Mean DMY lbs/Ac
Irrigated	
Perennial ryegrass	2957
Orchardgrass	5400
Timothy	5691
Creeping meadow foxtail	3405
Tall fescue	5549
Kentucky bluegrass	1804
§Meadow brome	6119

Orchardgrass

Adaptations

- **Medium to long-lived, high forage producing bunchgrass adapted to well drained soils.**

- **Widely preferred species for hay, pasture, or silage for livestock and wildlife.**

- **It can be grown under irrigation or dryland where at least 18 inches of annual precipitation are received.**

Later maturing type -- has higher digestibility and protein than early maturing types.

Medium maturing type -- 'Paiute' not more drought tolerant.

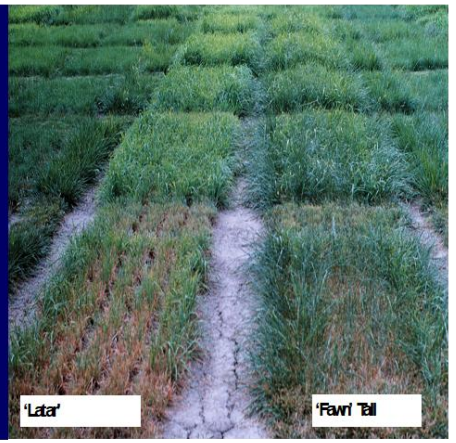
Early maturing type – 'Ambassador', 'Dawn', and 'Potomic' -- known for improved seedling vigor, high yielding, and rapid recovery after grazing.

Orchardgrass

Limitations

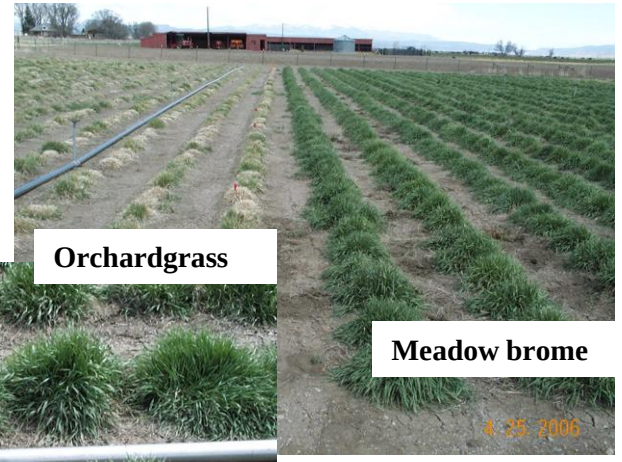
- For optimum production, requires increased irrigation
- Less drought tolerant then tall fescue and smooth brome

Species	Water Level (inches/week) 2.00	1.66	1.30	1.10	0.60
Meadow brome (1)	8.7	8.4	7.8	7.0	6.1
Orchardgrass (9)	**8.9**	**8.3**	**7.4**	**6.3**	**4.6**
Tall fescue (10)	9.7	9.8	9.7	8.9	7.3
Perennial ryegrass (9)	6.2	5.5	5.0	4.0	3.1
Smooth brome (1)	6.2	5.9	6.1	4.9	4.0
RS-Hybrid (1)	6.3	6.2	6.0	5.0	4.4



- Of the pasture grasses, the most susceptible to diseases
- Moderately winder hardy -- usually needs snow cover


Released UTDG-101 germplasm



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Orchardgrass

Cultivar differences … ?

Table 4. Dry matter yields (tons/acre), maturity and stand rating of orchardgrass varieties sown September 25, 2002 at Princeton, Kentucky.

Variety	Maturity[1] May 10, 2004	Maturity May 10, 2005	2005 Percent Stand Apr 15	2005 Percent Stand Nov 3	Yield (tons/acre) 2003 Total	2004 Total	2005 May 10	2005 Jun 13	2005 Jul 29	2005 Oct 6	2005 Total	3-yr Total
Commercial Varieties—Available for Farm Use												
Benchmark	58.5	56.5	81	89	4.46	4.21	1.82	0.80	0.26	0.69	3.57	12.24*
Crown Royale Plus	58.0	54.0	75	65	4.54	4.22	1.63	0.65	0.24	0.41	2.93	11.69*
Benchmark Plus	60.0	56.0	74	67	4.41	4.43	1.65	0.50	0.26	0.33	2.74	11.58*
Haymate	52.5	45.0	78	92	4.23	3.70	1.32	0.94	0.26	0.47	3.33	11.46*
Uncertified Potomac	57.0	54.7	80	84	4.14	4.16	1.40	0.67	0.35	0.42	2.84	11.30*
Prairie	57.5	56.0	73	70	4.25	4.33	1.49	0.60	0.24	0.37	2.69	11.27*
Hallmark	59.5	55.5	73	93	4.18	3.81	1.42	0.68	0.28	0.42	2.53	11.11*
Udder	57.5	50.0	75	65	4.05	3.84	1.47	0.56	0.31	0.34	2.69	11.01*
Crown	57.5	52.7	80	80	3.77	4.46	1.41	0.51	0.32	0.34	2.59	10.93*
Takena	48.5	45.0	75	80	4.04	3.76	0.92	0.79	0.30	0.45	2.44	10.84
Certified Potomac	56.5	56.0	78	83	4.05	3.90	1.71	0.67	0.21	0.49	2.87	10.59
Niva	49.5	39.0	46	43	3.47	3.59	0.66	0.56	0.20	0.23	1.65	8.71
Abertop	58.0	57.0	23	10	3.82	3.02	0.37	0.28	0.15	0.08	0.87	7.68
Experimental Varieties												
OG 9701	60.0	55.5	70	73	4.18	4.22	1.56	0.56	0.30	0.39	2.80	11.21*
OG-1	60.0	56.7	50	43	4.28	4.04	1.67	0.38	0.22	0.21	2.47	10.91*
Mean	56.6	52.5	69.9	70.5	4.09	4.01	1.39	0.63	0.26	0.39	2.68	10.93
CV,%	4.5	5.0	20.4	24.9	7.42	14.12	32.10	46.51	31.94	45.52	23.88	7.68
LSD,0.05	3.9	4.2	22.7	30.6	0.44	0.88	0.70	0.40	0.13	0.29	1.04	1.36

*Not significantly different from the highest numerical value in the column, based on the 0.05 LSD.
[1] Maturity rating scale: 37=flag leaf emergence, 45=boot swollen, 50=beginning of inflorescence emergence, 58=complete emergence of inflorescence, 62=beginning of pollen shed.

Variety	7/14	10/7	Total (T/ac)
Haymate	3.65	2.36	6.01
Icon	2.93	2.64	5.57
Paiute	3.13	2.40	5.53
Stampede	2.89	2.42	5.30
Barexcel	2.88	2.40	5.28
Century	3.10	2.19	5.28
Intensiv	2.93	2.30	5.23
Baridana	2.92	2.31	5.22
Renegade	2.86	2.35	5.21
Benchmark	2.83	2.30	5.12
Potomac	2.69	2.37	5.06
Pizza	2.79	2.25	5.04
Baroula	2.31	2.42	4.73
LSD (0.05)	0.74	0.38	0.97

% of Ranger			
ean WSC	Mean Sugars	Mean TNC	Mean DMY
			lbs/Ac
	126		
	117		
0.4	114	22.4	2957
3.3	111	15.2	5400
7.0	110	19.0	5691
4.5	110	16.4	3405
4.3	109	15.9	5549
3.7	109	15.1	1804
0.8	109	12.4	6119
	107		
	106		
	105		
	99		

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PLANTS FOR THE WEST

Effect of Nitrogen Fertilizer on Orchardgrass Hay Production

Fertilizer Level Split application	Orchardgrass (Boone) Lbs/Acre (3 Harvests)
0	~ 3000
80	~ 5300
160	~ 6900
240	~ 8800

SOURCE – University of Kentucky – AGR-58

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PLANTS FOR THE WEST

Timothy

Adaptation

- Cool moist climates at high elevations with an annual precipitation of 18 inches or more
- Very winter hardy
- Latest of the pasture grasses to reach maturity
- Tolerant of low soil acidity, moderately water logged soils, and can with stand a limited amount of spring flooding
- Forage quality is the highest of the pasture grasses when vegetative

Stage	CP %	ADF %	NDF%	TDN %
Late Vegetative	17.0	29	55	66
Early Bloom	15.0	32	61	61
Mid Bloom	9.1	36	67	58
Late Bloom	7.8	40	70	54

	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC	Mean DMY
Cool-season grasses	..... g kg^{-1}							lbs/Ac
Irrigated								
Perennial ryegrass	90.7	14.7	78.8	40.3	20.4	9.4	22.4	2957
Orchardgrass	88.1	15.2	75.5	45.0	13.3	8.0	15.2	5400
Timothy	87.9	14.4	75.2	43.0	17.0	10.6	19.0	5691
Creeping meadow foxtail	86.8	13.7	73.0	47.3	14.5	10.3	16.4	3405
Tall fescue	85.2	12.7	68.9	46.9	14.3	9.2	15.9	5549
Kentucky bluegrass	84.3	13.6	69.0	48.8	13.7	8.0	15.1	1804
[§]Meadow brome	84.2	14.2	70.6	49.2	10.8	7.2	12.4	6119

Timothy

Limitations

- Will not tolerate dry or hot periods throughout the growing season
- Rapid decline if forage quality as the plant matures
- Perhaps the slowest of the pasture grasses to recover after cutting
- Only 2 harvests per year?

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PLANTS FOR THE WEST

Timothy/Univ. of WY – Powell WY

Variety	7/14	10/7	Total (T/ac)	% of Ranger
Express	4.56	2.58	7.14	149
Treasure	3.92	2.44	6.36	133
Richmond	3.78	2.48	6.26	131
Talon	4.10	2.15	6.25	131
Summit	3.74	2.34	6.08	127
Erecta	4.67	1.29	5.96	125
Climax	4.15	1.74	5.89	123
Clair	3.48	2.25	5.73	120
Barmidi	4.33	1.27	5.60	117
Barliza	4.06	1.45	5.51	115
LSD (0.05)	**0.74**	**0.38**	**0.97**	

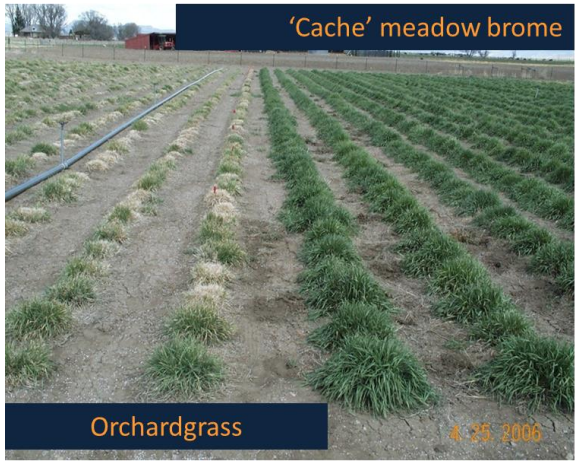
Meadow Brome – Characteristics

Adaptation

- Moderate rhizome development
- Early spring growth (earlier-smooth brome)
- High forage yields
- Adapted to dryland conditions (15 inches precipitation)
- Recovers quickly after cutting
- Stands are easy to establish
- Winter hardy

Limitations

- Highly pubescent
- Very sensitive to spring flooding
- Early maturing



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PLANTS FOR THE WEST

Meadow bromegrass – ‘Cache’

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Meadow bromegrass – 'Cache'

	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC	Mean DMY
Cool-season grasses	..... g kg^{-1}							lbs/Ac
Irrigated								
Perennial ryegrass	90.7	14.7	78.8	40.3	20.4	9.4	22.4	2957
Orchardgrass	88.1	15.2	75.5	45.0	13.3	8.0	15.2	5400
Timothy	87.9	14.4	75.2	43.0	17.0	10.6	19.0	5691
Creeping meadow foxtail	86.8	13.7	73.0	47.3	14.5	10.3	16.4	3405
Tall fescue	85.2	12.7	68.9	46.9	14.3	9.2	15.9	5549
Kentucky bluegrass	84.3	13.6	69.0	48.8	13.7	8.0	15.1	1804
§Meadow brome	84.2	14.2	70.6	49.2	10.8	7.2	12.4	6119
Dryland								
‡Crested WG	882.1	160.6	743	439.4	164.4	87.7	186.5	4165
‡Smooth brome	872.6	171.1	749.6	448.3	124.3	80.4	138.6	5671
‡Intermediate WG	867.1	149.6	735.2	472.1	130.3	85.1	147.9	4545
‡RS-hybrid	866.7	161.5	730.7	453.3	120.9	72.7	133.7	6540
‡Tall wheatgrass	845.3	145.9	718.8	497.5	114	84.4	131.5	8737
‡Sandberg bluegrass	792.7	119.3	652.3	578.7	102.9	66.4	114.5	4776

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PLANTS FOR THE WEST

Meadow bromegrass – Dryland - Nutritional Quality

Spring Traits:

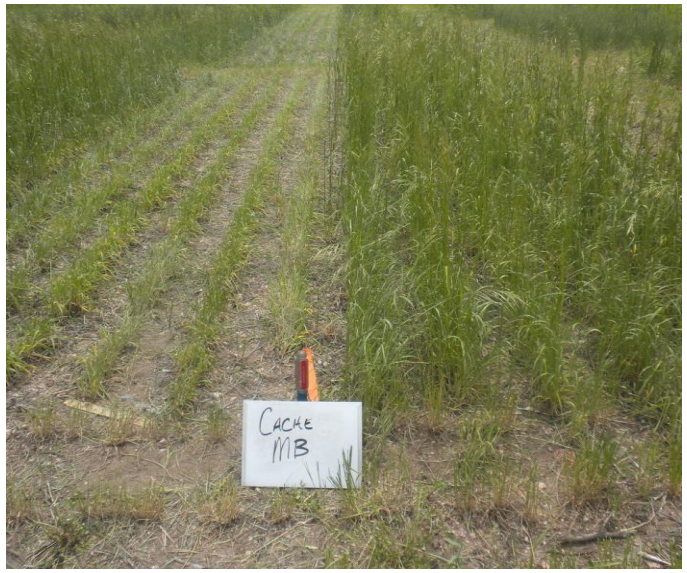
- 423 lbs ac^{-1} (May – dryland)
- CP 12.5%; Digestibility 84%
- NDF 52.1%

Regrowth Traits - October:

- 243 lbs ac^{-1}
- CP 14.2%; Digestibility 82%;
- NDF 54.7%

Fall Traits:

- 529 lbs ac^{-1} (Oct. – stockpiled - dryland)
- CP 10.7%; Digestibility 75%;
- NDF 60.5%



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Arsenal (2015)– meadow bromegrass

Arsenal meadow bromegrass (Eureka, UT).

Arsenal meadow bromegrass (Panguitch, UT).

RANGE SHIELD

BARENBRUG®

BARRICADE

THE DRYLAND MIX FOR YOUR PASTURE.

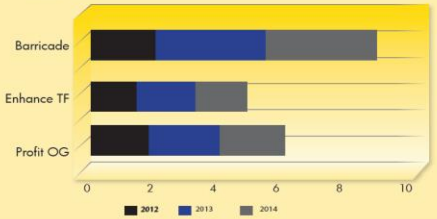
Part of our Range Shield portfolio, Barricade is designed for new planting or inter-seeding into rangeland and dryland pastures in low rainfall areas (12-18 inches growing season precipitation). Barricade contains the latest varieties of grasses selected for germination, establishment and drought tolerance under low rainfall conditions.

The seed in Barricade is enhanced with Barenbrug's exclusive Yellow Jacket brand seed coating which absorbs nearly 600 times its weight in water, which improves seed-to-soil contact and makes it ideal for rangeland seeding applications. The Yellow Jacket coating improves establishment in marginal conditions by keeping a layer of moisture around the developing seedling under less-than optimal soil moisture conditions.

Barricade is formulated from drought tolerant varieties of meadow, smooth and Alaska bromes, tall fescue and intermediate wheatgrass.

Picture: *Barenbrug's Arsenal meadow brome on the right. Developed in conjunction with ARS/Utah State University from the original Cache meadow brome germplasm.*

Forage Dry Matter Yield over 3 Years in Lincoln, Nebraska Dryland Trial



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PLANTS FOR THE WEST

Pasture Grasses

(Inadequate Water)

Grasses

- Intermediate Wheatgrass
- Pubescent Wheatgrass
- Tall Wheatgrass
- Meadow and Smooth brome
- Crested Whatgrass
- Russian Wildrye

Intermediate wheatgrass

Intermediate wheatgrass

- Moderate sod forming, late maturing, persistent
- Adapted to fertile soils that receive 14 to 18 inches of
- Tolerant to moderately alkaline soils
- The pubescent form Luna is better adapted to lower precipitation zones

FRRL
PLANTS FOR THE WEST

Intermediate wheatgrass – Yield

Means and trends in dry-matter yield (DMY) of 13 grass species across five years at Beaver, UT from 2010 to 2012.

	DMY		
Species	2010	2011	2012
Intermediate WG	1812 **A**	933 **AB**	792 **A**
Snake River WG	901 BC	666 BCD	303 DEF
Crested WG	896 B	730 B	522 ABCD
Russian WR	872 BC	638 BCD	569 ABC
Thickspike WG	699 BCD	384 F	503 BCD
Bluebunch WG	698 BCD	631 BCDE	579 ABC
Basin WR	656 CDE	972 A	561 ABC
Western WG	600 DE	705 BC	683 AB
Indian ricegrass	563 DE	470 DEF	280 EF
Smooth bromegrass	561 DE	838 AB	544 ABCDE
Siberian WG	557 DE	496 CDEF	403 CDEF
Slender WG	521 DE	110 G	198 F
Bottlebrush ST	440 E	396 EF	500 BCDE

	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC	Mean DMY
Cool-season grasses	..... g kg^{-1}							lbs/Ac
Irrigated								
Perennial ryegrass	90.7	14.7	78.8	40.3	20.4	9.4	22.4	2957
Orchardgrass	88.1	15.2	75.5	45.0	13.3	8.0	15.2	5400
Timothy	87.9	14.4	75.2	43.0	17.0	10.6	19.0	5691
Creeping meadow foxtail	86.8	13.7	73.0	47.3	14.5	10.3	16.4	3405
Tall fescue	85.2	12.7	68.9	46.9	14.3	9.2	15.9	5549
Kentucky bluegrass	84.3	13.6	69.0	48.8	13.7	8.0	15.1	1804
§Meadow brome	84.2	14.2	70.6	49.2	10.8	7.2	12.4	6119
Dryland								
‡Crested WG	882.1	160.6	743	439.4	164.4	87.7	186.5	4165
‡Smooth brome	872.6	171.1	749.6	448.3	124.3	80.4	138.6	5671
‡Intermediate WG	867.1	149.6	735.2	472.1	130.3	85.1	147.9	4545
‡RS-hybrid	866.7	161.5	730.7	453.3	120.9	72.7	133.7	6540
‡Tall wheatgrass	845.3	145.9	718.8	497.5	114	84.4	131.5	8737
‡Sandberg bluegrass	792.7	119.3	652.3	578.7	102.9	66.4	114.5	4776

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PLANTS FOR THE WEST

Intermediate wheatgrass – Nutritional Quality

Spring Traits:

- 360 lbs ac^{-1} (May – dryland)
- CP 14.1%; Digestibility 85%;
- NDF 51.2%

Regrowth Traits - November:

- 439 lbs ac^{-1}
- CP 11.4%; Digestibility 75%;
- NDF 57.1%

Fall Traits:

- 840 lbs ac^{-1} (Oct. - stockpiled)
- CP 9.7%; Digestibility 73%;
- NDF 60.3%

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PLANTS FOR THE WEST

Smooth Brome

- See ill
- Rec
- Wi
- Wi
  pre ive
- Agg
  -
  -

Varieties:
Manchar, Lincoln

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PLANTS FOR THE WEST

Smooth Bromegrass Forage Yield (Tons/Acre)

	Water Level (inches/week)				
Species	2.00	1.66	1.30	1.10	0.60
Perennial ryegrass (9)	6.2	5.5	5.0	4.0	3.1
Orchardgrass (9)	8.9	8.3	7.4	6.3	4.6
Tall fescue (1)	9.7	9.8	9.7	8.9	7.3
Meadow brome (1)	8.5	8.2	7.8	7.0	6.1
Smooth brome (1)	6.2	5.9	6.1	4.9	4.0
RS-Hybrid (1)	6.3	6.2	6.0	5.0	4.4

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PLANTS FOR THE WEST

Smooth bromegrass – Nutritional Quality

Spring Traits:

- 353 lbs ac^{-1} (May – dryland)
- CP 14.6%; Digestibility 84%;
- NDF 50.9%

Regrowth Traits – Oct.

- 197 lbs ac^{-1}
- CP 14.2%; Digestibility 80%;
- NDF 52.3%

Fall Traits:

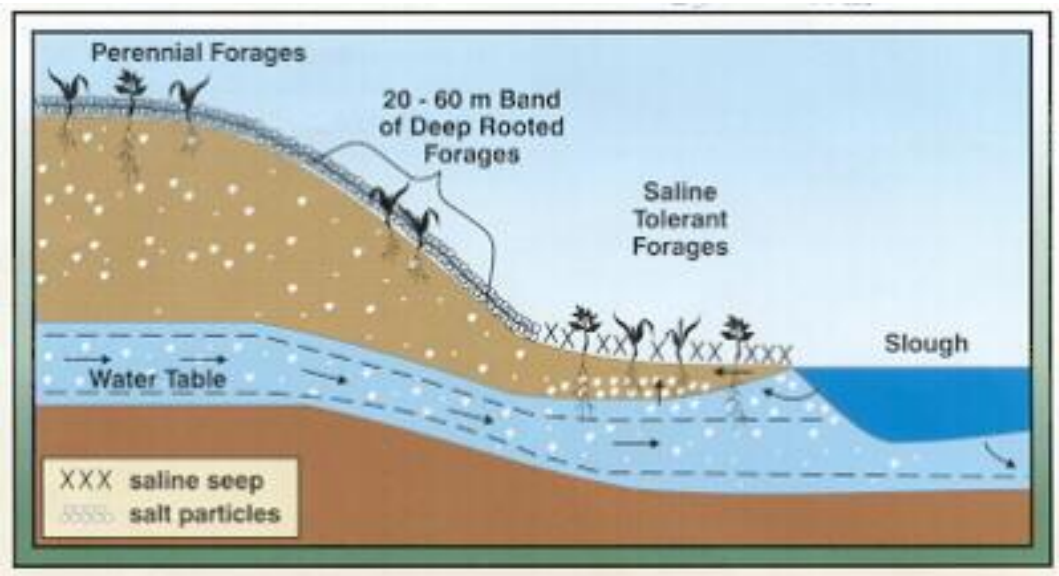
- 519 lbs ac^{-1} (Oct. - stockpiled)
- CP 10%; Digestibility 71%;
- NDF 58.8%

Pasture Grasses

(Saline Conditions)

Grasses

Tall wheatgrass (High)
NewHy (Mod-High)
Tall fescue (Mod-High)
Creeping foxtail (Mod)



Tall Wheatgrass

Adaptation

- Semiarid range sites receiving 14-16 inches precipitation
- Tolerant of imperfectly drained soils
- Tolerant high alkaline and saline soils
- Very winter hardy

FRRL
PLANTS FOR THE WEST

Tall Wheatgrass

	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC	Mean DMY
Cool-season grasses	..... g kg^{-1}							lbs/Ac
Dryland								
‡Crested WG	882.1	160.6	743	439.4	164.4	87.7	186.5	4165
‡Smooth brome	872.6	171.1	749.6	448.3	124.3	80.4	138.6	5671
‡Intermediate WG	867.1	149.6	735.2	472.1	130.3	85.1	147.9	4545
‡RS-hybrid	866.7	161.5	730.7	453.3	120.9	72.7	133.7	6540
‡Tall wheatgrass	845.3	145.9	718.8	497.5	114	84.4	131.5	8737
‡Sandberg bluegrass	792.7	119.3	652.3	578.7	102.9	66.4	114.5	4776

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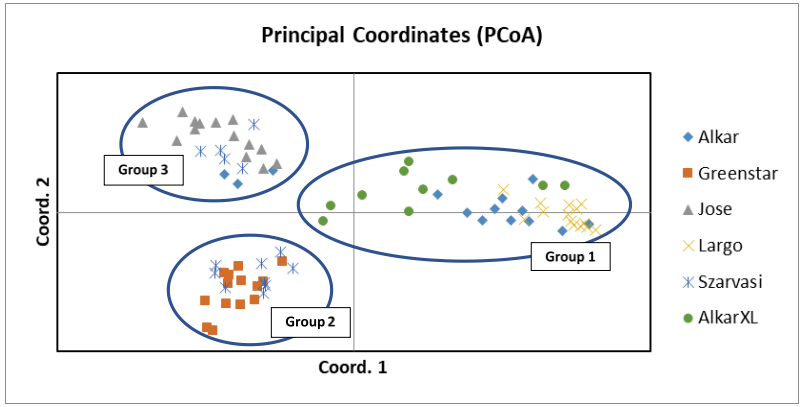
PLANTS FOR THE WEST

Tall Wheatgrass 'AlkarXL'

Table 3. Dry matter yield of AlkarXL tall wheatgrass compared to tall wheatgrass cultivars Alkar, Greenstar, Jose, Largo, and Szarvasi-1 at Millville and Panguitch, UT in 2018. H1 = July harvest; H2 = October harvest; and Comb. = combined over locations. (P < 0.20)

	kg ha-1									
	Millville, UT (2018)			Panguitch, UT (2018)			Combine (2018)			
Cultivars	H1	H2	Comb.	H1	H2	Comb.	H2	H2	Comb.	% AlkarXL
AlkarXL	8354 a	581 a	8936 a	4051 b	1417 ab	5468 b	6510 a	940 a	7450 a	
Alkar	7461 abc	613 a	8073 abc	4084 b	1485 ab	5569 b	6014 ab	986 a	7000 ab	-6
Greenstar	6062 c	430 ab	6493 c	3758 bc	1097 bc	4855 bc	5075 b	716 ab	5791 b	-22
Jose	7916 ab	527 ab	8444 ab	3566 bc	762 c	4328 c	6052 ab	628 b	6680 ab	-10
Largo	6483 bc	370 b	6853 bc	5291 a	1741 a	7032 a	5972 ab	958 a	6929 ab	-7
Szarvasi-1	8317 a	443 ab	8760 ab	3073 cd	1220 ab	4293 c	6069 ab	776 ab	6846 ab	-8



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PLANTS FOR THE WES

NewHy

- RS Hybrid cross between Quackgrass and Bluebunch Wheatgrass
- 14-16 inches of annual precipitation
- Excellent salt tolerance
- Good forage quality
- Maintains palatability throughout growing season

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PLANTS FOR THE WEST

NewHy (*Elymus hoffmannii*)

Forage Yield (Tons/Acre)

	Water Level (inches/week)				
Species	2.00	1.66	1.30	1.10	0.60
RS-Hybrid (1)	6.3	6.2	6.0	5.0	4.4
Orchardgrass (9)	8.9	8.3	7.4	6.3	4.6
Smooth brome (1)	6.2	5.9	6.1	4.9	4.0
Tall fescue (1)	9.7	9.8	9.7	8.9	7.3
Perennial ryegrass (9)	6.2	5.5	5.0	4.0	3.1
Meadow brome (1)	8.5	8.2	7.8	7.0	6.1

	Mean IVTD	Mean CP	Mean NDFD	Mean NDF	Mean WSC	Mean Sugars	Mean TNC	Mean DMY
Cool-season grasses	..... g kg^{-1}							lbs/Ac
Dryland								
‡Crested WG	882.1	160.6	743	439.4	164.4	87.7	186.5	4165
‡Smooth brome	872.6	171.1	749.6	448.3	124.3	80.4	138.6	5671
‡Intermediate WG	867.1	149.6	735.2	472.1	130.3	85.1	147.9	4545
‡RS-hybrid	866.7	161.5	730.7	453.3	120.9	72.7	133.7	6540
‡Tall wheatgrass	845.3	145.9	718.8	497.5	114	84.4	131.5	8737
‡Sandberg bluegrass	792.7	119.3	652.3	578.7	102.9	66.4	114.5	4776

Pasture Grasses

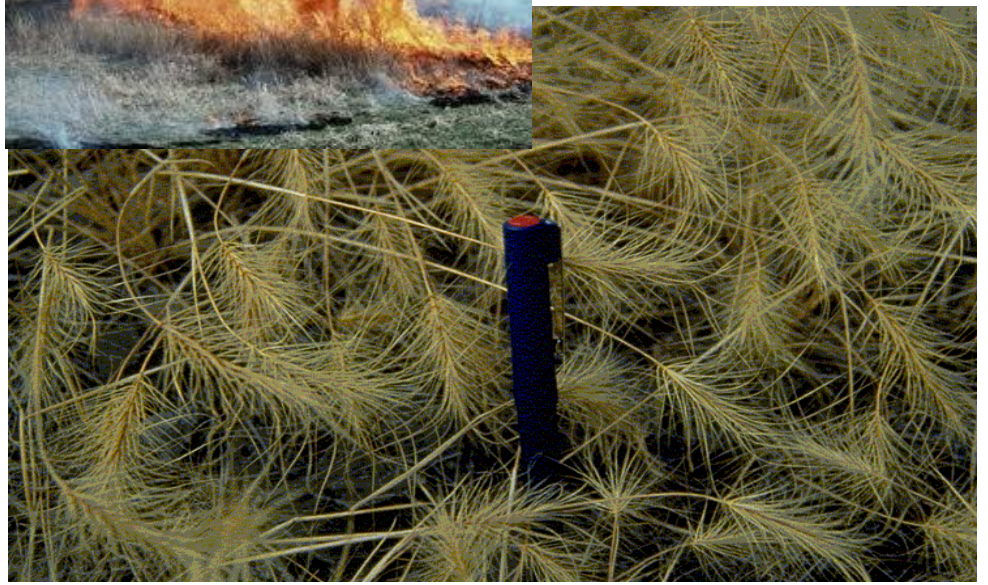
(High Water Table)

Grasses

Reed canarygrass
Creeping foxtail
Timothy
Tall fescue

Closing Thoughts

These events have been referred to by some as "the greatest ecological disaster in America?"



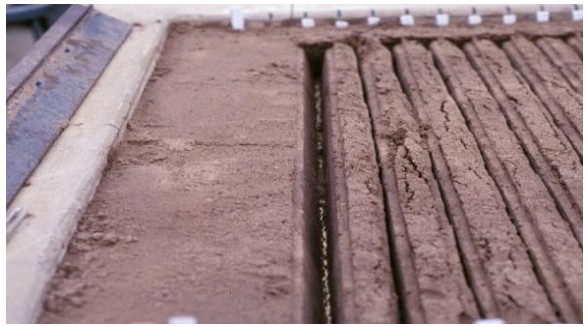
Generations from now…..how will they be referring to the affects of invasive annuals on our rangelands?

Questions

FRRL
PLANTS FOR THE WEST

Breeding for Drought Resistance

Rapid seedling establishment in early spring when water is available with persistence



Selection for individual lines that germinate and emerge from a deep seeding depth (3 inches).

Ability to out-compete weedy species