Special Report 1069
June 2006

Research in the Klamath Basin 2005 Annual Report

in cooperation with Klamath County

Oregon State University | Agricultural Experiment Station

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Klamath Falls, OR 97603

Agricultural Experiment Station
Oregon State University

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Note from the Superintendent

The 2005 year brought some definition to our future staffing at the Klamath Experiment Station (KES). The College of Agriculture Sciences (CAS) at Oregon State University (OSU), continues to deal with the limited number of faculty that current funding restrictions allow. In 2004 we had two faculty at KES and three extension faculty in the Klamath Extension Office. These five positions combined to provide a complementary research and educational program to address agricultural and natural resource needs for Klamath County.

Extension and research faculty retirements in 2005 and in 2006 will reduce the continuing faculty to one position, Dr. Richard Roseberg, at the KES. Extension faculty member, Rodney Todd, Agronomist, Department of Crop and Soil Science, retired in June of 2005; Dr. Kenneth Rykbost, Superintendent and researcher at KES completed his half-time appointment in February 2006. Extension faculty member Dr. Kerry Locke retires in June of 2006.

Following extensive conversations with local stakeholders and CAS administration we have approval to hire three faculty in 2006. These three positions will provide the research and extension program needs for local producers and stakeholders until we can receive additional resources and approval to fill the fifth faculty position. In the interim Brian Charlton will lead the potato research for KES.

We are continuing plans to move to implement a Research and Extension Center in Klamath Falls. Our expectation is this will enhance the research and educational programs for local and regional audiences that rely on information from our faculty.

Forage research projects initiated in 2002 were completed in 2005, including an alfalfa variety trial, an orchardgrass variety trial, and a mixed alfalfa/orchardgrass trial. A new test of selenium fertilizer was initiated in both orchardgrass and alfalfa hay areas at the KES site in 2005.

We grew teff (*Eragrostis tef* [Zucc.] Trotter), a warm-season annual bunch grass from Africa, as a demonstration in 2003 and 2004. Interest in this potential new forage crop resulted in an article in the *Hay & Forage Grower* magazine (Feb. 2005), which in turn resulted in over 300 inquiries from 41 states. Based on this interest, a local seed dealer has been packaging and selling teff seed. To better respond to grower interest and questions, we applied for and received a small grant to conduct trials on teff at Klamath Falls, Ontario, and Medford (in cooperation with Steve Norberg and Clint Shock at the OSU Malheur Experiment Station in Ontario). These trials mainly focused on the response of teff to various rates of nitrogen and irrigation. In 2006, we hope to evaluate a number of varieties, named land races, and numbered accessions to begin a more orderly selection and variety release program as funding allows.

Cereal research was expanded in 2005 compared to 2004. We increased the number of grain trials grown at both the KES site and the Lower Klamath Lake site, including the Western regional spring barley variety trial, the OSU Elite spring barley variety trial, the Western regional soft wheat and hard wheat spring variety trials, and the OSU elite spring wheat variety trial. A new trial in 2005 was the OSU elite winter wheat variety trial, which was grown only at the KES site. Moisture availability and growing conditions were both good in 2005, resulting in good grain yields at both sites.

A new project begun in 2005 involved peppermint. The mint area was planted in 2005 as an in-kind donation by local grower Rick Walsh. The local mint growers research group (led by Lee McKoen) pledged assistance to begin research trials on agronomic aspects of mint in 2006. Mint distillation will be done using the experimental mint still purchased with funds from the Klamath Basin Agricultural Endowment fund. The still is housed and operated by staff at the University of California - Intermountain Research and Extension Center in Tulelake, CA, with whom KES cooperates on several projects.

Other small-scale trials of potential new crops at KES included hybrid poplar and lingonberries. Poplar growth results are included in this report whereas other studies were simple adaptation tests that did not result in meaningful yield data.

Our 2005 potato variety screening program continued to evaluate material from Prosser, Washington and OSU breeding programs. Approximately 10,000 single-hill, first-generation selections were screened and over 200 second-, third-, and fourth-generation breeding lines of specialty potato selections were evaluated. Many of these selections have pigmented flesh, are high in antioxidant compounds, and are of interest to producers for niche marketing.

Potato studies in 2005 continued to evaluate nematode control in cooperation with OSU and industry personnel. Other studies involved the evaluation of alternative seed treatment carriers, yield as influenced by minituber seed size, and the use of 2,4-D to enhance red-skin color, frost-tolerant, and nematode-resistant germplasm.

The local Klamath County Master Gardener and Rotary First Harvest partnership continue to maintain the apple orchard located at the research center with assistance from KES and other community partners. Orchard production of fruit is distributed through the Klamath/Lake Food Bank. Monitoring and control of coddling moth were continued during 2005. This monitoring and reporting of insect incidence assists local orchard owners in planning control measures.

This is the 19th consecutive annual report of research activities at KES. Copies of most of these reports can be obtained by request from Klamath Experiment Station, 6941 Washburn Way, Klamath Falls, OR 97603, (541) 883-4590. Reports for 1999-2005 and additional information on Klamath Basin agriculture and KES programs are posted on our Internet Web page at http://www.orst.edu/dept/kes. We welcome comments and suggestions for improving the delivery of our research findings to our colleagues and clientele.

We extend our appreciation to our colleagues who cooperate in research activities, to industry and the organizations that provide financial support for research projects, to members of our Advisory Board for their counsel, and to Klamath County for continuing financial support for staffing, facilities, and equipment. Where appropriate, cooperators and financial support are acknowledged in project reports.

Ronald L. Hathaway
Superintendent – Staff Chair
Klamath Experiment Station

Major Cooperators in KES Research Programs

Oregon State University

Mr. Mylen Bohle, *Crook County Cooperative Extension Service*
Mr. Nick David, *Department of Botany and Plant Pathology*
Mr. Phil Hamm, *Hermiston Agricultural Research and Extension Center*
Dr. Dan Hane, *Hermiston Agricultural Research and Extension Center*
Dr. Patrick Hayes, *Department of Crop and Soil Science*
Dr. Russell Ingham, *Department of Botany and Plant Pathology*
Mr. Steve James, *Central Oregon Agricultural Research Center*
Dr. Russ Karow, *Department of Crop and Soil Science*
Dr. Kerry Locke, *Klamath County Cooperative Extension Service*
Dr. Alvin Mosley, *Department of Crop and Soil Science*
Mr. Steve Norberg, *Malheur County Cooperative Extension Service*
Dr. James Petersen, *Department of Crop and Soil Science*
Dr. Clinton Shock, *Malheur Experiment Station*
Mr. Rodney Todd, *Klamath County Cooperative Extension Service*
Mrs. Isabel Vales, *Department of Crop and Soil Science*
Mr. Phil VanBuskirk, *Southern Oregon Research and Extension Center*
Mr. Solomon Yilma, *Department of Crop and Soil Science*

University of California

Dr. Harry Carlson, *Intermountain Research and Extension Center*
Dr. Lee Jackson, *Department of Agronomy and Range Science*
Mr. Donald Kirby, *Intermountain Research and Extension Center*
Mr. Herb Philips, *Department of Vegetable Crops*
Dr. Ron Voss, *Department of Vegetable Crops*

Others

Dr. John Bamberg, *United States Potato Genebank, Sturgeon Bay, Wisconsin*
Dr. Chuck Brown, *USDA-Agricultural Research Service, Prosser, Washington*
Mr. Jim Dahm, *Whiskey Creek Timber Company, Klamath Falls, Oregon*
Dr. Steve Fransen, *Washington State University*
Dr. David Holm, *Colorado State University*
Dr. Rick Knowles, *Washington State University*
Dr. Stephen Love, *University of Idaho*
Mr. Norm McKinley, *Dupont Corporation, Salem, Oregon*
Dr. J. Creighton Miller, Jr., *Texas A&M University*
Dr. Richard Novy, *USDA-Agricultural Research Service, Aberdeen, Idaho*
Dr. Mark Pavek, *Washington State University*
Mr. Lucas Schmidt, *Dow AgroSciences*
Dr. Darrell Wesenberg, *USDA-Agricultural Research Service, Aberdeen, Idaho*
Mr. Harvey Yoshida, *Dow AgroSciences*

We deeply appreciate the involvement and contributions of these major cooperators to KES research efforts.

Advisory Board and Staff

KES Advisory Board Members

Mr. Rod Blackman, *Chairman*
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Mr. Steve Kandra
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Dr. Kenneth A. Rykbost, *Secretary, Superintendent KES*

KES Staff

Dr. Ronald L. Hathaway, *Superintendent-Extension Chair, Professor of Animal Science*
Dr. Kenneth A. Rykbost, *Professor of Crop and Soil Science, Emeritus*
Dr. Richard Roseberg, *Associate Professor of Crop and Soil Science*
Mr. Brian A. Charlton, *Senior Faculty Research Assistant*
Mrs. Jewel Haskins, *Office Specialist II*
Mr. Lawrence Johnson, *Facility Maintenance Leadworker (Klamath County)*
Mr. Jim E. Smith, *Faculty Research Assistant*
Mr. Efren Valencia, *Farm Worker (Klamath County)*
Mr. Robert Wright, *Farm Worker (Klamath County)*

Weather and Crop Summary, 2005

Kenneth A. Rykbost and Brian A. Charlton[1]

Klamath Falls and the surrounding area lie in the rain shadow of the southern Oregon Cascade Mountains. Climate in the region is characterized by a semi-arid moisture regime with about 60 percent of precipitation, averaging about 13.5 inches annually, occurring from November through March and less than 10 percent during July, August, and September. Agriculture in the region is highly dependent on irrigation to supplement precipitation during the growing season. Although the majority of crop production occurs at elevations of less than 4,200 ft, the risk of frost throughout the growing season limits crop selection. During the 1990's, frosts were recorded at Klamath Falls in each month in 3 years.

Mean air temperatures range from about 30ºF during January to nearly 70ºF in July and August. During summer months, diurnal temperature fluctuations are typically 30 to 40ºF and can be 50ºF or more. This combination of warm days and cool nights results in unique quality characteristics in crops grown in the region. Cereal grains achieve very high test weights. It is not uncommon to observe test weights of 65 lb/bushel (bu) in wheat, 40 lb/bu in oats, and 55 lb/bu in barley, compared to standards of 60, 32, and 48 lb/bu, respectively. High quality alfalfa with short internodes and high leaf to stem ratios, high specific gravity or dry matter content in potatoes, and high sugar content in sugarbeets are all manifestations of the photosynthetic advantages from warm days with high solar radiation, and limited night-time respiration at cool temperatures.

Conversely, the risk of frost throughout the summer, and a typical growing season of 110 days or less between last spring and first fall frosts limits production of crops such as corn, beans, and other crops favored by a warmer climate. Cereal production in the Klamath Basin has traditionally been dominated by spring planted crops due to the risk of late spring or early summer frosts at critical flowering and heading time, which occurs earlier for winter cereals. Frost risks for potato production are minimized by use of solid-set sprinklers that can provide protection down to about 25ºF for short duration frosts. Sugarbeet production during the 1990's experienced significant spring frost injury and the necessity to replant a portion of crops in most years.

Weather records for the region date back to the 1880's. A U.S. Weather Bureau station monitored weather at Klamath Falls, Oregon from 1884 through 1948. A National Oceanic and Atmospheric Administration (NOAA) station was established at Kingsley Field in 1949. This site is located at 42º44´ N latitude, 121º44´ W longitude, at an elevation of 4,092 ft above mean sea level. A standard mechanical weather station was established at the Klamath Experiment Station (KES) in 1984 at a site approximately one-fourth mile west of Kingsley Field.

[1]Professor Emeritus and Senior Faculty Research Assistant, respectively, Klamath Experiment Station, Klamath Falls, OR.

The Bureau of Reclamation (BOR) recently established additional weather stations in the region as part of the Agricultural Meteorological (AgriMet) network that includes over 150 stations throughout the Pacific Northwest. These stations provide local estimates of crop water use as a tool to improve irrigation efficiency for the crops produced in the region. The stations established locally include KES (1999), Lower Klamath Lake (2000), Agency Lake Ranch (2001), and Langell Valley (2001). Official codes for these stations in the BOR AgriMet network are KFLO, WRDO, AGKO, and LORO, respectively. Data can be accessed at the website: www.usbr.gov/pn/agrimet.

The KES AgriMet station was immediately adjacent to the standard weather station established at KES in 1984. Both stations were maintained from 2000 through 2003. The standard station was abandoned in January, 2004 due to staffing and funding reductions. Three years of comparative data indicated excellent agreement between the stations in precipitation, wind speed, and mean air temperatures. Maximum air temperatures were consistently 2 to 3ºF higher for the standard station while minimum air temperatures were consistently 1 to 2ºF lower in the standard station. Data for KES in this report are based on the standard station for 1984 through 2003 and the AgriMet station for 2004 and 2005.

Important micro-climate differences exist within the main crop production areas in the Klamath Basin. Cool air drainage during the growing season results in frost-prone areas south of Klamath Falls. Areas in the Lower Klamath Lake and Copic Bay, at the southern end of the Tulelake Basin, frequently experience minimum temperatures 5 to 7ºF lower than temperatures recorded at KES. Frost protection for potatoes grown in these areas is much more common than in most of the Klamath Reclamation Project area.

With the exception of 12 years from 1890 to 1903, annual precipitation records at Klamath Falls are available since 1884 (Table 1). Average annual precipitation over the era has been about 13 inches, but with a wide range from less than 7 inches in 1949 to more than 20 inches in 1948. The NOAA station consistently reported higher precipitation than the KES station in the 1990's. This was thought to be due to the proximity of the rain gauge to the airport runway and affects of airplane traffic blowing snow during winter months.

Precipitation in 2005 recorded by the KES AgriMet station was about 18 percent above the KES 21-year mean for 1984 through 2004 (Table 2). Unusually high rainfall in April, May, November, and December accounted for 84 percent of the annual total. Low 2004-2005 winter snowpack resulted in a drought declaration for most of Oregon and an initial estimate of severe water supply shortages. Precipitation during April and May salvaged the irrigation season for much of eastern Oregon and allowed near normal irrigation deliveries to Klamath Reclamation Project irrigators outside of lands served by Gerber and Clear Lake Reservoirs, except lands included in a BOR water bank program.

Spring rains allowed much of the first cutting of Klamath Basin forage crops to be produced without irrigation. Pastures enrolled in the BOR water bank program produced sufficient forage to allow several weeks of grazing without irrigation. Rains also avoided the necessity for pre-plant irrigation of row-crop fields, which was widely anticipated prior to mid-April. However, excessive soil moisture into June delayed planting of a portion of potato and cereal crops into June. Late planted and late maturing spring cereals presented harvesting challenges as frosts and showers in late September and October delayed harvest of some fields.

Less than 0.70 inch of precipitation was recorded at KES from June through October. This resulted in excellent conditions for forage harvesting on a timely basis with a high percentage of minimal or no rain damage. While delayed planting of some cereal crops resulted in late harvests and reduced yields, good yields and quality were achieved in general. A trend for increased local production of winter wheat continued in 2005.

Mean monthly air temperatures were typical throughout the year (Table 2). At KES, the last spring frost was recorded on June 2 and the first fall frost occurred on September 11, providing a 100-day frost-free season. Maximum air temperature exceeded 90ºF on 7 days in July and 4 days in August. The highest temperature experienced was 93ºF recorded on August 4. Minimum temperatures of 24ºF on September 24 and 22ºF on October 4 resulted in frost damage to potatoes exposed at the soil surface, as observed during grading of samples from KES trials. Potatoes also exhibited fairly extensive malformation problems in some varieties and selections. This was probably related to alternating periods of high and moderate maximum temperatures experienced in July and early August. Yields in commercial crops were lower than yields experienced in the very favorable 2004 season.

Summaries of mean April through September air temperatures, May through October 4-inch soil temperatures, and total precipitation for April through September and the year for 1970 through 2005 are presented in Table 3. Data are compiled from the NOAA, KES standard station, and KES AgriMet station for 1970-1983, 1984-2002, and 2003-2005, respectively. The 2005 growing season was similar to long-term trends in air temperatures. Differences in soil temperature trends suggest inaccuracies in data during the late 1980's to 2002. AgriMet data used in 2003 through 2005 show similar differences of about 10ºF between maximums and minimums at the 4-inch soil depth as observed at the NOAA station prior to 1984. Eighty-nine percent of the growing season precipitation in 2005 accumulated in April and May.

Weekly mean maximum and minimum air temperatures for 2005 are compared with 25-year means for the growing season from April 1 through October 27 in Table 4. During most of the season, temperatures were close to long-term means. Cool periods occurred in early June and late September and the only extended period of warmer than normal weather occurred in the first 3 weeks of August. Data on frost incidence and weekly precipitation for 2005 are compared with 25-year means in Table 5.

The 2005 weather can be generally classified as moderate with no departures from long-term trends with the exception of the rainfall pattern. Low precipitation in January through March was compensated for by more than twice normal rainfall in April and May. November and December started the 2005-2006 water year off to a surplus with more than twice normal precipitation for the first quarter of the water year. This pattern has continued into January of 2006.

Table 1. Annual precipitation at Klamath Falls, OR, recorded by the U.S. Weather Bureau (1884-1948), National Weather Service (NOAA) (1949-1996), and Klamath Experiment Station (KES) (1984-2005).

Year	in	Year	in	Year	in	Year	in	in
U.S. Weather Bureau precipitation				NOAA precipitation				KES precipitation
1884	17.94	1921	11.94	1949	6.86	1979	14.10	
1885	18.71	1922	15.19	1950	13.56	1980	11.03	
1886	18.06	1923	9.85	1951	10.76	1981	15.57	
1887	10.71	1924	11.28	1952	10.97	1982	13.90	
1888	13.75	1925	14.26	1953	10.76	1983	18.56	
1889	10.40	1926	13.23	1954	8.57	1984	12.98	13.32
1890	IN[1]	1927	15.47	1955	11.31	1985	9.17	10.15
1891-99	NA[2]	1928	11.65	1956	12.52	1986	13.49	13.06
1900	NA[2]	1929	8.56	1957	18.38	1987	10.11	10.13
1901	NA[2]	1930	9.44	1958	13.25	1988	10.32	10.15
1902	11.26	1931	9.50	1959	6.72	1989	12.11	12.08
1903	IN[1]	1932	9.84	1960	15.86	1990	13.33	12.46
1904	15.04	1933	11.01	1961	13.21	1991	10.50	9.29
1905	8.32	1934	10.47	1962	16.92	1992	11.68	11.34
1906	14.87	1935	11.25	1963	10.41	1993	16.78	14.96
1907	16.67	1936	13.44	1964	15.45	1994	9.84	7.72
1908	10.02	1937	19.41	1965	10.12	1995	22.66	19.06
1909	17.67	1938	13.05	1966	11.50	1996	23.91	19.54
1910	14.70	1939	11.99	1967	9.21	1997		14.29
1911	9.73	1940	17.12	1968	10.18	1998		19.51
1912	19.56	1941	19.71	1969	15.38	1999		11.54
1913	16.11	1942	14.09	1970	12.61	2000		11.51
1914	11.42	1943	13.82	1971	12.68	2001		10.03
1915	11.72	1944	12.42	1972	11.72	2002		9.05
1916	10.98	1945	16.52	1973	11.03	2003		11.90
1917	10.22	1946	11.46	1974	8.64	2004		12.17
1918	9.51	1947	11.32	1975	13.21	2005		14.77
1919	9.40	1948	20.91	1976	8.70			
1920	12.22			1977	12.37			
				1978	9.30			

Means		
U.S. Weather Bureau	1884-1948	13.22
NOAA	1949-1983	12.51
NOAA	1984-1996	13.61
KES	1984-1996	12.56
KES	1984-2005	12.63

[1]IN: datum incomplete.
[2]NA: datum unavailable.

Table 2. Mean monthly air temperatures and total monthly precipitation recorded at the Klamath Experiment Station, Klamath Falls, OR for 2005 and for 1984-2004.

Month	Mean monthly temperature max	min	mean	Total precipitation
	^{o}F			in
		2005		
January	39	20	30	0.50
February	48	25	37	0.50
March	54	27	41	0.69
April	54	29	42	1.80
May	63	39	51	2.27
June	67	40	54	0.19
July	85	49	67	0.02
August	84	48	66	0.00
September	72	37	54	0.14
October	62	31	47	0.32
November	45	26	36	4.16
December	37	22	30	4.18
Mean/Total	59	33	46	14.77
		1984-2004		
January	40	20	30	1.83
February	45	23	34	1.20
March	52	26	39	1.13
April	58	30	44	1.01
May	66	36	51	1.11
June	75	43	59	0.75
July	83	48	65	0.35
August	83	46	64	0.47
September	77	39	58	0.65
October	65	30	48	0.73
November	48	24	36	1.62
December	39	19	29	1.71
Mean/Total	61	32	46	12.56

Table 3. Mean air temperatures for April through September, mean 4-inch soil temperatures for May through October, and total precipitation for April through September and annually from 1970 to 2005 at Klamath Falls, OR.

	Air temperature Apr-Sep			4-in soil temperature May-Oct			Total precipitation	
Year	max	min	mean	max	min	mean	Apr-Sep	annual
	°F						in	
2005	71	40	56	71	61	66	4.56	14.77
2004	73	42	58	71	59	65	3.35	12.17
2003	75	41	58	70	59	65	4.61	11.90
2002	75	36	56	60	55	58	2.08	9.05
2001	76	37	56	74	59	66	2.78	10.03
2000	72	39	56	70	56	63	4.20	11.51
1999	72	39	55	68	55	61	3.98	11.54
1998	73	41	57	59	57	58	6.95	19.51
1997	73	41	57	60	57	58	4.52	14.29
1996	72	39	56	61	59	60	5.50	19.54
1995	72	40	56	61	57	59	7.10	19.06
1994	76	40	58	63	59	61	3.42	7.72
1993	70	38	54	60	55	58	5.82	14.96
1992	77	42	60	66	58	62	3.41	11.34
1991	73	40	57	61	55	59	3.41	9.29
1990	74	41	58	61	55	58	5.66	12.46
1989	72	40	56	62	55	59	5.16	12.08
1988	75	41	58	64	56	60	3.13	10.15
1987	76	41	59	65	56	61	3.24	10.13
1986	73	42	58	70	59	64	3.87	13.06
1985	74	40	57	64	53	59	5.50	10.15
1984	71	41	56	70	57	64	4.36	13.32
1983	69	40	55	73	59	66	3.88	18.56
1982	70	40	55	71	57	64	4.18	13.90
1981	74	42	58	73	58	66	2.43	15.57
1980	71	41	56	74	59	67	2.75	11.03
1979	74	42	58	ND[1]	ND	ND	3.77	14.10
1978	70	40	55	71	58	65	4.57	9.30
1977	73	43	58	71	58	65	4.97	12.37
1976	69	41	55	72	57	65	4.94	8.70
1975	71	41	56	ND	ND	ND	4.10	13.21
1974	74	42	58	70	56	63	1.82	8.64
1973	75	42	59	69	55	62	1.29	11.03
1972	73	41	57	ND	ND	ND	1.87	11.72
1971	70	40	55	ND	ND	ND	4.68	12.68
1970	74	39	57	70	57	64	1.25	12.61
Mean	73	41	57	67	57	62	3.98	12.54

[1]No data.

Table 4. Weekly average maximum, minimum, and mean air temperatures for the 2005 growing season and 1979-2004 at Klamath Falls, OR.

		2005 Weekly average			1979-2004 Weekly average		
Weekly period		max	min	mean	max	min	mean
		°F					
April	1-7	54	29	42	55	28	42
	8-14	48	26	37	57	29	43
	15-21	54	27	40	58	32	45
	22-28	61	34	48	59	32	46
	29-5	61	41	51	62	36	48
May	6-12	55	37	46	63	34	48
	13-19	59	39	49	66	36	51
	20-26	69	41	55	70	39	55
	27-2	68	48	55	70	40	55
June	3-9	59	35	47	70	41	56
	10-16	66	39	52	74	42	58
	17-23	68	41	55	76	44	60
	24-30	76	48	62	78	46	62
July	1-7	81	46	63	79	46	62
	8-14	82	50	66	82	47	65
	15-21	90	53	72	83	49	66
	22-28	86	51	68	86	50	68
	29-4	87	54	71	85	49	67
August	5-11	88	51	69	85	48	67
	12-18	84	49	67	84	46	65
	19-25	85	47	66	81	45	63
	26-1	80	44	62	81	43	62
September	2-8	78	45	61	80	42	61
	9-15	67	35	51	77	40	58
	16-22	72	36	54	74	38	56
	23-29	68	33	51	74	38	56
	30-6	61	29	45	73	35	54
October	7-13	66	34	50	68	33	50
	14-20	65	33	49	64	29	47
	21-27	64	29	46	62	30	46
Mean		70	40	55	73	39	56

Table 5. Weekly minimum air temperatures, frost days, and precipitation for the 2005 growing season and 1979-2004 at Klamath Falls, OR.

Weekly period		Weekly min.		Frost days/week		Weekly precip.		Accum. precip.	
		2005	1979-04	2005	1979-04	2005	1979-04	2005	1979-04
		---- ^{o}F ----		---- % ----		---- in ----			
April	1-7	21	11	71	76	0.11	0.16	0.11	0.16
	8-14	20	15	100	65	0.11	0.17	0.22	0.33
	15-21	21	17	100	56	0.24	0.28	0.46	0.61
	22-28	28	20	43	56	1.24	0.24	1.70	0.85
	29-5	37	19	0	38	0.54	0.30	2.24	1.15
May	6-12	32	18	0	49	1.10	0.21	3.34	1.36
	13-19	31	19	14	34	0.70	0.27	4.04	1.63
	20-26	31	24	14	19	0.01	0.19	4.05	1.82
	27-2	32	27	14	16	0.02	0.27	4.07	2.09
June	3-9	32	22	0	12	0.04	0.22	4.11	2.31
	10-16	35	25	0	8	0.04	0.15	4.15	2.46
	17-23	36	30	0	5	0.06	0.07	4.21	2.53
	24-30	43	31	0	0	0.05	0.18	4.26	2.71
July	1-7	39	31	0	2	0.01	0.06	4.27	2.77
	8-14	46	34	0	0	0.01	0.04	4.28	2.81
	15-21	50	32	0	1	0.00	0.10	4.28	2.91
	22-28	43	35	0	0	0.00	0.04	4.28	2.95
	29-4	52	33	0	0	0.00	0.07	4.28	3.02
August	5-11	44	28	0	1	0.00	0.11	4.28	3.13
	12-18	43	29	0	2	0.00	0.09	4.28	3.22
	19-25	45	30	0	3	0.00	0.16	4.28	3.38
	26-1	35	29	0	2	0.00	0.16	4.28	3.54
September	2-8	37	26	0	7	0.00	0.10	4.28	3.64
	9-15	30	24	28	10	0.00	0.14	4.28	3.78
	16-22	32	24	0	13	0.00	0.16	4.28	3.94
	23-29	24	24	57	22	0.12	0.12	4.40	4.06
	30-6	22	20	71	27	0.12	0.05	4.52	4.11
October	7-13	27	16	43	43	0.00	0.15	4.52	4.26
	14-20	26	18	28	71	0.05	0.12	4.57	4.38
	21-27	24	12	86	69	0.13	0.31	4.70	4.69

Russet-skinned 2005 Potato Variety Evaluation Trials

Kenneth A. Rykbost and Brian A. Charlton[1]

Introduction

The tri-state potato variety development program in Oregon, Washington, and Idaho was initiated in 1985 and has produced 21 new varieties. Oregon has been the lead state in the release of nine varieties in the past decade. The emphasis for the program has expanded from a primary focus on development of processing or dual-purpose russets to include red-skinned and specialty selections with unique skin and/or flesh colors and nutritional qualities including enhanced antioxidant and vitamin C content.

Additional recent emphasis has been aimed at improved resistance to diseases and pests. Extensive late blight resistance screening and breeding crosses at Corvallis, Oregon have produced parental material virtually immune to late blight. Recently released Defender has excellent resistance to foliar and tuber late blight infection. The long season and high insect and disease pressure experienced in the Columbia Basin is being exploited at the Hermiston Agricultural Research and Extension Center (HAREC) to screen for resistance to potato virus Y (PVY), potato leaf roll virus (PLRV), net necrosis caused by PLRV, and early die syndrome. Screening for resistance to nematodes and related diseases is being accomplished at several locations. Thirty five selections from the USDA-ARS breeding program at Prosser, Washington were screened for resistance to root-knot nematode and corky ringspot under high nematode population pressure at the Klamath Experiment Station (KES) in 2005. Cooperators in Idaho and Washington also contribute to the disease and pest resistance efforts. Future tri-state releases will offer the industry reduced production costs through genetic control of economically important diseases and pests.

This report will only summarize trials involving the more traditional breeding lines aimed at russet selections for processing and fresh markets. Red-skinned and specialty-type cultivars will be reported on separately.

KES participation in the russet evaluation component of tri-state efforts includes trials of Oregon preliminary and advanced material as well as trialing late-season Western Regional selections. Plant materials in the Preliminary Yield Trial (PYT) are typically clones selected from single-hills 2 or 3 years earlier. Clones selected from the PYT advance to the Statewide Trial the following year and may reach the regional trial level in year 7 or 8 of field evaluations. Oregon selections remain in the Oregon Statewide Trial until they complete

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regional evaluation or are discarded. Most tri-state releases have occurred about 12 or 13 years following the breeding cross that produced them.

Procedures

Trials were conducted on a Poe fine sandy loam soil at KES. The soil has a pH of 6.5 and an organic matter content of 1.5 percent in the plow layer. The trial site was cropped with orchardgrass from 2002 through 2004. Potatoes were last grown at the site in 1999. Field preparation included an herbicide application in fall of 2004, discing twice, and rototilling once to break up sod in April 2005. Following an 18-inch depth shanked application of Telone™ II (dichloropropene, Dow AgroSciences) at 20 gal/acre (gpa) on April 14, 2005, the site was moldboard plowed on May 13.

Seed for all trials was hand cut to approximately 1.5-2.0 oz/seedpiece on May 11 and 12, treated with Tops® MZ (thiophanate methyl-mancozeb, Gustafson), and suberized for 2 weeks at 55ºF and approximately 95 percent relative humidity. Potatoes were planted at 10-inch spacing in 32-inch rows with an assisted-feed, 2-row planter on May 25 (Preliminary) and May 26 (Statewide and Western Regional trials). Fertilizer was banded on both sides of rows at planting at 160 lb Nitrogen (N), 80 lb Phosphate (P_2O_5), 80 lb Potash (K_2O), and 140 lb Sulfur (S)/acre. The insecticide Admire® 2R (imidacloprid, Bayer Crop Sciences) at 0.17 lb active ingredient (ai)/acre and the fungicide Quadris® (azoxystrobin, Syngenta Crop Protection, Inc.) at 0.10 lb ai/acre were applied in the planting furrow.

The herbicides Dual II Magnum® (metolachlor, Syngenta Crop Protection, Inc.) and Prowl® 3.3 EC Herbicide (pendimethalin, BASF Ag Products) were applied pre-emergence with a ground sprayer at 1.5 pt/acre, each on June 10 and incorporated immediately following application with a rolling cultivator in two passes. Matrix® (rimsulfuron, DuPont) was applied at 1.5 oz/acre (0.375 lb ai/acre) through chemigation on July 21. Approximately 18 inches of irrigation was applied during the growing season with solid-set sprinklers arranged in a 40- by 48-ft pattern.

All trials were arranged in randomized complete block designs. The Preliminary Yield Trial included 2 replications of 20-hill plots. Entries included standard varieties Russet Burbank, Ranger Russet, Shepody, and Russet Norkotah, and 116 numbered selections. The Statewide Trial included 5 replications of 20-hill plots. Entries included standard varieties Russet Burbank, Ranger Russet, and Russet Norkotah, and 20 numbered selections. The Western Regional Trial included 5 replications of 20-hill plots, standard varieties Russet Burbank, Ranger Russet, and Russet Norkotah, and 18 numbered selections.

Plant stands were monitored on June 27 and July 7. Fungicides applied aerially on July 10, August 20 and September 10 included Quadris, Dithane® F-45, (Ethylene bisdithiocarbamate, Dow AgroSciences), and Bravo Ultrex® (chlorothalonil, Syngenta Crop Protection, Inc.), respectively, at labeled rates. Vines were desiccated with Reglone® desiccant (diquat dibromide, Syngenta Crop Protection, Inc.) applied with a ground sprayer at 1.5 pt/acre on September 15.

Tubers were harvested with a one-row digger-bagger on October 6 (Western Regional), October 7 (Preliminary Yield Trial), and October 10 (Statewide Trial). All tubers from each plot were saved and stored at about 55ºF until they were graded between October 19 and 24. USDA grade standards were used to separate U.S. No. 1s, No. 2s, and culls. Tubers under 4 oz were classified as Bs. U.S. No.1s were separated by weight to 4- to 8-oz, 8- to 12-oz, and over 12-oz groupings. Subsamples of approximately 10 lb from the 8- to 12-oz fraction were used to determine specific gravity by the weight-in-air, weight-in-water method. Ten large tubers from each plot were cut lengthwise to inspect for internal defects including hollow-heart, brown center, internal brown spot, vascular discoloration, stem end discoloration, corky ringspot, and black spot bruising.

External characteristics were noted on the total sample for each replication. Yields of U.S. No. 1s were not adjusted to account for external blemishes such as *Rhizoctonia* or silver scurf or internal defects such as hollow heart, brown center, and others. External defects including growth cracks, knobs, and misshapen tubers were downgraded to U.S. No. 2s or culls depending on the severity of the defect. A subsample of tubers from the U.S. No. 1 8- to 12-oz fraction was collected from 1 replication of each trial for evaluation of processing quality (fry color) on November 8 and 9.

Except for the Preliminary Yield Trial, which included only two replications, data were statistically analyzed with SAS® for Linear Models, Fourth Edition (SAS Institute Inc.) software. Least significant differences (LSDs) are based on Student's *t* at the 5 percent probability level. Only a portion of the data obtained is reported here. Data from all trial locations were summarized and reports were reviewed by all cooperators on January 12, 2006 as the basis for decisions on disposition of trial entries.

Results and Discussion

Average environmental conditions persisted throughout the growing season and resulted in typical yields for the region. This contrasted with 2004 conditions, which produced relatively high yields and good quality. No frosts were recorded from June 3 through September 10. Maximum temperatures exceeding 90ºF in mid-July and early August contributed to a significant incidence of misshapen tubers. Many of these tubers displayed dumbbell or bottleneck shapes which are typical responses to mid-season heat or moisture stress. Frosts were recorded at the nearby AgriMet weather station on September 24 (24ºF) and October 4 (22ºF). Minor frost damage (one to three or four rotted tubers per plot) was observed in many samples during grading. Yield of U.S. No. 1s for Russet Burbank and Russet Norkotah averaged about 100 cwt/acre less in 2005 than in 2004, which enjoyed an exceptionally favorable weather pattern.

Emergence and early season growth was excellent in all trials. With very few exceptions, final plant stands exceeded 95 percent. A number of selections remained vigorous until vines were desiccated on September 15. Several selections, particularly in the Preliminary Yield Trial, achieved exceptionally high yields but had immature skins and experienced skinning injury at harvest. Specific gravity values were normal for the area. Russet Burbank and Ranger Russet produced high percentages of off-type tubers and relatively low percentages of U.S. No. 1s in these trials at KES.

Preliminary Yield Trial

The four standard varieties averaged 350 cwt/acre of U.S. No. 1s at KES in 2005. This compares to 356 cwt/acre in 2003 and 473 cwt/acre in

2004. The yield of U.S. No. 1s averaged 62 percent of total yield for the standard varieties in 2005 compared with an average of 74 percent in 2004 and 54 percent in 2003. There was a much higher incidence of U.S. No. 2s and culls in 2005 and 2003. Mean specific gravity for the standards was 1.086 in 2004 and 1.081 in 2003.

Fourteen numbered selections out of 116 were retained for further evaluation (Table 1). Clones saved included 5 of the 10 highest-yielding clones for U.S. No. 1s at KES. Only 3 of these ranked in the top 10 clones across locations. AO98104-1 ranked highest at HAREC where it produced 1,332 cwt/acre of U.S. No. 1s, and second at KES with 512 cwt/acre ofU.S. No. 1s. AO00018-3 ranked first at KES but 49th across locations and 73rd at HAREC. AO00024-7 ranked in the top 6 at all locations except HAREC, where No. 1 yield ranked 41st. While yield rankings are often quite consistent between COARC and KES, that was not true for most clones in 2005. AO98104-1 ranked second in No. 1 yield at KES but 50th at COARC. AO99179-4 ranked second at COARC but 73rd at KES.

All of the entries retained for further evaluation were superior to Russet Burbank, Ranger Russet, and Shepody in No. 1 yields observed at KES. Only two selections exceeded Russet Norkotah in No. 1 yields.

Statewide Yield Trial

All entries in this trial achieved excellent stands (Table 2). Vine maturity ranged from earlier than Russet Norkotah in two selections to later than Ranger Russet in seven selections. A high incidence of hollow heart was noted in one clone. Cooling tuber samples below 50ºF prior to conducting fry tests resulted in several clones exhibiting a relatively dark fry color. Most clones were equal to or better than the standard varieties in fry color.

Yields of U.S. No. 1s for standard varieties were similar to yields observed in the Preliminary Yield Trial (Table 3). AO96160-3 and AO96164-1 were included in the 2005 Western Regional Trial. AO96160-3 ranked third in yield of U.S. No. 1s in Statewide Trials in 2002 and 2003. It was second in this trial at KES and across all locations in 2005. It has consistently produced a high percentage of U.S. No. 1s with few No. 2s or culls, and has good processing quality. The only internal defect noted in Oregon trials is a tendency for vascular discoloration. It will be retained in the Western Regional Trial for the third year in 2006.

AO96164-1 was included in the Western Regional Trial in 2005. It has consistently produced a high percentage of U.S. No. 1s and better than average yields. Processing quality of this selection is inferior to that of AO96160-3 based on Oregon data, but Washington data indicated the reverse. Misshapen tubers have been observed each year at KES. Susceptibility to shatter bruise has also been noted in each year of trials. This selection will be discarded.

AO96141-3 was included in the Tri-State Trial in 2005. It ranked first in yield of U.S. No. 1s in the late harvest trial and is being advanced to the Western Regional Trial for 2006. Performance in the 2005 Statewide Trial was mediocre. Misshapen tubers have been common at KES and it only ranked 11th in total U.S. No. 1 yield across locations in 2005. However, it has excellent processing quality and achieved the highest merit score for processing in the Tri-State Trial.

Three additional clones were retained for further evaluation in the Statewide Yield Trial. AO96365-2 and

AO98282-5 ranked first and third at KES and across all locations in yield of U.S. No. 1s. Both clones had acceptable processing quality. AO96305-3 was among the best clones in appearance but mediocre in yield at all locations. Each of these lines will remain in the Statewide Trial for 2006. AO98133-2 was included in the 2005 Tri-State Trial. It has produced high yields of very large tubers in all trials. A very low tuber set is probably the main limitation for this clone, which has attractive appearance and seldom exhibited external or internal defects. It will be discarded.

Western Regional Trial

Excellent stands were achieved by all entries in the trial (Table 4). A relatively high incidence of hollow heart was observed in A92030-5, A93157-6LS, and CO94035-15Ru for the second year at KES. TXA549-1Ru also had a high incidence of hollow heart. Most of the entries were intermediate in maturity. Several selections had better fry color than the standard varieties.

Russet Burbank and Russet Norkotah produced yields similar to those observed in the Statewide and Preliminary Yield Trials (Table 5). Ranger Russet yield of No. 1s was slightly higher than in the other KES trials.

Entries A92030-5, A92294-6, and A93157-6LS completed 3 years in the Western Regional Trial in 2005 and graduate from the program. Release is being pursued for A93157-6LS while the other two selections will be discarded. A95109-1, AO96160-3, and CO94035-15Ru were included in the 2005 regional trial for the second year and will remain in the trial for a third year in 2006. ATX91137-1Ru will be discarded after 2 years in this trial. All remaining entries were included in the regional trial for the first time in 2005. A96095-3, CO95086-8Ru, and PA97B3-2 are being discarded. Seven first-year entries will remain in the trial in 2006.

Selections producing the highest yields of U.S. No.1s at KES included TXA549-1Ru, A95109-1, MWTX2609-2RU, and AOA95155-7, in that order. Each of these selections will be included in the 2006 trial. Averaged over eight locations in the late harvest regional trials, AO96160-3 ranked eighth in total yield of U.S. No.1s and fifth and third in merit scores for fresh market and processing use, respectively. This selection is of interest to one or more processing firms and will be considered for release following one more year of evaluation in the regional trial.

Table 1. Tuber yield and specific gravity of potato entries selected from the Preliminary Yield Trial for further evaluation, Klamath Falls, OR, 2005.

Variety or	Yield U.S. No. 1s			Yield				Specific
selection	4-12 oz	>12 oz	total	Bs	No. 2s	culls	total	gravity
	cwt/acre							
Russet Burbank	213	78	291	80	237	21	629	1.084
Ranger Russet	226	83	309	34	146	37	526	1.089
Shepody	171	166	337	12	168	30	547	1.077
Russet Norkotah	228	234	462	25	45	11	543	1.068
AO98086-1	265	131	396	42	37	7	482	1.078
AO98104-1	383	130	513	73	56	12	654	1.080
AO98129-4	234	128	362	14	86	27	489	1.074
AO98170-4	270	130	400	29	40	5	474	1.081
AO99178-2	350	113	463	67	90	1	621	1.083
AO99179-1	294	134	428	17	26	19	490	1.070
AO99179-4	100	246	346	5	135	23	509	1.073
AO99192-2	313	31	344	98	13	2	457	1.093
AO00018-3	358	199	557	35	51	9	652	1.082
AO00024-7	283	185	468	25	46	10	549	1.074
AO00057-2	211	137	348	28	28	16	420	1.079
AO00076-4	339	54	393	81	23	11	508	1.089
AO00088-11	331	121	452	33	21	0	506	1.085
AO01012-4	341	93	434	54	22	4	514	1.089
Mean[1]	273	133	406	42	71	14	532	1.080

[1]Mean for standard varieties and selected clones only.

Table 2. Characteristics of potato entries in the Oregon Statewide Trial, Klamath Falls, OR, 2005.

Variety or selection	Percent stand	Vine maturity[1]	Specific gravity	Hollow heart[2]	Fry color[3]
	%			%	
Russet Burbank	100	3.0	1.082	2	1.0
Ranger Russet	100	3.4	1.089	0	1.5
Russet Norkotah	99	2.2	1.069	2	1.5
AO96160-3*	99	3.6	1.085	0	0.5
AO96164-1	99	2.0	1.081	0	0.5
AO96141-3	100	3.8	1.084	4	0.0
AO98133-2	99	3.8	1.087	10	0.5
AO96162-1	99	3.6	1.091	0	0.0
AO99099-3	97	4.0	1.085	6	1.0
COO00254-9	98	1.8	1.071	0	0.0
AO96305-3*	99	3.0	1.084	0	0.5
AO96365-2*	99	3.6	1.080	0	0.5
AO96370-2	99	2.2	1.083	0	2.5
AO98123-2	99	3.4	1.090	10	0.0
AO98268-5	99	3.4	1.087	8	0.0
AO98282-5*	100	3.4	1.095	14	0.0
AO98307-6	100	3.8	1.095	58	0.5
AO99081-1	95	3.8	1.083	16	2.5
AO99108-5	99	3.2	1.076	4	2.0
AO99111-9	100	3.0	1.081	0	0.5
OR00002-7	94	3.0	1.083	0	1.5
OR00043-5	97	3.0	1.083	6	1.5
OR00061-4	99	2.6	1.071	0	3.0
Mean	99	3.2	1.083	6.1	0.9
CV (%)	----	----	0.2	----	----
LSD (0.05)	----	----	0.003	----	----

[1]Vine maturity: 1 = early; 5 = late.

[2]Hollow heart in 10 tubers per sample.

[3] Fry color: 0.00 = light; 4.0 = dark.

* Retained for further evaluation.

Table 3. Tuber yield by grade for potato entries in the Oregon Statewide Trial, Klamath Falls, OR, 2005.

Variety or	Yield U.S. No. 1s				Yield				
selection	4-8 oz	8-12 oz	>12 oz	total	Bs	No. 2s	culls	total	rank[1]
	cwt/acre								
Russet Burbank	105	102	94	301	62	171	23	557	23/22
Ranger Russet	76	103	180	359	28	135	39	561	19/8
Russet Norkotah	92	142	206	440	23	45	2	510	9/20
AO96160-3*	163	167	162	492	35	22	4	553	2/2
AO96164-1	150	149	180	479	41	47	7	574	4/4
AO96141-3	88	114	170	372	25	70	6	473	16/11
AO98133-2	32	91	339	462	6	48	4	520	6/12
AO96162-1	155	142	32	329	62	37	12	440	21/10
AO99099-3	97	133	191	421	19	57	6	503	12/6
COO00254-9	145	203	115	463	39	2	0	504	5/9
AO96305-3*	93	175	188	456	33	40	9	538	8/17
AO96365-2*	188	196	130	514	52	26	18	610	1/1
AO96370-2	194	167	100	461	75	51	6	593	7/5
AO98123-2	137	160	61	358	45	25	13	441	20/13
AO98268-5	79	126	199	404	18	62	6	490	14/18
AO98282-5*	148	172	168	488	38	28	13	567	3/3
AO98307-6	174	132	113	419	43	36	18	516	13/7
AO99081-1	69	105	219	393	16	26	12	447	15/14
AO99108-5	87	159	183	429	20	72	9	530	10/19
AO99111-9	221	114	36	371	83	14	9	477	17/15
OR00002-7	77	134	155	366	17	152	6	541	18/16
OR00043-5	62	118	129	309	24	106	19	458	22/23
OR00061-4	155	179	89	423	41	66	17	547	11/21
Mean	121	143	150	413	37	58	11	520	----
CV (%)	24	23	29	10	36	42	109	8	----
LSD (0.05)	36	40	55	53	16	31	16	51	----

[1]Rank: ranking in total U.S. No. 1 yield for KES/4 location mean.

*Retained for further evaluation.

Table 4. Characteristics of potato entries in the Western Regional Trial, Klamath Falls, OR, 2005.

Variety or selection	Percent stand	Vine vigor[1]	Vine maturity[2]	Specific gravity	Hollow heart[3]	Fry color[4]
	%				—— % ——	
Ranger Russet	99	3.8	3.2	1.089	0	2.0
Russet Burbank	99	3.6	2.8	1.082	4	2.0
Russet Norkotah	99	3.2	2.2	1.072	6	3.0
A92030-5	100	2.8	2.8	1.088	38	2.5
A92294-6	100	3.6	3.4	1.090	0	1.0
A93157-6LS	99	2.8	3.0	1.090	18	1.0
A95109-1	99	2.6	3.8	1.085	0	1.5
A95409-1	97	3.2	3.4	1.088	4	1.5
A96095-3	99	3.6	3.0	1.080	0	2.5
A96104-2	100	3.0	3.2	1.077	8	1.5
AO96160-3	100	3.0	4.0	1.085	0	1.0
AO96164-1	99	3.2	2.6	1.079	0	1.0
AOA95154-1	98	2.2	3.2	1.084	0	1.0
AOA95155-7	100	2.2	3.8	1.084	8	0.5
ATX91137-1Ru	97	2.2	2.4	1.076	0	3.0
CO94035-15Ru	99	2.8	3.2	1.082	8	1.5
CO95086-8Ru	97	3.6	2.0	1.076	2	1.0
CO95172-3Ru	100	2.8	3.8	1.089	0	2.0
MWTX2609-2Ru	98	4.0	2.6	1.085	0	2.5
PA97B3-2	99	3.0	2.6	1.084	0	1.0
TXA549-1Ru	100	4.2	3.2	1.083	16	1.5
Mean	99	3.1	3.1	1.083	5	1.64
CV (%)	----	----	----	0.3	151	----
LSD (0.05)	----	----	----	0.004	10	----

[1]Vine vigor: 1 = weak; 5 = robust.

[2]Vine maturity: 1 = early; 5 = late.

[3]Hollow heart in 10 large tubers per sample.

[4]Fry color: 0.00 = light; 4.0 = dark.

Table 5. Tuber yield by grade for potato entries in the Western Regional Trial, Klamath Falls, OR, 2005.

Variety or	Yield U.S. No. 1s				Yield			
selection	4-8 oz	8-12 oz	>12 oz	total	Bs	No. 2s	culls	total
	cwt/acre							
Ranger Russet	116	110	163	389	23	116	30	558
Russet Burbank	113	98	74	285	46	186	27	544
Russet Norkotah	101	187	173	461	19	22	4	506
A92030-5	104	142	148	394	20	42	4	460
A92294-6	255	93	11	359	71	23	4	457
A93157-6LS	128	132	139	399	32	31	6	468
A95109-1	123	160	199	482	22	21	3	528
A95409-1	99	130	211	440	21	42	12	515
A96095-3	73	125	250	448	13	91	16	568
A96104-2	177	163	119	459	32	47	3	541
AO96160-3	178	182	88	448	33	14	3	498
AO96164-1	167	152	96	415	44	72	6	537
AOA95154-1	177	98	60	335	59	12	0	406
AOA95155-7	202	149	110	461	37	26	1	525
ATX91137-1Ru	99	150	156	405	16	27	15	463
CO94035-15Ru	135	114	82	331	46	26	0	403
CO95086-8Ru	138	173	136	447	24	23	0	494
CO95172-3Ru	148	150	97	395	39	28	2	464
MWTX2609-2Ru	148	176	148	472	33	52	7	564
PA97B3-2	182	94	48	324	70	10	2	406
TXA549-1Ru	171	121	232	524	29	22	7	582
Mean	144	138	130	413	35	44	7	499
CV (%)	22	20	37	13	36	65	170	11
LSD (0.05)	40	34	61	66	16	36	16	67

Red-skinned and Specialty Potato Variety Screening and Evaluation, 2005

Kenneth A. Rykbost and Brian A. Charlton[1]

Introduction

Potato variety development in the Pacific Northwest continues to emphasize russet-skinned selections for processing and fresh market use. However, breeding programs have increased efforts in recent years to improve disease and pest resistance and nutritional quality in progeny.

Several new red-skinned, white-fleshed varieties have been released from the tri-state program in the past 5 years, including three Oregon releases (Rykbost et al. 2001a, b; 2003). Most recently, efforts have included crosses with pigmented flesh lines. Carotenoids, anthocyanins, ascorbic acid (vitamin C), and other sources of antioxidants are usually found in higher concentrations in pigmented flesh cultivars compared to white-fleshed cultivars. Colorado State University recently released Purple Majesty, a purple-skinned, purple-fleshed selection, and Mountain Rose, a red-skinned, red-fleshed variety. Several processing firms have expressed interest in colored-flesh selections for novel products.

Progeny supplied by breeding programs at the USDA Agricultural Research Service (ARS) facility at Prosser, Washington and Oregon State University (OSU) Crop and Soil Science Department at Corvallis are currently being evaluated. The Klamath Experiment Station (KES) serves as the site for initial field screening of first-generation selections, second-year evaluation of four-hill plantings, and third-year evaluation at the early Preliminary Yield Trial level.

Procedures

Single-hill Screening

The screening site is 25 miles east of Klamath Falls at the Inland Fiber Tree Nursery Farm in the Yonna Valley. The soil at the site is Fordney loamy fine sand. The field was used for coniferous tree seedling production in 2003 and 2004. The field was treated with Terr-O-Gas® 67 (methyl bromide + chloropicrin, Great Lakes Chemical Corp.) at 25 gal/acre in the spring of 2003. The soil has approximately 1 percent organic matter in the top foot and a pH of 7.0.

Approximately 12,000 greenhouse-produced seedling tubers were planted, including progeny from 94 crosses from Prosser, Washington and 65 from Corvallis, Oregon. Most Washington crosses included at least one parent with pigmented flesh color. Several crosses included parents with virus or late blight resistance. Corvallis

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crosses included parents with red skins, colored flesh, and/or chipping quality. Several Corvallis crosses were aimed at a combination of red skin and yellow flesh color.

Seedling tubers were planted on May 31 with a 2-row, assisted-feed planter at 3-ft in-row spacing in 32-inch rows. Fertilizer was banded at planting on both sides of rows at 90-45-45-70 lb/acre of Nitrogen (N), Phosphate (P_2O_5), Potash (K_2O), and Sulfur (S), respectively. The insecticide Admire®2R (imidacloprid, Bayer Crop Sciences) at 0.31 lb active ingredient (ai)/acre and the fungicide Quadris® (azoxystrobin, Syngenta Crop Protection, Inc.) at 0.15 lb ai/acre were applied in the planting furrow. A mild infestation of Russian thistle (*Salsola iberica*), prostrate pigweed (*Amaranthus blitoides* S. Wats.) and redroot pigweed (*A. retroflexus* L.) were controlled with Matrix® herbicide (rimsulfuron, DuPont) applied with a conventional ground sprayer at labeled rate on July 12. Three aerial applications of fungicides adequately controlled foliar fungal diseases common to the area. Irrigation was applied as needed with solid-set sprinklers arranged in a 40- by 42-ft diamond pattern.

Vines were desiccated with Reglone® desiccant (diquat dibromide, Syngenta Crop Protection, Inc.) applied with a ground sprayer at 1.5 pt/acre on September 14. Vines were shredded with a rotobeater on October 10. Tuber families were lifted with a two-row, level-bed digger on October 11. A team of 10 research, extension, and industry personnel observed the crop and selected tubers from desirable clones, based primarily on external and internal visual appearance. Lines with pigmented flesh were cut to observe flesh color. Selected clones (148) were transported to Powell Butte, Oregon for storage in the Central Oregon Agricultural Research Center (COARC) potato storage facility for clonal propagation and further evaluation.

Second-year Four-hill Screening

Two hundred and 12 clones selected from 2004 single hills were planted in 4-hill observational plots at KES and in 12-hill seed increase plots at Powell Butte. The KES site has a Poe fine sandy loam soil with a pH of 6.5 and an organic matter content of approximately 1.5 percent in the plow layer. Potatoes were last grown at the site in 1999. Orchardgrass was produced at the site from 2001 to 2004. Field preparation included discing and rototilling to break up the sod, ripping to a depth of 18 inches in spring of 2005, shanked application of Telone™ II (dichloropropene, Dow AgroSciences LLC) at 20 gal/acre on April 14, 2005, and moldboard plowing on May 13.

Seed was hand cut and treated with Tops® MZ (thiophanate methyl-mancozeb, Gustafson) on May 12 and suberized at approximately 55ºF and 95 percent relative humidity until planting on May 25. Potatoes were planted at 10-inch spacing in 32-inch rows with a 2-row, assisted-feed planter, leaving a 3-ft void between clones. Fertilizer was banded on both sides of rows at 160-80-80-140 lb/acre of N, P_2O_5, K_2O, and S, respectively. Admire® 2R and Quadris® were applied in the planting furrow as indicated above.

Weeds were adequately controlled with Dual II Magnum® (metolachlor, Syngenta Crop Protection, Inc.) and Prowl® 3.3 EC Herbicide (pendimethalin, BASF Ag Products) applied with a ground sprayer at 1.5 pt/acre each on June 10. Herbicides were immediately incorporated with two passes using a rolling cultivator. Approximately 18 inches of irrigation was applied during the growing season with solid-set sprinklers arranged in a 40- by 48-ft diamond pattern.

Fungicides applied aerially on July 10, August 20 and September 10 included Quadris, Dithane® F-45, (ethylene bisdithiocarbamate, Dow AgroSciences), and Bravo Ultrex® (chlorothalonil, Syngenta Crop Protection, Inc.), respectively, at labeled rates. Vines were desiccated with Reglone® desiccant (diquat dibromide, Syngenta Crop Protection, Inc.) applied with a ground sprayer at 1.5 pt/acre on September 15.

Tubers were lifted with a two-row, level bed digger on October 11. Thirty-five clones were selected for further evaluation. Seed of these selections was subsequently saved at the COARC seed increase plantings at Powell Butte.

Preliminary Yield Trial

Specialty clones selected from single-hill screening from 2000 to 2003 were evaluated in a Preliminary Yield Trial with 2 replications of 12 hills. The trial included All Blue, Yukon Gold, 8 clones from Oregon crosses and 64 clones derived from Prosser, Washington crosses. Most of the material had pigmented skin and/or flesh. Seed was hand cut to 1.5- to 2.0-oz seed pieces on May 13, treated with Tops MZ and suberized as described above. Seed was planted at 10-inch spacing in 32-inch rows on May 25. All cultural practices were as described for the four-hill trial.

One replication was harvested with a one-row, digger-bagger on October 7. All tubers were saved for grading in late October. The second replication was harvested on October 12 with the selection screening team for single-hill and four-hill clones participating in the evaluation. Notes were taken in the field at harvest on external and internal characteristics. Tubers were stored until grading was completed in late October.

USDA grade standards were used to separate U.S. No. 1s and culls. Tubers less than 4 oz were classified as Bs. U.S. No. 1s were separated by weight to 4- to 6-oz, 6- to 10-oz, and over 10-oz groupings. Subsamples of approximately 10 lbs were used to determine specific gravity by the weight-in-air, weight-in-water method. Ten large tubers from each plot were cut lengthwise to inspect for internal defects and assess flesh color and other internal characteristics. External characteristics were noted on the total sample for each replication. U.S. No. 1 yields were not adjusted to account for external blemishes such as *Rhizoctonia* or silver scurf or internal defects such as hollow heart or brown center.

Regional Red-skinned/Specialty Trial

Dark Red Norland, Red LaSoda, All Blue, and Yukon Gold standard varieties and 17 numbered selections were compared in a trial of advanced red-skinned and specialty clones with unique skin and/or flesh pigmentation. Plots were 20 hills with 5 replicates, arranged in a randomized complete block design. Seed was cut as described above and suberized until planting on May 25. All cultural practices were as described for the Preliminary Yield Trial above. Potatoes were harvested with a one-row digger-bagger on October 5. All tubers were saved for grading in late October.

USDA grade standards were used to separate U.S. No. 1s in less than 4-oz, 4- to 6-oz, 6- to 10-oz and over 10-oz fractions and culls. All tubers over16 oz were graded as culls. External appearance ratings were made on the bulk sample from each plot. Ten large tubers from each plot were cut to inspect for internal defects and flesh color. Specific gravity was determined as described above. Data were analyzed using SAS® for Linear Models, Fourth Edition (SAS Institute, Inc.) software. Least significant differences (LSDs) were based on Student's *t* at the 5 percent probability level. Data from eight regional cooperators were compiled and summarized at KES and reviewed at the Western Regional Potato Variety Development Committee annual meeting in January 2006. Disposition of trial entries was determined primarily by the sponsoring state organization.

Results and Discussion

Single-hill Screening

Approximately 75 percent of the clones produced relatively vigorous plants and good tuber yields. Maturity varied widely and many late-maturing clones produced large vines that were not completely desiccated at harvest. The selection team retained 148 clones, mostly with pigmented flesh. These clones will be grown and evaluated in four-hill plots at KES in 2006.

Second-year Four-hill Screening

A number of the selections at KES produced very attractive tubers with interesting flesh pigmentation. Seed increase plots of these clones at Powell Butte were harvested on October 13. A team of about 15 research and industry personnel selected 35 clones for further evaluation. This material will be evaluated in 2006 in a Preliminary Yield Trial conducted at KES and possibly other locations in the Pacific Northwest.

Preliminary Yield Trial

A partial summary of characteristics of the clones selected for further evaluation based on performance at KES is presented in Table 1. Yield is not as important in the selection of specialty lines as it is in traditional clones for processing or fresh market use. Smooth skin with good color and sheen, bright flesh color, and uniformity in shape and size are important parameters that may outweigh yield and grade for selections that will be sold primarily on appearance or culinary characteristics.

Yields and tuber size distribution observed in the material selected at KES ranged widely (Table 2). Several clones produced high yields of tubers under 4 oz. Selection OR01057-2 produced 315 cwt/acre of tubers under 4 oz and no tubers over 6 oz. This selection has an attractive red skin color with bright white flesh. A high yield of small tubers is a desirable trait for red-skinned fresh market sales.

POR02PG2-4 is a round selection with excellent appearing red/burgundy skin and flesh color and a high yield of small, uniformly shaped tubers. Some large tubers were also produced. Late vine maturity detracts from the performance of this clone.

A third selection with a high yield of small tubers and attractive skin was POR03PG25-2. This burgundy clone with dark red flesh and fingerling shape was intermediate in maturity, low specific gravity, but uniform shape.

Interest in processing for chips with selections having unique flesh color patterns would require higher yields of larger tubers. POR02PG5-1 has an attractive dark purple flesh color with a white mottling that would make a very attractive chip. It also has high specific gravity, a desirable trait for processing, but is late maturing. Cultural management practices would need to be determined, including plant population, seed management, and vine desiccation timing to manipulate tuber size distribution. POR02PG5-1 was the highest yielding clone in the trial. Other selections with interesting flesh color patterns that would make attractive chips included PA97B36-3, POR02PG2-4, and POR03PG12-2.

Interest in fingerling types and dark yellow flesh color is also prominent. POR03PG14-4 was probably the most promising fingerling type. It was rated very high for size/shape uniformity with a high yield of tubers less than 6 oz. It has a light yellow flesh color, a high specific gravity, and intermediate maturity.

The most attractive yellow-fleshed clone was POR03PG80-2. It has purple skin and moderately dark flesh color. It was awarded the highest rating for size/shape uniformity even though it produced large tubers. The light-yellow-skinned clone, POR02PG37-2 received the highest rating for yellow flesh color. It was intermediate in yield with excellent skin rating and a tendency for small tuber size.

Most of the clones in this trial will be advanced to a statewide trial in 2006 with up to five locations. Sufficient seed will be available to conduct replicated trials allowing for statistical evaluations.

Regional Red-skinned/Specialty Trial

All entries had excellent stands (Table 3). Vine maturity and tuber external and internal quality parameters at time of grading are characterized in Tables 3 and 4. Yields and tuber size distribution data are presented in Table 5. Entries are grouped by skin/flesh color. As in other 2005 KES trials, yields were similar to yields achieved in 2003 and about 100 cwt/acre less than total yields observed in 2004 trials.

Three red-skinned, white-fleshed selections were included in the trial for the second year. A96741-1R and VC1075-1R will be discarded after 2 years in this trial. A96741-2R will remain in the trial in 2006. It has not performed as well as A96741-1R at KES in yield or quality. It had very low specific gravity in both years at KES.

Two red-skinned, yellow-fleshed entries produced high total yields. VC1015-7R/Y had excessive size at KES in both years of evaluation. Tubers over 10 oz and culls accounted for 55 and 43 percent of total yield in 2004 and 2005, respectively. The sponsoring state program will keep this selection in the trial for a third year in 2006. VCO967-2R/Y has completed 3 years in trial and graduates from the program. Both entries had light red skin color and light yellow flesh color. Tuber shape was irregular in both clones at KES.

The Colorado varieties Mountain Rose (CO94183-1R/R) and Purple Majesty (CO94165-3P/P) had attractive skin and flesh colors. Both selections have completed 3 years in this trial and are in commercial production. Skin bronzing was noted for both clones in KES evaluations and in a commercial lot of Purple Majesty in the Klamath Basin in 2005.

PA99P20-2 and POR01PG20-12 are red-fleshed clones with long tubers. Pointy shape and skin russeting detracted from the appearance of PA99P20-2, which will be discarded. The other clone will remain in this trial in 2006. It has not been outstanding at KES.

Three of the yellow-fleshed clones in the trial completed 3 years in trial and graduate from the program. VC1002-3W/Y had the best flesh color of the group and the highest yield of desirable size tubers across all locations in the 2005 trial. BTX1544-2W/Y and NDA5507-3W/Y produced higher total yields at KES but both selections had excessive size and lighter flesh color than Yukon Gold.

None of the entries were equal to Yukon Gold in skin appearance or tuber conformation. CO94157-2W/Y will be discarded. VC1009-1W/Y and VC1123-2W/Y will be returned to the 2006 trial. Neither entry was attractive at KES in 2005. VC1123-2W/Y produced excessive size while VC1009-1W/Y had a low yield and both entries had flat shape noted at KES and other locations.

A95074-6 is a late-maturing, low-yielding russet-skinned selection with light yellow flesh. It was among the lowest yielding clones in trials at KES in both years of evaluation. Poor shape and numerous growth cracks detracted from its appearance at KES. However, it will be reevaluated in 2006 in the regional russet trial at the request of industry.

Summary

All levels of clonal screening and evaluation included lines that appeared to have outstanding appearance with unique characteristics. Currently available red- and purple-fleshed varieties have less intense flesh color than many of the clones evaluated in the 2005 trials. Pigmented clones from the Colorado program, Purple Majesty and Mountain Rose, are clearly superior to similar cultivars currently available. A number of clones have been identified in early generation material that have distinct patterns with mottled coloring, white centers in star patterns, and other unique and attractive flesh colors. In addition to the Colorado clones mentioned above, yellow-fleshed VC1002-3W/Y appears to be a promising line for fresh market or processing use.

References

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Table 1. Characteristics of potato clones selected from the 2005 Specialty Preliminary Yield Trial grown at the Klamath Experiment Station, Klamath Falls, OR.

Selection	Skin color	Flesh color	Flesh intensity[1]	Shape	Vine maturity[2]	Specific gravity	Size/shape uniformity[3]
All Blue	Purple	Purple	4.8	Long	4.0	1.081	3.3
Yukon Gold	White/lt yellow	Yellow	3.0	Round	3.0	1.083	4.0
PA97B36-3	Red	Red	2.0	Round	3.0	1.084	4.0
POR00PG4-1	Pink/yellow	Pink/yellow	4.5	Oblong	2.0	1.077	4.0
OR01057-2	Red	White	1.0	Round	3.0	1.079	5.0
POR01PG16-1	Purple	Purple	5.0	Long	3.0	!.070	3.5
POR01PG20-12	Red	Red/burgundy	3.0	Oblong	4.5	1.087	3.8
POR01PG22-1	Red	Red/burgundy	3.5	Long	4.5	1.078	3.8
POR01PG45-5	Purple	Yellow	2.8	Round	3.0	1.085	3.0
POR02PG2-4	Red/burgundy	Red/burgundy	3.5	Round	4.5	1.071	3.8
POR02PG5-1	Purple	Purple/white	4.0	Oval	5.0	1.085	4.0
POR02PG12-1	White	Yellow	1.5	Round	2.5	1.080	5.0
POR02PG26-11	White/lt yellow	Yellow	3.3	Round	3.0	1.080	3.5
POR02PG37-2	White/lt yellow	Yellow	4.0	Round	3.0	1.081	4.0
POR03PG12-2	Purple	Purple/white	3.0	Oblong	2.5	1.086	4.0
POR03PG14-4	Yellow	Yellow	2.0	Long	3.0	1.094	5.0
POR03PG23-1	Red	Red	4.5	Round	3.0	1.067	3.8
POR03PG25-2	Burgundy	Red	4.5	Long	3.0	1.063	4.3
POR03PG33-2	Red	Red	3.5	Oval	2.0	1.073	4.0
POR03PG46-1	Purple	Purple	3.0	Oblong	2.0	1.063	4.0
POR03PG68-1	Yellow	Yellow	3.3	Round	2.5	1.072	4.0
POR03PG74-3	Purple	Purple	3.0	Oval	2.0	1.062	5.0
POR03PG74-4	Purple	White	1.0	Oval	2.5	1.078	4.0
POR03PG80-2	Purple	Yellow	3.5	Long	3.5	1.077	5.0

[1]Flesh intensity: 1 = light; 5 = dark.

[2]Vine maturity: 1 = early; 5 = late.

[3]Size/shape uniformity: 1 = poor; 5 = excellent.

Table 2. Yield and grade of potato clones selected from the 2005 Speciality Preliminary Yield Trial grown at the Klamath Experiment Station, Klamath Falls, OR.

Variety or	Yield U.S. No. 1s				Yield		
Selection	4-6 oz	6-10 oz	>10 oz	total	<4 oz	culls	total
				cwt/acre			
All Blue	165	76	21	262	180	54	496
Yukon Gold	71	151	232	454	43	0	497
PA97B36-3	110	192	92	394	68	30	492
POR00PG4-1	61	147	41	249	50	89	388
OR01057-2	61	0	0	61	315	0	376
POR01PG16-1	124	36	6	166	120	62	348
POR01PG20-12	175	134	38	347	93	13	453
POR01PG22-1	43	8	0	51	298	21	370
POR01PG45-5	124	68	23	215	209	20	444
POR02PG2-4	167	88	13	268	324	42	634
POR02PG5-1	43	192	462	697	27	22	746
POR02PG12-1	0	0	0	0	281	0	281
POR02PG26-11	150	116	13	279	192	0	471
POR02PG37-2	87	115	33	235	131	14	380
POR03PG12-2	155	120	62	337	36	10	383
POR03PG14-4	124	0	0	124	270	52	446
POR03PG23-1	175	80	37	292	182	7	481
POR03PG25-2	87	8	0	95	308	4	407
POR03PG33-2	156	133	8	297	199	0	496
POR03PG46-1	117	117	152	386	54	31	471
POR03PG68-1	118	218	57	393	109	0	502
POR03PG74-3	158	267	36	461	70	61	592
POR03PG74-4	86	159	212	457	30	65	552
POR03PG80-2	40	153	384	577	13	29	619
Mean[1]	108	107	80	295	150	26	471

[1]Mean for All Blue, Yukon Gold, and selected clones only.

Table 3. Plant and tuber characteristics of advanced red-skinned and specialty-type potato selections grown at Klamath Falls, OR, 2005.

Variety or selection	Percent stand	Vine maturity[1]	Tuber characteristics[2]					
			Skin color	Flesh color	Eyes	Shape	Skinning	% HH
Red/white flesh								
Dk. Red Norland	98	2.4	3.3	1.0	3.1	2.0	4.4	6
Red LaSoda	100	2.6	2.3	1.0	2.2	3.0	3.7	2
A96741-1R	99	2.6	4.5	1.0	4.1	1.5	3.5	0
A96741-2R	100	2.8	4.2	1.0	3.8	1.0	3.4	0
VC1075-1R	100	2.6	4.5	1.0	3.8	1.0	3.0	0
Red/yellow flesh								
VC0967-2R/Y	99	3.0	2.0	3.2	4.0	2.2	4.5	0
VC1015-7R/Y	100	2.6	2.0	3.5	2.5	1.8	4.3	0
Red/red flesh								
Mountain Rose	98	3.2	4.8	1.7	3.5	4.0	4.4	0
PA99P20-2	100	4.2	5.0	3.3	4.5	5.0	3.6	0
POR01PG20-12	100	5.0	5.0	2.7	4.0	5.0	3.4	0
Purple/purple flesh								
All Blue	100	4.4	5.0	4.3	3.0	5.0	4.1	0
Purple Majesty	100	2.6	5.0	4.8	4.0	2.0	4.6	0
Yellow/yellow flesh								
Yukon Gold	99	2.2	2.8	2.7	5.0	1.5	4.4	0
A95074-6	100	3.8	3.3	2.2	4.0	4.0	2.2	4
BTX1544-2W/Y	100	2.4	3.0	2.3	3.0	2.5	4.8	0
CO94157-2W/Y	97	2.6	3.0	2.8	4.5	2.8	4.4	0
NDA5507-3YF	99	3.4	3.0	2.2	4.1	1.5	4.4	0
NY 126	96	3.4	3.0	2.5	4.1	1.5	4.2	2
VC1002-3W/Y	100	4	3.0	3.5	4.2	1.5	4.0	0
VC1009-1W/Y	99	4.8	2.5	3.3	4.0	2.2	2.6	2
VC1123-2W/Y	100	4.0	3.0	3.5	4.0	2.5	3.9	2
Mean	99	2.6	3.5	2.5	3.8	2.5	3.9	1

[1]Vine vigor rating: 1 = small, weak; 5 = large, robust.

[2]Skin color: 1 = light; 5 = dark.

Flesh color: 1 = light; 5 = dark

Eyes: 1 = deep; 5 = shallow.

Shape: 1 = round; 2 = oval; 3 = oblong, 4 = blocky, 5 = long.

Skinning: 1 = severe; 5 = none.

% HH: percent hollow heart.

Table 4. Tuber characteristics of advanced red-skinned and specialty-type potato selections grown at Klamath Falls, OR, 2005.

Variety or selection	Size/shape uniformity[1]	Greening[2]	Growth cracks[2]	Shatter bruise[2]	Common scab[2]	Comments
Red/white flesh						
Dk. Red Norland	3.0	4.5	5.0	5.0	5.0	pale color
Red LaSoda	3.0	4.3	4.0	4.8	5.0	pale, big, lumpy
A96741-1R	4.0	4.3	5.0	4.8	5.0	small, attractive
A96741-2R	3.8	4.5	4.5	4.8	5.0	nice, russeted, skinning
VC1075-1R	3.8	4.5	5.0	4.8	5.0	nice, smooth
Red/yellow flesh						
VC0967-2R/Y	3.5	5.0	5.0	4.0	5.0	flat, pale, skinning
VC1015-7R/Y	3.3	4.3	4.5	5.0	5.0	pale flesh
Red/red flesh						
Mountain Rose	3.8	4.8	4.0	4.8	5.0	nice skin & shape
PA99P20-2	3.3	4.3	5.0	5.0	5.0	pointy, russeted
POR01PG20-12	3.5	4.0	4.8	5.0	5.0	smooth, skinning
Purple/purple flesh						
All Blue	2.8	4.5	4.8	5.0	5.0	dumbell, crooked, limpy
Purple Majesty	3.3	4.3	5.0	5.0	5.0	variable shape, dark flesh
Yellow/yellow flesh						
Yukon Gold	4.0	4.5	5.0	4.3	5.0	nice, smooth, keeper
A95074-6	3.3	4.3	4.0	5.0	5.0	poor, skinning
BTX1544-2W/Y	3.3	4.8	5.0	5.0	5.0	flat, lumpy, poor
CO94157-2W/Y	3.8	4.3	5.0	5.0	5.0	no yield, scaley
NDA5507-3YF	4.3	4.0	5.0	5.0	5.0	fair, nice shape, pink eyes
NY 126	3.3	4.0	5.0	4.5	5.0	flat, russeted
VC1002-3W/Y	4.0	5.0	4.8	5.0	5.0	fair, russeted, small
VC1009-1W/Y	3.0	4.0	3.8	5.0	5.0	flat, poor, no yield
VC1123-2W/Y	3.5	4.3	4.0	5.0	5.0	flat, scaley
Mean	3.5	4.4	4.6	4.8	5.0	

[1]Size/shape uniformity: 1 = poor; 5 = excellent.

[2]Greening, growth cracks, shatter bruise, scab: 1 = severe; 5 = none.

Table 5. Yield, grade, tuber size distribution, and specific gravity of advanced red-skinned and specialty-type potato selections grown at Klamath Falls, OR, 2005.

Variety or selection	Yield U.S. No. 1s 4-6 oz	6-10 oz	>10 oz	total	Yield <4 oz	<10 oz[1]	culls	total	Specific gravity
	cwt/acre								
Red/white flesh									
Dk. Red Norland	110	206	166	482	30	346	34	546	1.07
Red LaSoda	66	147	224	437	21	234	58	516	1.069
A96741-1R	170	189	71	430	62	421	6	498	1.065
A96741-2R	135	199	139	473	50	384	21	544	1.06
VC1075-1R	167	175	64	406	80	422	24	510	1.07
Red/yellow flesh									
VC0967-2R/Y	169	223	128	520	44	436	5	569	1.069
VC1015-7R/Y	86	182	196	464	25	293	25	514	1.069
Red/red flesh									
Mountain Rose	125	180	69	374	45	350	32	451	1.075
PA99P20-2	103	141	134	378	38	282	50	466	1.077
POR01PG20-12	144	137	69	350	48	329	29	427	1.079
Purple/purple flesh									
All Blue	166	59	25	250	115	340	56	421	1.079
Purple Majesty	151	116	30	297	141	408	22	460	1.076
Yellow/yellow flesh									
Yukon Gold	88	165	206	459	22	275	8	489	1.084
A95074-6	115	120	118	353	43	278	14	410	1.082
BTX1544-2W/Y	145	201	170	516	33	379	35	584	1.076
CO94157-2W/Y	183	79	13	275	141`	403	13	429	1.084
NDA5507-3YF	147	269	167	583	31	447	17	631	1.073
NY 126	70	173	292	535	25	268	5	565	1.083
VC1002-3W/Y	157	147	47	351	84	388	10	445	1.083
VC1009-1W/Y	150	163	83	396	77	390	51	524	1.074
VC1123-2W/Y	84	180	219	483	27	291	38	548	1.078
Mean	130	164	125	420	56	351	26	502	1.075
CV (%)	21	23	38	16	31	13	60	13	0.3
LSD (0.05)	35	48	61	84	22	58	23	82	0.004

[1]High-value size profiles <4 oz to 10 oz U.S. No. 1s.

Effects of Prenuclear Minituber Seed Size on Production of Wallowa Russet Seed

Kenneth A. Rykbost and Brian A. Charlton[1]

Introduction

Commercial seed lots in Oregon originate from greenhouse-produced minitubers derived from tissue-cultured plantlets. These prenuclear seed lots typically include tubers ranging in size from 1 to 20 g. High production costs for seed produced in greenhouse culture is passed on to growers using the material. Information on the relative performance of wide ranging minituber size would help seed growers plan cultural practices and those producing the minitubers determine pricing to reflect performance.

Over 3 years, research at the Klamath Experiment Station (KES) demonstrated varietal differences in response to seed-piece size for commercial production of Russet Burbank, Russet Norkotah, and Century Russet (Rykbost and Locke 1999). Seed sizes evaluated ranged from approximately 20 to 80 g, a typical size range used in commercial production. Optimum performance was observed for seed pieces in the 40- to 60-g range. Extrapolating these findings to minitubers approximately one-twentieth this size is not feasible.

Experience in production of single-hill, first generation, seedling screening material in the variety development program has shown that minitubers as small as 1-2 g can produce viable and productive plants. However, single-hill plant populations are usually about 20 percent of populations used in commercial culture. Widely spaced plants allow better separation at harvest to isolate tubers from individual hills. The low population provides individual plants an advantage in access to moisture, nutrients, and sunlight. To evaluate productivity from prenuclear minitubers, plant populations should closely mirror populations typically used for seed production.

An initial investigation was established at KES in 2004 to determine the production potential of Wallowa Russet minitubers in size groupings ranging from about 1 to 14 g. The study was repeated in 2005 using Wallowa Russet minitubers ranging in size from about 2 to 24 g.

Procedures

2004

Prenuclear minitubers of Wallowa Russet were obtained from the Oregon State University Foundation Seed Potato program at Corvallis, Oregon. Tubers were sorted by size into 7 groups and weighed to determine the average weight for each 120-tuber group. Seed was planted in single-row

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plots of 30 hills at 9-inch spacing in 32-inch rows on May 25 with a 2-row, assisted-feed planter. Individual plots were arranged in a randomized complete block design with four replications. Border rows on both sides of plot rows were planted with GemStar Russet for uniform border conditions.

The trial site had been planted to spring cereals in each of the previous 3 years. Field preparation included ripping to 18-inch depth in fall of 2003, shanked applications of Telone™ II (dichloropropene, Dow AgroSciences) at 20 gal/acre and Vapam® HL (sodium methyldithiocarbamate, Amvac Chemical Corp.) at 30 gal/acre on April 9, 2004, and moldboard plowing on May 12. Fertilizer was applied in bands at planting at 160 lb Nitrogen (N), 80 lb Phosphate (P_2O_5), 80 lb Potash (K_2O), and 140 lb Sulfur (S)/acre. The insecticide Admire® 2R (imidacloprid, Bayer Crop Sciences) at 0.17 lb active ingredient (ai)/acre and the fungicide Quadris® (azoxystrobin, Syngenta Crop Protection, Inc.) at 0.10 lb ai/acre were applied in the planting furrow. Weeds were adequately controlled with Dual II Magnum® (metolachlor, Syngenta Crop Protection, Inc.) and Prowl® 3.3 EC herbicide (pendimethalin, BASF Ag Products) applied with a ground sprayer at 1.75 pt/acre each on June 7. Herbicides were incorporated immediately following application with a rolling cultivator in two passes. Approximately 20 inches of irrigation was applied during the growing season with solid-set sprinklers arranged in a 40- by 48-ft pattern.

Plant stands were recorded on June 21 and July 7. Fungicides were applied aerially on July 2 and July 18 included Bravo Ultrex® (chlorothalonil, Syngenta Crop Protection, Inc.) and Ridomil Gold®/Bravo® (mefenoxam plus chlorothalonil, Syngenta Crop Protection, Inc.) at labeled rates. Vines were desiccated with Reglone® desiccant (diquat dibromide, Syngenta Crop Protection, Inc.) applied with a ground sprayer at 1.5 pt/acre on September 9. The fungicide Dithane® M-45 (mancozeb, Dow AgroSciences) was tank-mixed with Reglone in this application.

Tubers were harvested with a one-row, digger-bagger on September 27. Small tubers that fell through the digger chain were picked up by hand from each plot to ensure more complete recovery of the crop. All tubers were saved and graded on October 21. Grades included USDA No. 1s, 4-8 oz, 8-12 oz, and over 12 oz, Bs (< 4 oz) and culls. All tubers were counted to determine mean tuber weight for each grade. Data were statistically analyzed with SAS® for Linear Models, Fourth Edition (SAS Institute Inc.) software. Least significant differences (LSDs) are based on Student's *t* at the 5 percent probability level when the F test showed significant treatment effects ($P<0.05$).

2005

Prenuclear minitubers of Wallowa Russet were again obtained from the Oregon State University Foundation Seed Potato program at Corvallis, Oregon. Tubers were sorted by size into 7 groups with mean weights ranging from 1.9 to 24 g.

Seed was planted in single-row plots of 26 hills at 10-inch spacing in 32-inch rows on May 26 with a 2-row, assisted-feed planter. Individual plots were arranged in a randomized complete block design with four replications. Border rows on both sides of plot rows were planted with GemStar Russet to provide uniform border conditions.

The trial site had been cropped with orchardgrass from 2002 through 2004. Grass was desiccated with Roundup® (glyphosate, Monsanto) in early October, 2004. Sod was disked and rototilled in April, 2005. Telone II was shanked in at 18-inch depth at 20 gal/acre on April 14, 2005. The field was moldboard plowed on May 13.

Insecticide and fungicide applications, fertilizer applications, and irrigation were as described for 2004. Weed control was achieved with Dual and Prowl as described for 2004 plus a chemigation application of Matrix® (rimsulfuron, DuPont) on July 21.

Plant stands were recorded on June 21 and 27 and July 5 and 12. Aerial applications of Quadris, Dithane® F-45 (Ethylene bisdithiocarbamate, Dow AgroSciences), and Bravo Ultrex were made on July 10, August 20, and September 10, respectively. Vines were desiccated with Reglone applied with a ground sprayer on September 7.

Tubers were harvested with a one-row, digger-bagger on October 5. As in 2004, small tubers that were not recovered by the digger were picked up by hand. All tubers were saved and graded as described above on October 25. Data analyses were as described for 2004.

Results and Discussion

2004

Minituber size clearly affected rate of emergence and canopy vigor (Table 1). At 27 days after planting (DAP), emergence ranged from 21 percent for the smallest minitubers to 82 percent for the largest size. The 1.2-g seeds were significantly lower in emergence than all other sizes, while differences among the four largest sizes were not significant. At 43 DAP all seed sizes except the smallest had 91 percent or higher emergence. Differences between treatments were not significant. Final plant stands were nearly the same as observed on July 7. Canopy vigor differences between seed sizes were statistically significant for all sizes except the two largest sizes. Differences in canopy vigor between treatments were evident throughout the season. Lower leaf area index and radiation interception in small seed treatments undoubtedly reduced tuber production of photoassimilates.

Total yields ranged from 183 cwt/acre for 1.2-g seed size to over 400 cwt/acre for the 2 largest seed sizes (Table 3). Yields were dominated by tubers under 8 oz in all treatments. Increasing seed size resulted in significant increases in yield of 4- to 8- and 8- to 12-oz U.S. No. 1s. Yield of Bs (tubers < 4 oz) did not significantly differ among treatments. We observed a tendency for larger tubers within the Bs for each increase in minituber size. In the smallest seed sizes, many of the Bs were less than 2 oz. Few culls or tubers larger than 12 oz were produced in any treatment.

2005

Emergence and canopy vigor were similar to those observed in 2004. At 25 DAP, emergence was 96 percent for the largest seed size but only 20 percent for the 1.9g treatment (Table 2). At 47 DAP, stands ranged from 90 percent for the 1.9g treatment to 99 percent for 3 of the 4 largest seed sizes. Canopy vigor was not rated but followed trends reported for 2004.

Yields in 2005 were somewhat higher than in 2004 with a larger size profile (Table 4). The relationship between seed size and yield was very similar to that observed in 2004. Total yield increased by 57 percent as seed size increased from 1.9 to 7.2 g. Further increases in seed size did not significantly increase yield.

Two-year Summary

Effects of increasing minituber size on yield are attributed to a combination of increases in both number and size of daughter tubers (Tables 3 and 4). Increasing seed size from 1.2 to 13.6 g, which represents an 11-fold increase, resulted in a 40 percent increase in average tuber size and a 60 percent increase in tuber number in 2004. In 2005, increasing seed size from 1.9 to 24 g, a 12.6-fold increase, resulted in a 42 percent increase in average tuber weight and a 29 percent increase in tuber numbers. Differences between years in these ratios are probably largely influenced by the differences in size for smallest and largest minitubers evaluated.

The increase ratio, a common measure of seed productivity, is the ratio of production per unit of seed planted. In eastern Canada and the northeastern United States, where yields seldom exceed 300 cwt/acre, a typical seed increase expectation is 15 or 20 to 1. In irrigated production in the northwest, where yields are 400 to 500 cwt/acre, the increase ratio is likely to be 20 or 25 to 1. Results observed in this trial demonstrated extremely high increase ratios and a large reduction in this ratio as minituber size increased (Tables 5 and 6). Production potential can also be measured as the acreage that can be planted from the production obtained from 1 acre of seed. Seed potential was calculated assuming a seed-piece size of 2 oz and plant population based on 10-inch spacing in 36-inch rows. On that basis, in 2004, 1 acre of seed using 1.2-g minitubers produced sufficient seed to plant 8.4 acres in a subsequent crop. Increasing seed size 11-fold to 13.6 g only increased the seed potential 233 percent. With a significant portion of the 1.2-g production being tubers less than 2 oz, the seed potential was probably considerably higher than 8.4 acres.

In 2005, 1.9g seed produced enough seed to plant 12.6 acres while 24g seed produced sufficient seed for 22.4 acres (Table 6). In this case a 12.6-fold increase in seed size increased the seed potential 78 percent.

The results suggest that the greatest economic returns would occur for the smallest minitubers if price/lb of the minitubers is uniform for all seed sizes. Pricing compensation for larger seed sizes would need to be large to offset the much lower production potential for minitubers 5-10 times larger than the 1.2-g material.

Commercial production of nuclear seed from minitubers of Mazama and Klamath Russet at a field in Hildebrand, Oregon in 2004 provided an opportunity to compare production observed at KES with actual commercial seed production from prenuclear minitubers. The site is 25 miles east of Klamath Falls, OR. The seed lots included a range in size similar to the Wallowa Russet seed. However, for commercial production most of the larger size fraction was cut into two pieces. For Mazama, 55 lbs of minitubers planted 0.42 acres, while 39 lbs of Klamath Russet planted 0.21 acres. Both lots were planted at 12-inch seed spacing in 34-inch rows. The average seed sizes were 3.8 g for Mazama and 5.4 g for Klamath Russet.

Both varieties were planted on May 21, vines were desiccated on September 1, and crops were harvested on October 10. Total yields of 388 cwt/acre for Mazama and 390 cwt/acre for Klamath Russet were well within the range observed in the KES experiments.

It would be useful to conduct further studies to evaluate effects of blended seed sizes and plant productivity response.

Production of nuclear seed from minitubers is very costly. The Oregon Foundation Seed Potato program typically sells prenuclear minitubers for $25/lb. Thus seed costs alone in the commercial lots grown at Hildebrand would be about $3,200 and $4,600/acre, respectively, for Mazama and Klamath Russet. Determining optimum seed management practices is vital for economical production of nuclear seed stocks.

References

Rykbost, K.A., and K.A. Locke. 1999. Effects of seed piece size on performance of three potato varieties in the Klamath Basin of Oregon. Am. J. Potato Res. 75:91-96.

Table 1. Effect of minituber size on plant emergence and early season canopy vigor of Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2004.

Minituber	Emergence		Canopy vigor[1]
size	June 21	July 7	July 7
g	%		rating[1]
1.2	21	79	1.0
2.5	50	92	1.8
3.8	52	91	2.3
4.9	68	95	2.8
7.0	69	91	4.0
11.9	77	99	4.8
13.6	82	95	5.0
Mean	60	92	3.1
LSD (0.05)	5	NS	0.5
CV (%)	17	11	10

[1]Canopy vigor rating: 1 = small, weak; 5 = large, robust.

Table 2. Effect of minituber size on plant emergence of Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2005.

Minituber	Emergence			
size	June 21	June 27	July5	July 12
g	%			
1.9	20	73	87	90
3.1	41	85	88	91
4.4	43	87	95	96
7.2	71	94	96	99
10.1	74	89	94	95
13.7	86	94	96	99
24	96	97	97	99
Mean	62	88	93	96
LSD (0.05)	5	8	NS	NS
CV (%)	17	15	13	11

Table 3. Effect of minituber size on yield and grade of Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2004.

Minituber	Yield U.S. No. 1s			Yield		
size	4-8 oz	8-12 oz	>12 oz	Bs	Culls	Total
g	cwt/acre					
1.2	64	5	0	113	1	183
2.5	99	24	8	119	1	251
3.8	121	25	0	125	0	271
4.9	144	74	9	124	3	354
7.0	177	42	8	137	3	367
11.9	202	73	7	141	6	429
13.6	202	63	15	142	4	426
Mean	144	44	7	129	3	326
LSD (0.05)	35	38	NS	NS	NS	64
CV (%)	16	58	137	22	190	13

Table 4. Effect of minituber size on yield and grade of Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2005.

Minituber	Yield U.S. No. 1s			Yield		
size	4-8 oz	8-12 oz	>12 oz	Bs	Culls	Total
g	cwt/acre					
1.9	127	40	6	98	3	274
3.1	132	54	27	88	8	309
4.4	169	72	20	118	4	383
7.2	193	100	24	107	6	430
10.1	193	108	34	91	16	442
13.7	200	129	31	88	25	473
24.0	222	115	40	84	0	461
Mean	177	88	26	96	9	396
LSD (0.05)	45	42	25	NS	NS	59
CV (%)	17	32	66	28	190	10

Table 5. Effect of minituber size on average tuber weight, number of tubers per acre, increase ratio, and seed potential for Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2004.

Minituber size	Average tuber weight	Tuber number	Increase ratio[1]	Seed potential[2]
g	oz	tubers/acre	lb/lb	acres
1.2	3.0	102,370	317	8.4
2.5	3.2	122,880	209	11.5
3.8	3.6	123,060	148	12.4
4.9	4.0	144,480	150	16.2
7.0	4.0	148,110	109	16.9
11.9	4.2	165,710	75	19.7
13.6	4.2	164,620	65	19.6
Mean	3.7	138,750	153	15.0
LSD (0.05)	0.6	23,000	46	2.9
CV (%)	11	11	20	13

[1]Increase ratio: lbs produced/lb of seed planted.

[2]Seed potential: acres of seed that could be planted from production from 1 acre of prenuclear seed.

Table 6. Effect of minituber size on average tuber weight, number of tubers per acre, increase ratio, and seed potential for Wallowa Russet potatoes grown at the Klamath Experiment Station, Klamath Falls, OR, 2005.

Minituber size	Average tuber weight	Tuber number	Increase ratio[1]	Seed potential[2]
g	oz	tubers/acre	lb/lb	acres
1.9	3.6	119,230	334	12.6
3.1	4.3	120,390	227	14.0
4.4	4.2	146,540	201	17.5
7.2	4.5	152,500	138	19.8
10.1	4.7	149,230	101	20.3
13.7	4.6	153,270	80	21.7
24.0	5.1	152,880	47	22.4
Mean	4.4	138,750	161	18.3
LSD (0.05)	0.7	29,230	32	2.7
CV (%)	11	14	13	10

[1]Increase ratio: lbs produced/lb of seed planted.

[2] Seed potential: acres of nuclear seed that would be planted from production from 1 acre of prenuclear seed.

Evaluation of Alternative Carriers for Potato Seed Treatment Fungicides

Kenneth A. Rykbost[1], Steve James[2], Clinton Shock[3], Eric Eldredge[4], Brian A. Charlton[5], and Paul Kresge[6]

Introduction

Potato seed treatment product formulations typically include a blend of red alder (*Alnus rubra*) or Douglas fir (*Pseudotsuga menziesii*) bark, talc, and zeolite as the diluent materials or carrier. Physical properties of these materials provide acceptable adherence to moist surfaces of cut seed while avoiding coagulating or clumping, which can plug application equipment. As expected, costs of these ingredients vary depending on availability and proximity to supplies. Actual relative composition of these materials in commercial seed treatment products is proprietary information and unavailable.

Alternative diluent materials are being evaluated to reduce costs and or take advantage of materials that might otherwise be waste products with little or no value. One such product that is abundantly available in the Midwest region is sunflower (*Helianthus annuus)* hulls, a byproduct of the seed oil production process. Alternative wood flours, such as western juniper (*Juniperus occidentalis*), are also of interest as the availability of red alder fluctuates due to its association with riparian and wetland habitats (Rykbost, et al*.,* 2005). Although products using juniper flour performed satisfactorily, difficulty in grinding flour from this species led to an interest in looking at alternative species.

Trials were established at the Klamath Experiment Station (KES), Malheur Experiment Station (MES), and Central Oregon Agricultural Research Center (COARC) in 2005 to evaluate seed treatment products formulated with maple (*Acer* spp.) flour and sunflower hulls in various ratios as diluent for fungicide dusts. Three locations were included to expose the formulations to a range of soil and climatic conditions with potentially different disease pressures.

Procedures

Six experimental formulations based on maple wood flour and sunflower hulls (obtained from Sigco-Sun Co., Breckenridge, MN) were compared with standard products at each experimental site. At KES, the standard seed treatment fungicide product was Tops® MZ (thiophanate methyl-mancozeb, Gustafson). At

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COARC, Evolve® (thiophanate-methyl-mancozeb-cymoxonil, Gustafson) and Tops (thiophanate-methyl, Gustafson) served as standards. The MES standard product evaluated was Tops® MZ Gaucho® (thiophanate methyl-mancozeb, Gustafson, and imidacloprid, Bayer CropScience LP).

Each experimental formulation included talc at 43.9 percent, zeolite at 24.3 percent, and Dithane® (mancozeb, Dow AgroSciences) at 7.45 percent by weight. Experimental formulations evaluated also included: F1) maple flour at 24.3 percent; F2) maple flour at 18.2 percent and sunflower hulls at 6.1 percent; F3) maple flour at 12.2 percent and sunflower hulls at 12.2 percent; F4) maple flour at 6.1 percent and sunflower hulls at 18.2 percent; F5) sunflower hulls at 24.3 percent; and F6) maple flour at 17.8 percent, sunflower hulls at 5.9 percent, and GS-48 (8-20-20 plus plant growth regulator at 1 oz per cwt of cut seed) at 1 percent.

KES

The seed lot used at KES was Oregon class G III Russet Norkotah (Colorado strain 8). Tubers were sorted to obtain 50 tubers of approximately 8 oz for each of 7 treatments. A range of 7.5 to 8.5 oz/tuber was allowed. On May 17, each batch of 50 tubers was hand-cut into 4 seed pieces per tuber. The total weight of cut seed pieces was determined. Seed treatment materials were pre-weighed into Styrofoam cups at 60g (0.5 lb/cwt) for approximately 25 lb of cut seed. Seed pieces for each batch were slowly transferred from one clean and dry 5-gal plastic bucket to a second bucket while seed treatment dust was sprinkled onto the seed during the transfer. Approximately one-half of the product was applied during each of two transfers between buckets. After all product was applied, the seed was again poured from one to another bucket for complete mixing. The cut and treated seed was then transferred to mesh onion bags for storage under suberization conditions (55ºF at 90-95 percent relative humidity). Onion bags were held over the second bucket during this transfer to collect any seed treatment dust lost during this transfer. Both buckets were wiped down with clean paper towels to accumulate any remaining product, which was then poured back to the Styrofoam cups and weighed. Cups of residue product were heated in a microwave oven for 1 minute to remove any moisture that might have adhered to the product. Dried residue samples were again weighed.

The experimental site was planted to orchardgrass in 2002, managed for hay production through 2004, and was last used for potato production in 1999. Telone™ II (dichloropropene, Dow AgroSciences LLC) was shanked in at 20 gal/acre on April 14 to control nematodes and related diseases. The experiment was arranged in a randomized complete block design with 6 replications of single-row, 30-hill plots. Seed was planted on May 26 with a 2-row, assisted-feed planter at 10-inch seed spacing in 32-inch rows. Fertilizer was applied in bands on both sides of rows at 160 lb Nitrogen (N), 80 lb Phosphate (P_2O_5), 80 lb Potash (K_2O), and 140 lb Sulfur (S)/acre at planting. The insecticide Admire® 2R (imidacloprid, Bayer Crop Sciences) and the fungicide Quadris® (azoxystrobin, Syngenta Crop Protection, Inc.) were applied in-furrow at planting at 0.17 and 0.10 lb ai/acre, respectively.

Weeds were adequately controlled with Dual II Magnum® (metolachlor, Syngenta Crop Protection, Inc.) and Prowl® 3.3 EC herbicide (pendimethalin, BASF Ag Products) applied with a ground sprayer at 1.75 pt/acre, each on June 7 and Matrix® (rimsulfuron, DuPont) applied via chemigation at 1.5 oz/acre on July 21. Dual and Prowl were incorporated immediately following application with a rolling cultivator in two passes. Approximately 20 inches of irrigation was applied during the growing season with solid-set sprinklers arranged in a 40- by 48-ft pattern.

Plant stands were monitored on June 21, June 27, July 5, and July 12. Fungicides were applied aerially on July 10 (Quadris), August 15 (Dithane F-45 (ethylene bisdithiocarbamate, Dow AgroSciences), and September 10 (Bravo Ultrex® (mancozeb, Syngenta Crop Protection, Inc.) at labeled rates. Insecticide Asana® XL (esfenvalerate, DuPont) was applied aerially on August 20 for control of loopers. Vines were desiccated with Reglone® desiccant (diquat dibromide, Syngenta Crop Protection, Inc.) applied with a ground sprayer at 1.5 pt/acre on September 7. Tubers were harvested with a one-row, digger-bagger on October 3. All tubers were saved and graded on October 24. Grades included USDA No. 1s, 4-8 oz, 8-12 oz, and >12 oz, Bs (<4 oz), U.S. No.2s, and culls. Data were statistically analyzed with SAS® for Linear Models, Fourth Edition (SAS Institute Inc.) software. Least significant differences (LSDs) were tested based on Student's *t* at the 5 percent probability level.

COARC

Certified Russet Norkotah seed was sorted into 6- to 8-oz tubers and cut into 4 pieces per tuber on May 9. One hundred thirty-two seedpieces (32 per replicate) were weighed and placed into a clean, dry bucket. Treatment materials were weighed and about 400 g of material added to each respective bucket. Seed pieces and treatment material were mixed and transferred several times between two buckets. Seed pieces were allowed to air-dry and any remaining treatment material was collected and weighed.

The experiment included four replications of single-row, 32-hill plots arranged in a randomized complete block design. Seed was spaced at 9 inches in 36-inch rows. Fertilizer was banded at planting on May 25 at 151 lb N, 110 lb P_2O_5 and K_2O, and 66 lb S/acre. Admire was applied at 0.36 lbs ai/acre at planting to control insects. Eptam 7-E® (s-ethyl dipropylthiocarbamate, Gowen) and Matrix were applied at 5 pt/acre and 1.5 oz/acre, respectively, to control weeds. The experiment was irrigated with solid-set sprinklers based on AgriMet crop water use calculations. Emergence data were collected on June 22. Stem counts were taken on October 18 prior to harvest. Vines were rolled on September 14 and tubers were harvested on October 18. All tubers were graded to USDA standards in late October.

MES

Russet Norkotah seed was cut and treated on April 13. As at other locations seed was 4-cut to provide uniform cut surfaces. Seed was suberized in paper bags for 5 days at 43ºF and planted on April 18. Plots of 30 hills arranged in a randomized complete block design were replicated 6 times. Seed was spaced at 9 inches in 36-inch rows. Standard cultural practices were followed for weed, pest, and disease control. Vines were senescing by the end of July and completely dead by the end of August. Tubers were harvested on October 7. All tubers were saved and graded to USDA standards in mid-October.

Results and Discussion

KES

The recovery of seed treatment dust following batch treatments was 5.1 g for Tops MZ. Residual product for experimental formulations ranged from 7.1 to 10.7 g, which represents 12 to 18 percent of applied product. One problem reported by growers is that seed treatment products will sometimes clump in applicator hoppers, requiring frequent cleaning for consistent application. This tendency was evaluated when the products were emptied out of Styrofoam cups. Clumping was not observed in any of the formulations.

A second complaint occasionally mentioned with use of seed treatment products when seed is suberized for several days prior to planting is a tendency for shrinking of seed pieces due to hydroscopic moisture depletion. This tendency was not observed at KES during the 9-day suberization period for any of the treatment products. Plant emergence data indicated no significant effects of treatments on rate of emergence. Mean percent emergence was 35, 81, 95, and 98 percent at 27, 33, 40, and 47 days after planting. Uniform plant vigor among the seed treatments was observed throughout the growing season.

Data documented no significant yield or grade responses to products or formulations evaluated (Table 1). The F6 treatment, which included a plant growth regulator, exceeded all other treatments in total yield of U.S. No.1s by 27-63 cwt/acre but this difference was not statistically significant. Overall, 2005 yields at KES were similar to yields observed in numerous studies with Russet Norkotah over more than 10 years.

COARC

The amount of product adhered to cut seed ranged from 0.55 to 0.75 lb/cwt of cut seed for the experimental formulations. Evolve and Tops treatments were much higher at 1.27 and 1.09 lb/cwt, respectively. Emergence at Madras, Oregon 28 days after planting ranged from 91 to 100 percent with no statistical difference (Table 2). Stem counts showed a uniform canopy with treatments and standards at 2.1-2.5 stems per plant with no statistically significant differences.

High yields were observed with a high percentage of large tubers (Table 2). Excessive tuber size contributed to relatively high cullage in all treatments except F6. Total yield was significantly higher for Evolve than Tops and F6. Differences between other experimental formulations and Evolve were not significant. Total yield of U.S. No. 1s was significantly higher for the standard treatment of Evolve than for Tops but not for any of the experimental formulations. Evolve also produced high yields in the 2004 trial conducted at COARC. This suggests there may be a disease issue at this site that is being suppressed by the cymoxonil component in this product. As at the other locations, data were not obtained on disease incidence.

MES

Full, uniform emergence was observed by May 15. Stand and stem count data were not taken. Yields were much lower for Russet Norkotah at this site than for Russet Norkotah at KES and COARC (Table 3). No yield differences were observed between treatments for any of the yield parameters. A much smaller size profile was observed at MES than at KES or COARC. High temperatures in this long growing season area frequently result in total U.S. No. 1 yields for Russet Norkotah being100 to 200 cwt/acre lower than at KES. The yields in all grades and sizes for the standard treatment of Tops MZ Gaucho were nearly identical to trial mean yields.

Summary

Data from two sites indicated relatively uniform amounts of product adhered to cut surfaces for the experimental formulations with greater adherence for standard products, particularly at COARC. In most treatments, approximately 0.5 lb of product/cwt of cut seed was retained on the seed. That is consistent with the experience from similar studies at KES in prior years with a range of seed treatment products. With the exception of high yields for the standard product Evolve and low yield for Tops at COARC, there were no apparent effects of seed treatment formulation on yield or grade at any location. The F6 formulation that included a nutrient and growth regulator component produced no significant yield responses. During a 9-day suberization period at KES, excessive dehydration of seed pieces was not observed in any of the formulations. At KES and MES, emergence was uniform and there were no significant differences in yield between treatments, including standard products.

References

Rykbost, K. A., B. A. Charlton *et al*. 2005. Evaluation of alternative carriers for potato seed treatment fungicides. Pages 31-37 in Research in the Klamath Basin, 2004 Annual Report. Special Report 1063. Agricultural Experiment Station, Oregon State University, Corvallis, OR.

Table 1. Effect of seed treatment product or formulation on performance of Russet Norkotah potatoes at the Klamath Experiment Station, Klamath Falls, OR, 2005.

	Yield U.S. No. 1s				Yield			
Treatment	4-8 oz	8-12 oz	>12 oz	Total	Bs	No. 2s	Culls	Total
	cwt/acre							
F1	76	110	193	379	19	33	22	453
F2	98	121	193	412	15	36	18	481
F3	95	124	171	390	20	32	16	458
F4	88	106	182	376	14	50	17	457
F5	91	138	165	394	15	41	15	465
F6	90	131	218	439	16	36	19	510
Tops MZ	93	123	166	382	20	47	20	469
Mean	90	122	184	396	17	39	18	470
CV (%)	17	19	24	12	33	33	57	10
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2. Effect of seed treatment product or formulation on performance of Russet Norkotah potatoes at the Central Oregon Agricultural Research Center, Madras, OR, 2005.

	Yield U.S. No. 1s			Yield			Stem/	Emerg.
Treatment	4-12 oz	>12 oz	Total	Bs	Culls	Total	plant	28 DAP[1]
	cwt/acre							
F1	140	296	436	27	110	573	2.4	97
F2	142	335	477	19	118	614	2.1	94
F3	187	331	518	22	71	611	2.3	97
F4	194	289	483	22	116	621	2.3	91
F5	184	307	491	22	70	583	2.3	94
F6	207	283	490	26	36	552	2.5	100
Evolve	158	371	529	24	109	662	2.3	94
Tops	178	207	385	25	85	495	2.4	97
Mean	174	302	476	23	89	589	2.3	96
CV (%)	29	24	17	28	50	10	12	5
LSD (0.05)	NS	108	118	NS	65	88	NS	NS

[1]Days After Planting

Table 3. Effect of seed treatment product or formulation on performance of Russet Norkotah potatoes at the Malheur Experiment Station, Ontario, OR, 2005.

	Yield U.S. No. 1s				Yield			
Treatment	4-6 oz	6-12 oz	>12 oz	Total	Bs	No. 2s	Culls	Total
	cwt/acre							
F1	90	202	26	318	76	54	5	453
F2	84	219	25	328	75	63	0	466
F3	92	206	27	325	71	55	4	455
F4	85	177	24	286	71	64	1	422
F5	76	218	54	348	60	63	0	471
F6	87	201	17	305	76	66	0	447
Tops MZ G	85	205	30	320	76	64	1	461
Mean	86	204	29	319	72	61	2	454
CV (%)	57	21	68	15	19	30	338	8
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Hybrid Poplar Performance

Brian A. Charlton[1] and Jim Dahm[2]

Introduction

Reduced availability of timber supplies from Pacific Northwest public lands and declining harvest from private lands has encouraged several companies in the wood products industry to search for alternative timber supply sources. Hybrid poplar has generated much interest and is currently grown on tens of thousands of acres in the northwest. Initially, hybrid poplar was considered primarily as a source of pulp. Changing economics for pulp has heightened interest in evaluating the potential for production of other wood products. Most northwest commercial hybrid poplar production is concentrated in the long growing season environment of the Columbia Basin.

Poplar is a generic term used to refer to trees in the genus *Populus*. Aspen, Lombardy poplar, black cottonwood, and eastern cottonwood are all members of this genus. Several hybrid (products of cross-fertilizing plants of different species) clones have been developed and constitute most of the commercial acreage. In the Pacific Northwest, hybrid poplar trees have grown to 70 ft in height and 15 inches in diameter in just 7 years in the long-season environment of the Columbia Basin.

The availability of timber supplies for pulp and wood products in the Klamath Basin has been severely curtailed by loss of access to timber on public lands. Several mills in the area have closed in the past decade and supply to remaining mills from private land is rapidly being depleted. Wood product companies in the area are interested in determining if hybrid poplar is an economic alternative for the short-season environment of the Klamath Basin.

A study was established at the Klamath Experiment Station (KES) in 1999 to evaluate the performance of clone OP-367 in a short-season environment.

Procedures

1999

Hybrid poplar clone OP-367, selected from earlier experiments (Leavengood et al. 1997), was planted in two observational blocks at KES on June 15. The northern block is a Poe fine sandy loam soil with pH about 7.0. The southern block is a Fordney fine sandy loam soil with pH ranging from 7.5 to 8.5 in a west-to-east direction. Both fields were ripped to 18-inch depth with shanks spaced 18 inches apart. Fields were moldboard plowed and a broadcast application of 500 lb/acre of 16-16-16 fertilizer was incorporated to a depth of 6

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inches. Poplar cuttings ("sticks") were planted at 7-ft spacing in 14-ft rows on June 15. Irrigation was provided with solid-set sprinklers arranged on a 40- by 40-ft spacing equipped to apply 0.123 inch/hour. The total water applied for the 1999 season was approximately 24 inches, including rainfall. Irrigation was stopped in early September to allow tree buds to harden off. Weed control was achieved by cultivating between rows with a tractor-drawn harrow and within rows with an ATV-drawn harrow.

2000

The total irrigation plus rainfall for the season was approximately 24 inches, as in 1999. To prevent root pruning, mechanical cultivation was not used for weed control in 2000. As an alternative, winter wheat was planted on May 2 as a cover crop to suppress weed competition. The cover crop and weeds were periodically flail-mowed during the summer. Foliar analysis performed in August of 1999 indicated elevated nutrient concentrations in both observational blocks. Therefore, no additional fertilizer was applied in 2000. Foliar analysis performed in August of 2000 indicated all major elements were at or well above recommended levels. Calcium and a few minor elements tested low, but deficiency symptoms were not identified.

2001

Vandals cut down all trees in the southern block on March 21, 2001. No further work was done with this block.

A serious drought in the region and Federal regulatory actions left about 170,000 acres within the Klamath Reclamation Project with no surface water during 2001. Therefore, aside from approximately 4 inches of rainfall during the growing season, no additional moisture was provided for trees in the northern block.

2002 and 2003

The total irrigation plus rainfall for the season was approximately 20 inches. Natural groundcover (grass and weeds) was periodically flail-mowed during the summer. Groundcover that could not be mowed because of close proximity to tree bases was sprayed with a tank mix of Roundup® (glyphosate, Monsanto Co.), Goal® (oxyfluorfen, Dow AgroSciences LLC), and Surflan® (oryzalin, Dow AgroSciences LLC) at labeled rates prior to bud break. Nitrogen (N) at 50 lb/acre was injected with the irrigation water during the growing season.

2004 and 2005

The total irrigation plus rainfall was approximately 19 inches for both growing seasons. Natural groundcover (grass, clover, weeds) was flail-mowed as needed during summer months. Herbicide applications were not necessary in 2004 or 2005 to control vegetation around basal portions of trees as previous herbicide applications continued to remain effective and increased shading from the trees reduced groundcover growth. Nitrogen was injected at 50 lb/acre with the irrigation water during 2004; however, no additional N was supplied in 2005.

Results and Discussion

A group of 12 trees (4 by 3) in the northern block was chosen for data collection. This is the largest contiguous block of trees without a border effect or missing trees. All data reported are derived from this block.

1999

All trees in the northern block appeared healthy throughout the growing season. Growth data were collected on September 8. Trees averaged about 4.5 ft of growth during the year of establishment (Fig. 1). Diameter at breast height (DBH) measurements were not taken; therefore, volume per acre values are not available. Weed control with the cover crop and mowing was adequate.

2000

Mortality of trees in the northern block was 7.1 percent. The winter wheat cover crop required minimal mowing and effectively reduced weed competition. Ceasing irrigation in the first week of September allowed adequate time for buds to "harden off" and appears to have prevented further winter mortality.

Growth data were collected in October. Trees averaged about 8.9 ft of new growth. Average height was about 13.4 ft. As in 1999, DBH measurements were not taken.

2001

Despite the moisture stress experienced during the growing season, all trees survived. Growth data were collected in January 2002. Trees averaged about 4.3 ft of new growth. Average height and DBH measured 17.7 ft and 2.5 inches. Volume per acre was approximately 44.0 ft^3 (Fig. 2).

2002

Growth data were collected in February 2003. Trees averaged about 5.9 ft of new growth during 2002. Average height and DBH measured 23.6 ft and 3.8 inches. Volume per acre was approximately 154.0 ft^3.

2003

Growth data were collected in April 2004. Trees averaged about 7.8 ft of new growth during 2003. Average height and DBH measured 31.4 ft and 5.3 inches. Volume per acre was approximately 364.0 ft^3.

2004

Growth data were collected in March 2005. Trees averaged about 12.4 ft of new growth during 2004. Average height and DBH measured 43.8 ft and 6.7 inches. Volume per acre was approximately 820.5 ft^3.

2005

Growth data were collected in late December 2005. Trees averaged about 10.6 ft of new growth during 2005. Average height and DBH measured 54.4 ft and 7.8 inches. Wood volume increased substantially to approximately 1,441.7 ft^3.

Future Direction

All trees have been pruned to remove multiple leaders and limbs to approximately 12 ft above the soil surface. Canopy shading in recent years has prohibited development of new limbs below 12 ft and the lowest remaining limbs will continue to be deprived of sunlight as canopy shading increases. This scenario will essentially promote "natural pruning" as lower limbs become devoid of substantial sunlight. Annual production practices will continue to operate under full irrigation and minimal input strategies. Height and diameter data will be collected annually.

References

Leavengood, S., J. Dahm, and K.A. Rykbost. 1997. Hybrid poplar research. Pages 84-88 *in* Crop

Research in the Klamath Basin, 1996 Annual Report. Special Report 981, Agricultural Experiment Station, Oregon State University, Corvallis, OR.

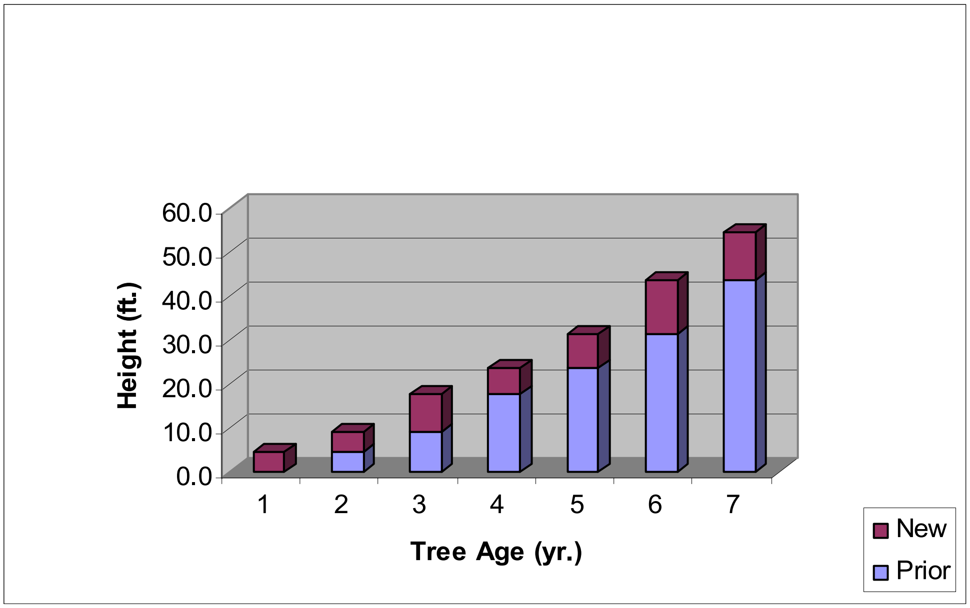

Figure 1. Tree height and growth of hybrid poplars at Klamath Experiment Station, Klamath Falls, OR, 1999-2004.

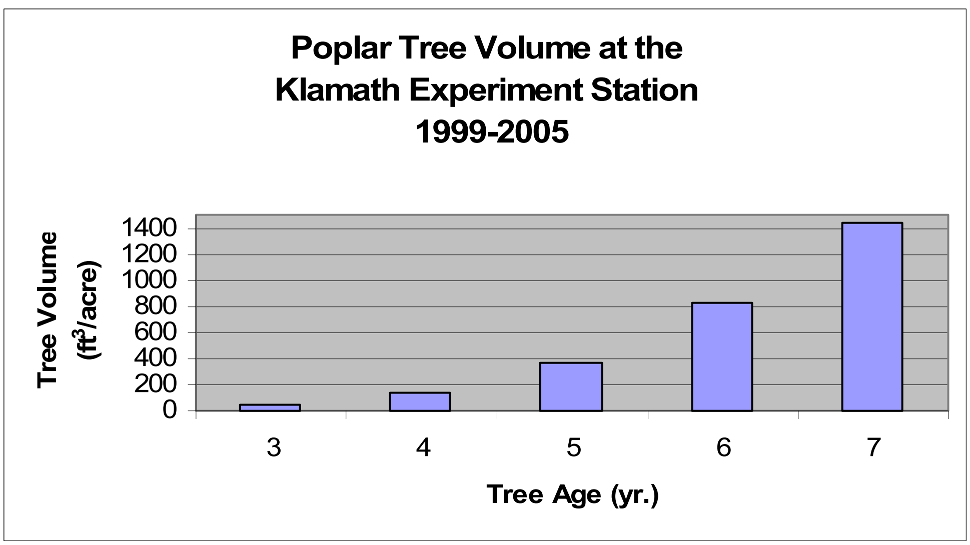

Figure 2. Tree volume of hybrid poplars at Klamath Experiment Station, Klamath Falls, OR, as measured in April 2004.

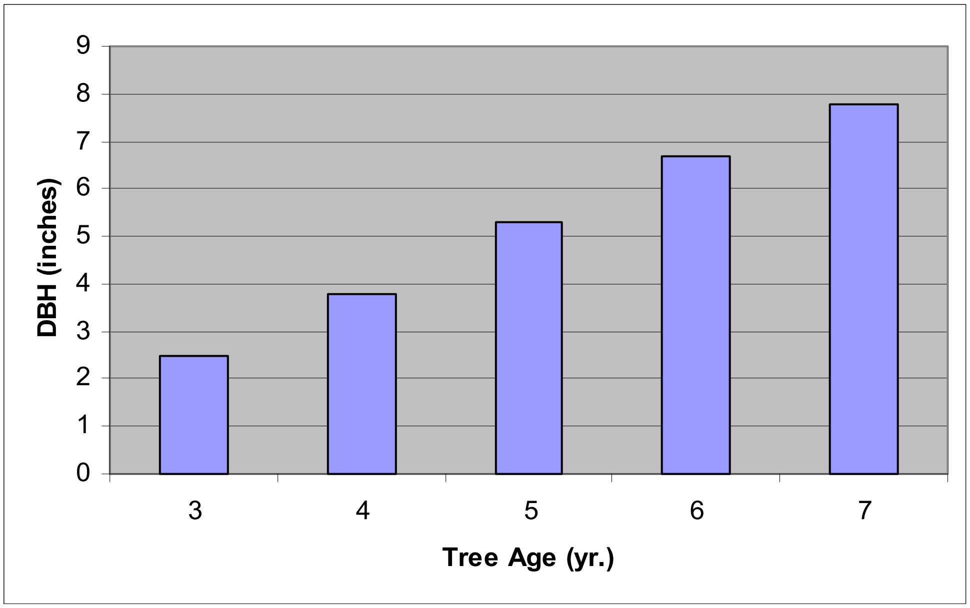

Figure 3. Tree diameter at breast height (DBH) of hybrid poplars at Klamath Experiment Station, Klamath Falls, OR, as measured in April 2004.

Hybrid Poplar Production in the Rogue Valley, 1997-2005

Richard J. Roseberg[1]

Introduction

This small scale research/ demonstration project was initiated in 1996, in cooperation with the City of Medford Water Reclamation Division. Initially, its purpose was to evaluate the potential for disposing of treated sewage effluent by irrigating nonfood (fiber) crops instead of discharging it into waterways. If such an agricultural reuse system were developed, it could help to solve three problems (both locally and throughout much of the West).

I. The City of Medford water reclamation facility produces about 10,000 acre-ft of treated effluent from spring through early fall. During the summer, when river flows decrease and more stringent standards are in effect, the treated effluent may have some detrimental effects on water quality. Currently the main concern is temperature elevation, but future regulations may require further nutrient removal before discharge into the river.

II. Agriculture in southwestern Oregon is often limited by a lack of water, and reusing the effluent would expand the amount of irrigation water available, while reducing pressure on other uses, such as stream habitat and recreation. Current regulations limit use of Level 2 effluent to nonfood crops only, with significant restrictions on use in forage crops. If effluent is to be used to irrigate food crops, additional treatment facilities would be needed to raise effluent quality to Level 4 (contains dissolved nutrients but no pathogens or sediment).

III. The recent decrease in availability of inexpensive wood chips (a by-product of lumber and veneer production) has forced local medium-density fiberboard (MDF) and particleboard plants to compete for increasingly scarce timber resources for their raw material. This has renewed interest in nontraditional fiber sources to augment conifer wood fiber in a wide range of products. Agricultural fibers can be substituted for conifer trees in most products, and are renewable in a much shorter time period. Most of the world has used nonwood fibers for paper and other fiber-based materials for centuries.

Research Approach

At the Medford Regional Water Reclamation Facility (sewage treatment plant) we made field-based measurements of root zone and groundwater chemistry, crop growth, water use, and nutrient uptake, in order to evaluate and reduce the risk of ground and surface water pollution while maximizing crop growth. The initial year of 1996 was predominantly an installation year, with 1997 including more installation as well as evaluation and data collection. In 1998 through 2001, we collected soil moisture data and groundwater and root zone water

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samples to measure water use and potential movement of nutrients or heavy metals through the soil. Implicit in this experiment was the evaluation of management requirements and production potential of several fiber crops, since the growth and management of likely agricultural fiber crops are not well understood in this region.

Three potential fiber crops (hybrid poplar [*Populus trichocarpa x P. deltoides*], kenaf [*Hibiscus cannabinus*], and miscanthus [*Miscanthus giganteus*]) were initially chosen for the study at the reclamation facility. However, recognizing that the Agate-Winlo soil at the treatment plant site was not ideal for crop production due to shallowness and high rock content, we planted a companion experiment at the Southern Oregon Research and Extension Center (SOREC) Hanley farm, which has Central Point sandy loam soil. The three poplar clones planted at the sewage treatment plant, plus three additional clones, were planted at the Hanley farm in 1997 to provide a better estimate of hybrid poplar production in a good agricultural soil. The Hanley farm site was not irrigated with treated effluent, but with standard irrigation water supplied by the Medford Irrigation District. Further details on the characteristics of these fiber crop species was provided in the Klamath Experiment Station 2003 Annual Report.

Procedures

Irrigation

From 1997 through 2002, the volume of effluent applied at the sewage treatment plant (STP) was measured using standard in-line water meters, and thus application amounts as volume per unit area (cubic inches per square inch, or simply as inches), could be calculated. Research at the STP was not continued beyond 2002. The Hanley farm site was irrigated for the full season from 1997 to 2002, and was irrigated once in 2003. The Hanley farm site was not irrigated in 2004 or 2005 to examine the ability of the poplar trees to grow using only groundwater and the limited summer rainfall. Precipitation for the April-September growing season totaled 2.54 inch in 2004 and 6.50 inch in 2005. Other irrigation details for the earlier years of these experiments are included in the 2003 and 2004 Klamath Experiment Station Annual Reports.

Fertilizer

Fertilizer was applied to the Hanley farm site in early summer each year from 1997 to 2003. No fertilizer was applied at the Hanley farm site in 2004 or 2005. No fertilizer was applied to the STP site; however, the amount of total nitrogen and phosphorous applied through the effluent could be calculated given the volume and nutrient concentration, which is measured routinely by the treatment plant staff. Further details of the fertilizer rates and effluent nutrient values for the earlier years of these studies can be found in the 2003 and 2004 Klamath Experiment Station Annual Reports.

Crop Growth

Tree height and breast height diameter were measured each year in the winter when the trees were dormant. Trunk diameter at 4.5-ft height was measured using calipers. Tree height was initially measured directly with tall ladders, graduated pipes, and hydraulic lifts. Once the trees grew taller than about 40 ft, we used the clinometer method with a base distance of 100 ft. This method is accurate to within about

1 ft for this situation (level ground, distinct planting pattern). The mean for each clone is typically an average of 24 individual trees, but in some cases the number of trees was slightly less due to tree damage through the years.

Results and Discussion

Growth and Yield

It is clear that the poplar trees grew much better at the Hanley site than at the STP site (Figures 1 and 2). Even though sufficient water and nutrients were applied at both sites (until the last 2 years at Hanley), the conditions at the Hanley site are more ideal for poplar growth. The Central Point sandy loam soil at the Hanley farm is very deep, with about 4 percent organic matter and a permanent water table at 6-20 ft deep. It is the native habitat of the related cottonwood tree, which grows prolifically along streambanks in the area. The Agate-Winlo soil at the STP, however, is only about 50 percent soil, with the remaining volume consisting of various sizes of gravel and rocks. The soil fraction has high clay content, and the whole area is underlain with a permanently cemented hardpan (primarily iron oxides). Although the area was ripped to a depth of about 40 inches before planting, in some areas the hardpan was slightly deeper, and thus not disturbed by the ripping. In its natural state this soil produces mainly annual grasses and weedy broadleaves, and is not considered a productive soil even when irrigated. This site was chosen due to its proximity to the effluent and the likelihood that similar soils would be used if the project was expanded to a commercial scale.

In addition to the location difference, it is clear the clone 15-29 grew slightly taller and quite a bit thicker than the other clones at Hanley, although it was similar to the other clones at the STP. This effect is due mainly to the unanticipated tree spacing that occurred for the 15-29 clone at Hanley. When the Hanley site was planted, virtually all the poplar sticks produced healthy trees for all clones except 15-29. In that case, only about 20 percent of the 15-29 clones produced healthy trees. Based on the results of the other clones, it seems likely that this batch of 15-29 was damaged somehow in storage before purchase. We replanted a new batch of 15-29 sticks in mid-summer, but the new saplings never were able to catch up with the first group. Thus, the first group of 15-29 saplings was able to grow with less competition, and behaved as if sticks were planted at a much wider spacing than was the case. This was most apparent in the diameter data, demonstrating the often-observed situation in forestry where trees at close spacing remain significantly thinner than similar trees planted at a wider spacing. Thus, the growth advantage for 15-29 at Hanley is probably not a reflection of a superior clone, but rather the different growing conditions this clone experienced compared to the others.

Interestingly, the growth at Hanley during years 7 and 8 was only slightly affected by the lack of irrigation, and then the tree growth rate in year 9 was similar to that observed in the early years, despite the complete lack of irrigation and fertilizer in years 8 and 9. The trees undoubtedly benefited from the wetter than normal spring in 2005, but still continued to grow throughout the dry summer months. Poplars are not very efficient water users; thus, the continued growth of all clones indicates that the tree roots had reached the shallow water table and were accessing sufficient water for transpiration from that source.

Insect and Disease Pests

At Hanley, disease and insect problems were minimal until the seventh year, when a few spots of damage began to show up. The few trees that were affected were removed each year and destroyed to reduce further spread, although the problem seemed to get slightly worse each year after year 7. However, trees grown at the STP began suffering obvious damage starting in about the fourth year and the problem became progressively worse each year. Details of this problem, identification of the causal agents, and resulting termination of the study after the sixth year due to severe infestation is described in detail in the 2003 Klamath Experiment Station Annual Report. In summary, it appeared that a boring-type beetle harbored in old, nearby cottonwood tress moved into the young poplar stand at the STP. After weakening the trees, secondary fungal and bacteria pathogens invaded, including a previously undescribed fungal species from the genus *Botryozyma.* The appearance of damage did not coincide with any observable spray pattern or effect, and is not thought to be related to the use of effluent for irrigation.

Summary

Hybrid poplar trees are well suited to the climate in the Rogue Valley in southwestern Oregon, provided they receive sufficient irrigation water during the summer, or are able to reach groundwater aquifers once deep roots are established. Growth was excellent in good agricultural soil, but was reduced in poor quality soil. However, trees were able to grow in poor soils using water and nutrients provided only by treated sewage effluent. Boring insects and subsequent fungal disease were a major problem at the sewage treatment plant site after several years, but were only a minor problem at the Hanley farm for most of the study period. The nearby environments and plant communities at the two sites more likely affected the presence or absence of these insect and disease organisms, rather than the presence or absence of treated effluent *per se*. If a market for poplar veneer or lumber were developed in the Rogue Valley, local production, possibly using treated effluent as an irrigation source, would be a likely source for at least some of the raw material.

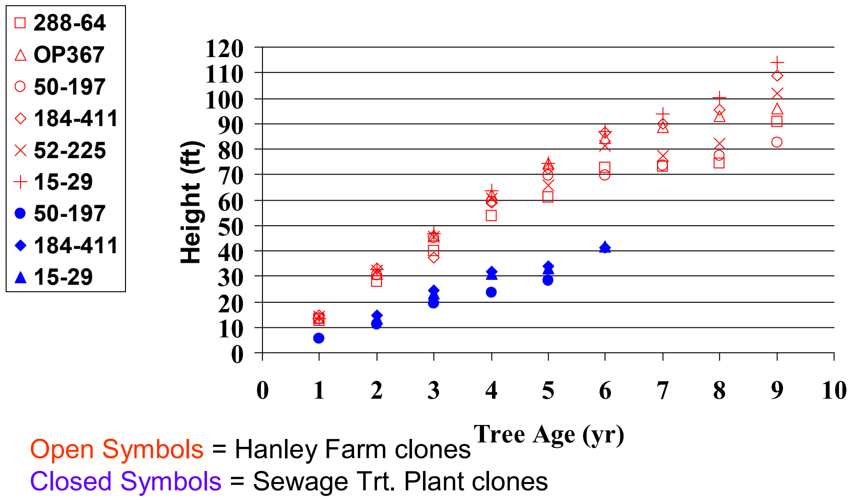

Figure 1. Mean height of poplar tree clones grown at the Medford Sewage Treatment Plant and the Southern Oregon Research and Extension Center Hanley farm, 1997-2005.

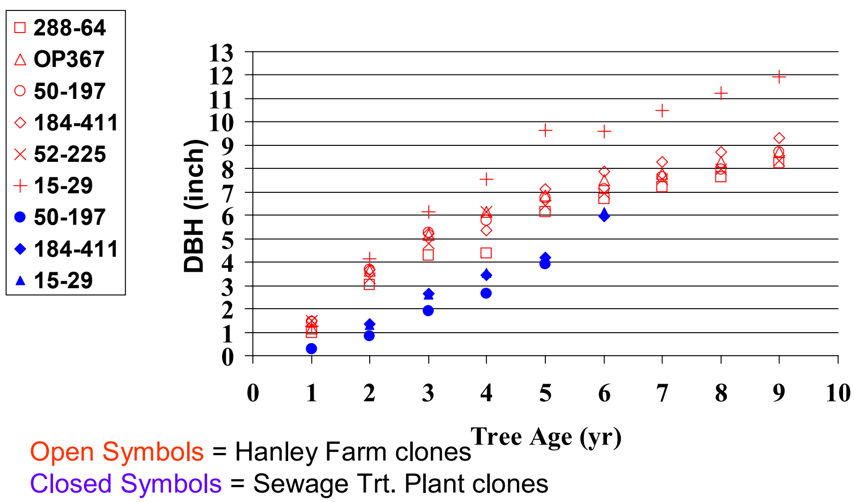

Figure. 2. Mean breast height diameter (DBH) of poplar tree clones grown at the Medford Sewage Treatment Plant and the Southern Oregon Research and Extension Center Hanley farm, 1997-2005.

Irrigated Alfalfa Variety Trials

Richard J. Roseberg and Jim E. Smith[1]

Introduction

Alfalfa accounts for more than 51,000 acres within the Klamath Irrigation Project, and close to 40,000 acres are in Klamath County. Major markets in Oregon and California include dairies, cattle ranches, and horse ranches. A portion of local production is compressed for export markets. In the Klamath Basin, alfalfa yields and quality are typically highest in the first few full production years, but over time both yield and quality tend to decrease due to diseases, pests, and soil compaction and crown damage from equipment traffic that reduce the stand density, resulting in increased acid detergent fiber and neutral detergent fiber, and a decline in crude protein. Fields are generally rotated out of alfalfa after 5 to 7 years. However, based on past experience, varieties differ in their ability to withstand this reduction in yield and quality over time.

Production of high yields of high-quality alfalfa is difficult in the Klamath Basin due to extreme daily and seasonal changes in weather. Although mild days and cool night-time temperatures slow growth, and thus increase potential quality of locally grown alfalfa, these conditions also reduce yield potential. Cold winters stress plants, resulting in reduced stand persistence, and can dramatically reduce the survival of fall-seeded stands, especially if they are seeded after about September 1. Severe late-spring frosts sometimes reduce first cutting yields, and spring rains can reduce quality in the first cutting. In addition, water availability in the Klamath Basin is uncertain, and performance of alfalfa grown without irrigation is not well understood.

Alfalfa breeding programs are striving for improved quality and are marketing varieties reported to have superior quality due to increased leafiness and finer stems. Breeders are also attempting to improve drought tolerance in dryland-adapted varieties. Variety trials were established at the Klamath Experiment Station (KES) in 2002 to evaluate performance of 50 varieties under both irrigated and dryland management regimes. Most entries in the trials were released varieties and experimental lines with fall dormancy (FD) ratings ranging from 2 to 5, along with a single FD 1 and one FD 6 entry. About one-half of the entries were standard trifoliate selections adapted to irrigation management while the rest were described as being more adapted to dryland management. However, the unexpected presence of subsurface moisture under parts of the dryland trial area in 2003 rendered those results meaningless, and thus that trial was not continued in 2004 or beyond. The objective of the remaining study was to compare the yield and quality performance of a representative number of released and experimental varieties over several years in a high-input

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production system in the Klamath Basin.

Procedures

The irrigated trial was established on Fordney loamy fine sand at KES in the spring of 2002 by Dr. Don Clark, the previous KES agronomist. A total of 50 released varieties and experimental alfalfa lines were included in the trial. Entries were arranged in a randomized complete block design with four replications. In 2002, fertilizer was applied prior to planting according to recommendations based on analysis of soil samples from the field. Preplant fertilizer included elemental (popcorn) sulfur (S) at 300 lb/acre S, and 10-34-0 liquid to supply phosphorus at 150 lb/acre P_2O_5. In addition, 310 lb/acre of 16-20-0-13 fertilizer was applied at planting to supply 50 lb/acre nitrogen (N), 63 lb/acre P_2O_5, and 41 lb/acre S. Seed was drilled to a depth of 0.25 inch at 20 lb/acre using a modified Kincaid (Kincaid Equipment Manufacturing) planter, which planted 9 rows at six-inch row spacing. Individual plots were 4.5 by 20 ft, with 3 by 15.5 ft harvested.

Sprinkler irrigation was applied with a solid-set system according to crop needs during the establishment year, and to meet crop needs in 2003, 2004, and 2005 using crop evapotranspiration (Et) for irrigation scheduling. Soil moisture content was monitored with watermark soil moisture sensors (Irrometer Corp., Inc., Riverside, CA). In 2005, irrigation water was consistently available, and so crop water needs were met for the full season. Irrigation was applied on 16 occasions during the season, for a total of 14.6 inches. At times, irrigation scheduling was modified according to weather changes. Precipitation totaled 4.63 inches from March 25 (when growth began in the spring) through September 30. Most of this fell during the unusually wet spring, including 1.8 inches in April and 2.05 inches in May. Only 0.02 inches of rain fell in July, and there was no precipitation in August. It remained dry until the latter half of September, when 0.21 inch of rain fell. Overall, the 2005 growing season had a wet spring with near normal temperatures, followed by near normal conditions (warm, dry summer) providing excellent forage growing and harvest conditions (see the Weather and Crop Summary section of this annual report for further weather details).

Weed control included a dormant spray of Sencor® DF (metribuzin), at 1.0 lb/acre, Gramoxone Max®, (paraquat dichloride), at 1.5 pt/acre, and LI-700 non-ionic spreader at 2 pt/acre on March 15. No additional fertilizers or pesticides were applied in 2005.

Plots were harvested when the alfalfa was observed, on average, to reach late bud stage, using a tractor-mounted Carter (Carter Manufacturing Co., Inc.) flail harvester with a 3-ft-wide header. Harvest dates were June 10, July 18, and August 25. In 2004 we harvested four times, but had minimal yield on the fourth cutting in late September. It was decided to allow a slightly longer regrowth period following first and second cutting, resulting in three stronger cuttings in 2005. After plot harvest was complete, border areas were then cut with a Mathews (Mathews Co., Crystal Lake, IL) flail mower.

Harvested material from each plot was immediately weighed, followed by random-grab sampling about 1 lb from each plot for oven drying in order to calculate dry matter yield. After drying and weighing, samples were ground to 2-mm-sieve size in a Wiley Mill (Arthur H. Thomas Co.) and to 1-

mm-sieve size in an Udy Mill (Udy Corp.) before being analyzed in a near infrared spectrophotometer (NIRS, NIRSystems) to determine forage quality.

Quality testing at KES is accomplished using the NIRS and equations developed by the NIRS Consortium, Madison, Wisconsin. KES also uses equations developed in house, equation updates to our commercial (FOSS North America) equations, and with data collected from analytical chemistry in partnership with the Oregon Hay and Forage Association's Oregon State Hay King Contest. Oregon State University's KES Forage Quality Laboratory was able to join the consortium due to substantial support by the Oregon Hay and Forage Association. The NIRS system generates several forage quality parameters, but for simplicity this report includes only relative feed value (RFV), and a new parameter, relative forage quality (RFQ).

Statistics on all yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's t test at the 5 percent level.

Results and Discussion

Observations on Abandoned Dryland Trial

The abandoned dryland variety trial area was managed as a bulk hay field in 2004 and 2005. Irrigation was first applied to this area after the first cutting in 2004 and was continued for the remainder of that year as well as all of 2005. Areas without access to subsurface moisture in 2003 exhibited obvious and severe stress and growth reduction carrying into early 2004. However, many plants did survive; after reintroduction of irrigation after first cutting in 2004, it was difficult to identify the areas that had access to subsurface moisture in 2003 and those that did not. In 2004 and 2005, growth in the field appeared remarkably uniform, suggesting that, in general, the alfalfa varieties were able to survive extreme drought conditions and recover when irrigation was reapplied the next year. However, we have no data to prove this effect or to determine if some varieties are better able to recover in this way than others.

Yield

Three cuttings were made in 2005. First-cutting yields ranged from 2.4 to 3.2 ton/acre with a mean of 2.8 ton/acre, all of which were greater than in 2004 (Table 1). Second-cutting yields ranged from 2.0 to 2.8 ton/acre with a mean yield of 2.4 ton/acre, which were also all greater than the second cutting in 2004. Third-cutting yields ranged from 1.3 to 1.7 ton/acre, with a mean yield of 1.6 ton/acre, nearly identical to third cutting in 2004. Total yield ranged from 6.2 to 7.2 ton/acre in 2005, with a mean of 6.8 ton/acre. This result was very similar to 2004, except the highest yielding varieties did slightly better in 2004 (four cuttings) than 2005 (three cuttings). In most cases, the three cuttings in 2005 resulted in yields that were very similar overall to what was produced under four cuttings in 2004. In 2005 there was a significant difference in yield between entries for the first cutting only. There were no significant differences in yield between entries for the second cutting, third cutting, or the annual total, although the P value for annual total yield was 0.073, approaching the 0.05 cutoff value where a significant yield difference between entries would have been indicated.

Comparing the change in yield ranking for individual varieties, some varieties did much better or much worse in 2005 compared to 2004. Varieties that improved dramatically (by at least 25 ranks) relative to the other entries included Ladak 65, Hybriforce-400, Rampage, Renovator, Maxigraze GT, Nomad, and Rambler. It is interesting that in 2004 four of these entries (Hybriforce-400, Rampage, Renovator, and Rambler) were in the group that was dramatically poorer in 2004 compared to 2003. In other words, this group underperformed in 2004 compared to the other entries, but then improved dramatically in 2005.

Varieties that were dramatically poorer in 2005 (by at least 25 ranks) compared to 2004 included Plumas, Runner 212, Select, Macon, BlazerXL, Reliance, and C-316. From this group, Select and Runner 212 were among the most improved in 2004 compared to 2003, indicating they outperformed the other entries in 2004 compared to the previous year, but then declined dramatically in 2005 relative to the other entries.

The only entries that remained in the top fourth of all entries for all 3 years were CW74013 and 54Q25. The yield ranking of WL342, Reliance, and Geneva all dropped dramatically in 2005 after remaining near the top of the list for both 2003 and 2004. While WL342 held the unusual distinction of producing the greatest yield in both 2003 and 2004, its annual yield slipped to 23rd in 2005.

Wrangler was the only entry that produced consistently low yields all 3 years. Nomad and Ladak 65 had among the lowest yields in 2003 and 2004, but were both dramatically higher in 2005. Whereas Nomad had the unusual and dubious distinction of producing the lowest yield in both 2003 and 2004, it improved to 19th in 2005. Ladak 65 improved from 48th in 2004 to sixth in 2005.

Evaluating Forage Quality

In Oregon's hay market, alfalfa marketing classes are based on RFV. In the California hay market, alfalfa marketing classes are based on the level of acid detergent fiber (ADF) or total digestible nutrients (TDN) at 90 percent dry matter. In Oregon, TDN is reported at 100 percent dry matter. This classification system is important to Klamath Basin producers since much of their hay is sold in California. For reference, the USDA Quality Guidelines for alfalfa hay are shown in Table 2, using the following parameters: RFV, ADF, neutral detergent fiber (NDF), TDN, and crude protein (CP).

Calculation and Use of RFQ

RFQ is a relatively new quality parameter developed by the University of Wisconsin and the USDA-ARS Forage Quality Laboratory at Madison, Wisconsin, in conjunction with an association of forage laboratories including universities, alfalfa breeders, and the NIRS Consortium. Whereas RFV is a relatively simple calculation derived from ADF and NDF, RFQ is a more complicated calculation derived from nonfibrous carbohydrate, CP, fatty acids, nitrogen-free NDF, 48-hour *in vitro* digestibility, and NDF (Undersander and Moore 2002). Thus, the RFQ calculation attempts to estimate animal intake more accurately than RFV by including additional important nutritive qualities in the equation.

RFV and RFQ calculations are both designed to differentiate between hay of differing quality grades, and in most cases RFV and RFQ will provide similar predictions of forage quality. However, in cases where they do not, it is helpful to remember how the two values are calculated and therefore how they might best be used by hay growers and buyers, depending on the planned end-use of the forage. Because RFQ uses additional factors representing animal assimilation, it is thought by some to be a more accurate predictor of actual animal performance on particular forage (Undersander 2003). At this point, RFQ has not been officially adopted as a legal parameter to determine alfalfa quality, but it may become a useful new standard in the near future. We calculated RFQ along with the more traditional parameters to aid interpretation and application of these results.

There were significant differences between entries for RFV and RFQ values for the first and third cuttings (Tables 3 and 4). In general, forage quality was highest for first and third cuttings, with many entries reaching “Supreme” or “Premium” status using RFV guidelines. The quality was lower overall for second cutting, with most entries grading either “fair” or “low”. Any particular variety tended to have relatively higher or lower RFV at one or two cuttings, but not all three, presumably due to differences in maturity expressed under the regrowth period that was equal for all entries. Exceptions to this trend included WL319HQ, Hybriforce-400, 9429, Setter, and Runner 211, which all had consistently high RFV for all three cuttings. On the other hand, Lahontan, Max 85, Ranger, and Forager Plus had consistently low RFV on all three cutting dates.

The results were similar for RFQ, as WL319HQ, WL342, Hybriforce-400, 9429, BlazerXL, Setter, and Runner 211 all had relatively high RFQ on all three dates, whereas Geneva, Lahontan, Max 85, Ranger, and Forager Plus all had relatively low RFQ on all three dates. Quality results were similar in 2005 for the two parameters, but the difference in RFV and RFQ calculations should be kept in mind when deciding which is best to use when grading hay for a particular situation.

Annual and cumulative yield totals for 2003, 2004, and 2005 were also analyzed (Table 5). There was a significant difference between entries for annual yield in 2003, but not in 2004. The *P* value in 2005 was nearly significant. The 3-year cumulative total also exhibited significant differences between entries. As the stand matured and persistence factors began to come into play, differences between varieties became more obvious. The change in rankings over time illustrates why single year data are not as useful as multi-year results, especially if results for a particular variety hold true at multiple locations.

This trial was completed at the end of the 2005 season. In addition, ongoing concerns about water availability and qualitative observations from the 2002 dryland trial area suggest a new trial with limited or no irrigation should be planted in the future to evaluate variety performance under conditions of limited moisture.

References

Undersander, D. 2003. RFQ- A new way to rank forage quality for buying and selling. http://www.agry.purdue.edu/ForageDay/rfq.pdf

Undersander, D., and J.E. Moore. 2002. Relative Forage Quality. Focus on Forage, Vol. 4, No. 5. Univ. of Wisconsin Extension, 2 pp.

Table 1. 2005 yield results for the irrigated alfalfa variety trial, planted spring 2002 at the Klamath Experiment Station, Klamath Falls, Oregon.

Variety	Seed source	Fall dormancy	Cut 1 June 10	Cut 2 July 18	Cut 3 Aug 25	Total	% Vernal	2005 rank	Rank change from 2004
			tons/acre						
WL 319HQ	W-L Research	3	3.2	2.5	1.6	7.2	108	1	20+
Hybriforce-400	Dairyland Research International	5	3.2	2.5	1.6	7.2	108	2	38+
Maxigraze GT	Croplan Genetics	2	3.1	2.5	1.5	7.2	107	3	31+
329	D & D Seed (Cal West)	2	3.0	2.5	1.7	7.2	107	4	16+
Forager Plus	Ray Brothers Seed	1	3.0	2.6	1.6	7.2	107	5	8+
Ladak 65	Gooding Seed Co.	2	2.9	2.8	1.5	7.2	107	6	42+
DS9809 HYB	Dairyland Research International	3	2.9	2.4	1.7	7.1	106	7	7+
CW74013	D & D Seed (Cal West)	4	3.0	2.5	1.6	7.1	105	8	2-
Spredor GT	Croplan Genetics	3	3.1	2.3	1.6	7.1	105	9	19+
54Q25	Pioneer Hi-Bred International	5	2.9	2.6	1.6	7.1	105	10	1+
Rampage	Gooding Seed Co.	3	3.0	2.4	1.7	7.0	105	11	35+
Accord	Highland Seed	3	3.1	2.3	1.7	7.0	104	12	11+
Vitro	Eureka Seeds	4	3.0	2.3	1.6	7.0	104	13	13+
9429	Eureka Seeds	3	2.9	2.5	1.6	7.0	104	14	15+
Renovator	Croplan Genetics	2	2.9	2.5	1.5	6.9	103	15	34+
Setter	D & D Seed	4	3.0	2.3	1.5	6.9	103	16	1+
Shaw	Montana State University	3	3.0	2.4	1.6	6.9	103	17	8-
Rambler	L. Hankins Seed and Sales	2	2.9	2.4	1.6	6.9	103	18	25+
Nomad	L. Hankins Seed and Sales	2	3.1	2.3	1.5	6.9	103	19	31+
DKA42-15	Monsanto	4	2.5	2.8	1.6	6.9	103	20	5-
Magnum V	Dairyland Research International	4	2.7	2.5	1.7	6.9	103	21	15+
Goliath	Allied Seed, L. L. C.	3	3.0	2.3	1.6	6.9	103	22	10+
WL 342	W-L Research	4	3.0	2.3	1.6	6.9	103	23	22-
Runner 211	Geertson Seeds	2	2.8	2.5	1.6	6.9	102	24	11+
Ladak	L. Hankins Seed and Sales	2	3.0	2.3	1.5	6.8	102	25	9-
WL 327	W-L Research	4	2.9	2.3	1.6	6.7	100	26	4-
Geneva	Croplan Genetics	4	2.7	2.4	1.6	6.7	100	27	19-
Vernal	L. Hankins Seed and Sales	2	2.7	2.5	1.5	6.7	100	28	10+
Reliance	Allied Seed, L. L. C.	3	2.7	2.4	1.6	6.7	100	29	26-
Cooper	Montana State University	3	2.7	2.5	1.5	6.7	99	30	5-
DK127	Monsanto	4	2.6	2.4	1.5	6.6	99	31	13+
Ladak Plus	Landmark Seed Co.	2	2.6	2.5	1.5	6.6	99	32	5+
Max 85	L. Hankins Seed and Sales	2	2.5	2.5	1.6	6.6	99	33	=
Leafmaster	Highland Seed	3	2.9	2.1	1.6	6.6	99	34	24-
Ranger	Gooding Seed Co.	2	2.7	2.3	1.6	6.6	98	35	12+
Dura 512	Farm Valley	5	2.8	2.2	1.6	6.6	98	36	5-
Rebel	Target Seed	4	2.9	2.3	1.3	6.6	98	37	5+
4A135	Forage Genetics International	5	2.5	2.5	1.6	6.5	98	38	19-
Macon	Allied Seed, L. L. C.	4	2.8	2.3	1.5	6.5	97	39	35-
AL-355	UAP	3	2.7	2.4	1.5	6.5	97	40	13-
Lahontan	L. Hankins Seed and Sales	6	2.4	2.5	1.6	6.5	97	41	=
Reno	Croplan Genetics	5	2.6	2.3	1.6	6.5	96	42	18-
C-316	Lohse Mill, Inc.	4	2.5	2.4	1.5	6.5	96	43	25-
Select	Forage Genetics International	4	2.7	2.2	1.6	6.5	96	44	39-
Blazer XL	Croplan Genetics	4	2.8	2.1	1.6	6.5	96	45	33-
Plumas	Eureka Seeds	4	2.8	2.2	1.4	6.4	95	46	44-
Runner 212	Geertson Seeds	2	2.8	2.0	1.5	6.3	94	47	40-
LM459	Lohse Mill, Inc.	5	2.6	2.1	1.6	6.3	94	48	18-
Mariner II	Allied Seed, L. L. C.	2	2.5	2.2	1.5	6.3	93	49	10-
Wrangler	Highland Seed	2	2.8	2.0	1.5	6.2	93	50	5-
Mean			2.8	2.4	1.6	6.8			
P value			<0.001	0.915	0.948	0.073			
LSD (0.05)			0.4	NS	NS	NS			
CV (%)			9.5	16.6	11.2	6.9			

Table 2. USDA quality guidelines for alfalfa hay[1].

Quality grade[2]	RFV[3]	ADF %	NDF %	TDN-100%[4]	TDN-90%	Crude protein %
Supreme	>185	<27	<34	>62	>55.9	>22
Premium	170-185	27-29	34-36	60.5-62	54.5-55.9	20-22
Good	150-170	29-32	36-40	58-60	52.5-54.5	18-20
Fair	130-150	32-35	40-44	56-58	50.5-52.5	16-18
Low	<130	>35	>44	<56	<50.5	<16

[1]For the latest hay market report contact: USDA Livestock and Grain Market News, 1498 S. Pioneer Way, Moses Lake, WA 98837; Phone: 509/765-3611; Fax: 509/765-0454.

[2]Hay quality designation--physical description.

Supreme	Very early maturity, prebloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
Premium	Early maturity, prebloom, extra leafy and fine stemmed. Factors indicative of high nutritive content. Hay is green and free of damage.
Good	Early to average maturity, early to mid-bloom, leafy, fine to medium stemmed, free of damage other than slight discoloration.
Fair	Late maturity, mid- to late-bloom, moderate or below leaf content, generally coarse stemmed. Hay may show light damage.
Utility	Hay in very late maturity, mature seed pods, coarse stemmed. Includes hay with excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

[3]RFV calculated using the AFGC formula.

[4]TDN calculated using the western formula.

Table 3. 2005 relative feed value summary for the irrigated alfalfa variety trial, planted spring 2002 at the Klamath Experiment Station, Klamath Falls, Oregon.

Variety	Seed source	Fall dormancy	Cut 1 June 10	Rank	Cut 2 July 18	Rank	Cut 3 Aug 25	Rank
			Relative feed value					
Dura 512	Farm Valley	5	173	24	123	42	149	46
WL 319HQ	W-L Research	3	179	12	135	14	186	2
WL 327	W-L Research	4	170	31	130	34	154	40
WL 342	W-L Research	4	175	20	143	2	184	3
Magnum V	Dairyland Research International	4	169	36	129	36	158	33
Hybriforce-400	Dairyland Research International	5	185	4	135	11	170	12
DS9809 HYB	Dairyland Research International	3	175	19	136	10	158	31
C-316	Lohse Mill, Inc.	4	170	30	131	29	155	39
LM459	Lohse Mill, Inc.	5	178	14	130	32	138	50
AL-355	UAP	3	169	37	133	22	153	43
Goliath	Allied Seed, L. L. C.	3	176	17	133	20	169	14
Macon	Allied Seed, L. L. C.	4	173	25	134	16	169	16
Reliance	Allied Seed, L. L. C.	3	185	5	130	31	162	26
Mariner II	Allied Seed, L. L. C.	2	169	34	121	45	141	49
Rebel	Target Seed	4	181	10	131	27	164	22
4A135	Forage Genetics International	5	174	22	130	30	156	37
Select	Forage Genetics International	4	180	11	135	12	163	25
Reno	Croplan Genetics	5	173	26	121	44	159	29
Geneva	Croplan Genetics	4	164	42	127	39	155	38
DKA42-15	Monsanto	4	170	32	129	35	157	35
CW74013	D & D Seed (Cal West)	4	174	21	130	33	160	28
329	D & D Seed (Cal West)	2	172	28	134	18	167	17
Plumas	Eureka Seeds	4	186	3	131	25	159	30
Vitro	Eureka Seeds	4	184	6	139	7	158	32
9429	Eureka Seeds	3	184	7	138	8	169	13
54Q25	Pioneer Hi-Bred International	5	176	18	118	48	157	34
Blazer XL	Croplan Genetics	4	188	1	133	19	188	1
Accord	Highland Seed	3	166	38	141	4	152	44
Leafmaster	Highland Seed	3	169	35	137	9	153	41
Wrangler	Highland Seed	2	178	13	140	5	163	24
Setter	D & D Seed	4	181	9	140	6	174	8
Vernal	L. Hankins Seed and Sales	2	184	8	123	43	180	5
Lahontan	L. Hankins Seed and Sales	6	166	39	114	49	146	47
Ladak Plus	Landmark Seed Co.	2	164	43	131	26	166	19
Maxigraze GT	Croplan Genetics	2	174	23	132	24	165	21
Spredor GT	Croplan Genetics	3	164	41	132	23	173	10
Renovator	Croplan Genetics	2	159	49	134	15	161	27
DK127	Monsanto	4	177	16	143	3	179	6
Max 85	L. Hankins Seed and Sales	2	162	44	126	40	144	48
Ranger	Gooding Seed Co.	2	159	50	124	41	151	45
Ladak	L. Hankins Seed and Sales	2	171	29	131	28	164	23
Nomad	L. Hankins Seed and Sales	2	161	47	109	50	173	9
Rambler	L. Hankins Seed and Sales	2	162	45	133	21	165	20
Runner 211	Geertson Seeds	2	188	2	150	1	176	7
Runner 212	Geertson Seeds	2	161	46	129	37	169	15
Ladak 65	Gooding Seed Co.	2	165	40	134	17	167	18
Rampage	Gooding Seed Co.	3	177	15	120	46	156	36
Forager Plus	Ray Brothers Seed	1	160	48	129	38	153	42
Shaw	Montana State University	3	170	33	135	13	184	4
Cooper	Montana State University	3	173	27	118	47	171	11
Mean			173		131		163	
P value			0.002		0.785		0.004	
LSD (0.05)			16		NS		24	
CV (%)			6.8		12.9		10.4	

Table 4. 2005 relative forage quality summary for the irrigated alfalfa variety trial, planted spring 2002 at the Klamath Experime Station, Klamath Falls, Oregon.

Variety	Seed source	Fall dormancy	Cut 1 June 10	Rank	Cut 2 July 18	Rank	Cut 3 Aug 25	Rank
			Relative forage quality					
Dura 512	Farm Valley	5	199	19	135	42	163	46
WL 319HQ	W-L Research	3	201	14	150	12	205	2
WL 327	W-L Research	4	194	26	144	33	170	41
WL 342	W-L Research	4	202	13	162	2	202	4
Magnum V	Dairyland Research International	4	190	34	140	37	177	29
Hybriforce-400	Dairyland Research International	5	208	5	150	11	187	11
DS9809 HYB	Dairyland Research International	3	197	22	151	9	176	31
C-316	Lohse Mill, Inc.	4	189	36	143	34	171	39
LM459	Lohse Mill, Inc.	5	202	10	146	21	153	50
AL-355	UAP	3	188	38	145	25	167	44
Goliath	Allied Seed, L. L. C.	3	199	17	145	27	185	17
Macon	Allied Seed, L. L. C.	4	196	23	147	17	185	16
Reliance	Allied Seed, L. L. C.	3	202	12	144	31	180	24
Mariner II	Allied Seed, L. L. C.	2	191	33	133	43	155	49
Rebel	Target Seed	4	201	15	144	32	181	23
4A135	Forage Genetics International	5	195	25	144	29	171	37
Select	Forage Genetics International	4	206	8	150	10	179	26
Reno	Croplan Genetics	5	194	28	132	44	171	38
Geneva	Croplan Genetics	4	184	44	138	39	169	42
DKA42-15	Monsanto	4	188	37	142	35	173	34
CW74013	D & D Seed (Cal West)	4	195	24	145	24	178	28
329	D & D Seed (Cal West)	2	190	35	145	22	187	12
Plumas	Eureka Seeds	4	212	2	145	23	176	30
Vitro	Eureka Seeds	4	206	7	157	5	172	36
9429	Eureka Seeds	3	207	6	149	14	186	13
54Q25	Pioneer Hi-Bred International	5	199	20	129	47	174	33
Blazer XL	Croplan Genetics	4	216	1	149	13	210	1
Accord	Highland Seed	3	191	32	157	6	170	40
Leafmaster	Highland Seed	3	192	31	152	8	172	35
Wrangler	Highland Seed	2	202	11	152	7	182	22
Setter	D & D Seed	4	210	4	159	3	194	7
Vernal	L. Hankins Seed and Sales	2	205	9	131	46	196	5
Lahontan	L. Hankins Seed and Sales	6	185	42	126	49	159	48
Ladak Plus	Landmark Seed Co.	2	182	46	144	30	186	14
Maxigraze GT	Croplan Genetics	2	197	21	144	28	179	25
Spredor GT	Croplan Genetics	3	187	39	146	20	191	8
Renovator	Croplan Genetics	2	177	50	146	19	179	27
DK127	Monsanto	4	199	18	158	4	196	6
Max 85	L. Hankins Seed and Sales	2	184	45	138	41	160	47
Ranger	Gooding Seed Co.	2	180	48	138	40	164	45
Ladak	L. Hankins Seed and Sales	2	194	29	145	26	182	21
Nomad	L. Hankins Seed and Sales	2	186	41	121	50	191	9
Rambler	L. Hankins Seed and Sales	2	185	43	149	15	184	20
Runner 211	Geertson Seeds	2	211	3	163	1	191	10
Runner 212	Geertson Seeds	2	182	47	141	36	185	18
Ladak 65	Gooding Seed Co.	2	187	40	146	18	184	19
Rampage	Gooding Seed Co.	3	200	16	131	45	174	32
Forager Plus	Ray Brothers Seed	1	180	49	139	38	167	43
Shaw	Montana State University	3	193	30	147	16	204	3
Cooper	Montana State University	3	194	27	128	48	186	15
Mean			195		144		180	
P value			0.005		0.839		0.006	
LSD (0.05)			19		NS		27	
CV (%)			7.1		14.3		10.7	

Table 5. 2003-2005 annual yield summaries for the irrigated alfalfa variety trial, planted spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

		2003		2004		2005		Total	
Variety	Fall dormancy	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank
WL 342	4	7.6	1	7.5	1	6.9	23	22.0	1
CW74013	4	7.4	5	7.3	6	7.1	8	21.8	2
DS9809 HYB	3	7.5	4	7.2	14	7.1	7	21.7	3
DKA42-15	4	7.5	3	7.2	15	6.9	20	21.5	4
54Q25	5	7.2	10	7.2	11	7.1	10	21.4	5
Reliance	3	7.4	7	7.4	3	6.7	29	21.4	6
Hybriforce-400	5	7.4	8	6.7	40	7.2	2	21.3	7
WL 319HQ	3	7.0	17	7.0	21	7.2	1	21.2	8
C-316	5	7.6	2	7.1	18	6.5	43	21.1	9
Geneva	4	7.1	13	7.3	8	6.7	27	21.1	10
329	2	6.8	29	7.0	20	7.2	4	21.1	11
Spredor GT	3	7.0	15	7.0	28	7.1	9	21.1	12
Forager Plus	1	6.7	39	7.2	13	7.2	5	21.0	13
Plumas	4	7.1	12	7.4	2	6.4	46	20.9	14
Dura 512	5	7.4	6	6.9	31	6.6	36	20.9	15
9429	3	7.0	19	7.0	29	7.0	14	20.9	16
Vitro	4	6.9	28	7.0	26	7.0	13	20.8	17
Macon	4	7.0	21	7.3	4	6.5	39	20.8	18
Accord	3	6.8	33	7.0	23	7.0	12	20.8	19
Setter	4	6.7	35	7.1	17	6.9	16	20.7	20
Renovator	2	7.3	9	6.4	49	6.9	15	20.7	21
Shaw	3	6.5	45	7.2	9	6.9	17	20.6	22
WL 327	4	6.8	30	7.0	22	6.7	26	20.6	23
4A135	5	7.0	18	7.1	19	6.5	38	20.6	24
Maxigraze GT	2	6.6	42	6.8	34	7.2	3	20.6	25
Goliath	3	6.8	31	6.9	32	6.9	22	20.6	26
Blazer XL	4	6.9	25	7.2	12	6.5	45	20.6	27
Rambler	2	7.0	16	6.6	43	6.9	18	20.5	28
Max 85	2	7.0	20	6.9	33	6.6	33	20.4	29
Select	4	6.7	38	7.3	5	6.5	44	20.4	30
Rampage	3	6.9	24	6.5	46	7.0	11	20.4	31
Ladak	2	6.4	46	7.2	16	6.8	25	20.4	32
Magnum V	4	6.7	37	6.8	36	6.9	21	20.4	33
Reno	5	6.9	27	7.0	24	6.5	42	20.4	34
Leafmaster	3	6.5	44	7.2	10	6.6	34	20.4	35
Runner 211	2	6.6	40	6.8	35	6.9	24	20.3	36
Lahontan	6	7.1	11	6.7	41	6.5	41	20.3	37
Cooper	3	6.6	41	7.0	25	6.7	30	20.3	38
AL-355	3	6.8	32	7.0	27	6.5	40	20.3	39
DK127	4	7.1	14	6.5	44	6.6	31	20.3	40
Vernal	2	6.7	34	6.8	38	6.7	28	20.2	41
Rebel	4	6.9	23	6.6	42	6.6	37	20.1	42
LM459	2	6.9	26	6.9	30	6.3	48	20.1	43
Mariner II	2	6.9	22	6.7	39	6.3	49	19.9	44
Runner 212	2	6.3	47	7.3	7	6.3	47	19.9	45
Ranger	2	6.7	36	6.4	47	6.6	35	19.7	46
Ladak 65	2	6.1	49	6.4	48	7.2	6	19.7	47
Ladak Plus	2	6.3	48	6.8	37	6.6	32	19.7	48
Wrangler	2	6.6	43	6.5	45	6.2	50	19.3	49
Nomad	2	5.9	50	6.3	50	6.9	19	19.1	50
Mean		6.9		6.9		6.8		20.6	
P value		0.002		0.462		0.073		0.010	
LSD (0.05)		0.8		NS		NS		1.3	
CV (%)		7.9		8.3		6.9		4.5	

Orchardgrass Variety Trial

Richard J. Roseberg and Jim E. Smith[1]

Introduction

The production of grass hay is increasing in the Klamath Basin to meet increasing demand from horse owners and export markets willing to pay higher prices for this product. This hay primarily consists of cool-season grasses, sometimes mixed with a legume such as clover or alfalfa. Most of this hay is baled in two- or three-string bales (less than 100 lb each) that are easier to handle than the 0.5-ton or 1.0-ton round or square bales commonly used in alfalfa hay production. Orchardgrass is the predominant grass species grown for hay. However, fields of quackgrass, endophyte-free tall fescue, annual and perennial ryegrass, or timothy are also common because each of these cool-season grasses is well adapted to Klamath Basin climatic conditions.

Timothy and orchardgrass are the most desired grass species for the horse industry due to higher palatability and perceived value. Timothy has the least acreage and lowest yields in the Klamath Basin, but sometimes commands the highest price, even though orchardgrass generally produces higher quality forage.

To learn more about these forages and to identify varieties of orchardgrass that are well-suited to the Klamath Basin, a trial was established by Dr. Don Clark, the previous agronomist at the Klamath Experiment Station (KES), in the spring of 2002 to evaluate 16 orchardgrass varieties in pure stands. The trial was set up to allow measurement of yield and quality for several cutting dates to determine which varieties might perform better during various times in the growing season. The 2005 crop year marked the end of the data collection period for this study, although the planting will not be removed until the space is needed for another study.

Procedures

The orchardgrass variety trial was established in June 2002 at the KES on a Fordney loamy fine sand soil. The field was ripped to a depth of 12-18 inches, followed by moldboard plowing, disking, and harrowing. A Brillion packer (Brillion Farm Equipment) was pulled behind the harrow on the last pass to form a smooth, firm seedbed.

All plots were 4.5 ft wide and 20 ft long. In the orchardgrass variety trial, seed was planted at 0.25- to 0.5-inch depth, at a seeding rate of 12 lb/acre. All plots were seeded with a Kincaid (Kincaid Equipment Manufacturing) experimental plot drill, which planted 9 rows at a 6-inch spacing per row. This trial was arranged in a randomized complete block design with four replications.

As part of field preparation, the trial area received preplant incorporated additions of elemental (popcorn) sulfur (S) at 300 lb/acre S, and 10-34-0 liquid at 400 lb/acre to supply phosphorus at 136 lb/acre P_2O_5 and nitrogen (N) at 40 lb/acre N. At planting, the area also

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received 310 lb/acre of 16-20-0-13, (supplying 50 lb/acre N, 62.5 lb/acre P_2O_5, and 41 lb/acre S). In 2002 and 2003, additional N and S applications were made following each harvest.

In 2004 the orchardgrass variety trial area received 80 lb/acre N as ammonium sulfate at 390 degree days (March 22, about when the grass started to actively grow). The same fertilizer rate and material was also applied after the first and second cutting dates. The trial area did not receive any herbicide prior to or during the 2004 season.

In 2005, the trial area received 84 lb/acre N as ammonium sulfate on April 25, soon after the grass started to actively grow. After first cutting, the trial area received 71 lb/acre N as ammonium sulfate on June 2. After second cutting, the trial area received 75 lb/acre N as ammonium sulfate on July 20. The trial area did not receive any herbicide prior to or during the 2005 season.

Irrigation water deliveries to KES were not interrupted for any significant time periods in 2005. All forage trials were irrigated with solid-set sprinklers to meet crop needs based upon crop evapotranspiration (Et), and were monitored with Watermark (Irrometer Co, Inc.) moisture sensors at 6-, 12-, and 24-inch soil depth. Water was applied when tensiometer readings were at 50 kPa for the 12-inch depth sensor. This generally coincided with Et requirements for irrigation. Irrigation rate for all forage trials was based upon alfalfa needs since most of the field was devoted to alfalfa test plots, and there was no practical way to irrigate the alfalfa trials separate from the orchardgrass or orchardgrass/alfalfa plantings. The trial area received one irrigation in April (0.64 inch), none in May, five irrigations between first and second cutting (4.45 inch total), five irrigations between second and third cutting (6.15 inch total), and five irrigations between third cutting and the end of September (4.24 inch total), for a seasonal total of 15.48 inches of irrigation water applied in 2005.

In addition to irrigation, a total of 4.51 inches of precipitation fell during the April-September growing season. This amount was greater than typical, and was due to an unusually wet spring, where 1.80 inches of precipitation fell during April, and another 2.24 inches fell from May 1 to May 18. Thus only one small irrigation application (in April) was needed before the first cutting on May 27. Only 0.47 inches of precipitation fell the remainder of the season (May 19- September 30). No rain fell in August, and only 0.02 inches fell in July, resulting in excellent harvest and hay curing weather, especially for the second and third cuttings. After the unusually wet spring, the 2005 growing season was somewhat warmer than 2004 (especially in mid-summer), and ended up being fairly typical for the Klamath Basin, providing good growing conditions for most of the summer, as well as excellent harvest conditions (see the Weather and Crop Summary section of this annual report for further weather details).

The orchardgrass variety trial was harvested three times, on May 27, July 20, and August 26. Prior to each harvest, 5.5-ft strips were cut between plot rows for separation. Forages were harvested with a Carter (Carter Manufacturing Co., Inc.) power take-off powered flail harvester with a 3-ft-wide cutting width. Residue in border areas was removed with a Mathews (Mathews Co.) flail chopper after plot harvests.

After the cut material from each plot was weighed, random samples were collected from the chopped plot material, weighed, and then oven dried to determine dry matter content and calculate dry matter yield. Dried samples were ground to pass a 2-mm sieve in a Wiley Mill (Arthur H. Thomas Co.) and then to pass a 1-mm-sieve size in a Udy Mill (Udy Corp.). The ground samples were then analyzed in a near infrared spectrophotometer (NIRS, NIRSystems) to determine forage quality expressed as crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), and relative forage quality (RFQ), with equations developed by FOSS North America, Minneapolis, Minnesota; the NIRS Consortium, Madison, Wisconsin; or by KES.

Statistics on yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level.

To assist interpretation of forage quality data, the USDA grass hay quality guidelines are included in this report (Table 1). KES grass hay quality ratings are reported on 100 percent dry matter and are based upon USDA guidelines. Ratings for total digestible nutrients (TDN), ADF, NDF, RFV, and RFQ are not included in USDA grass hay quality grading guidelines at this time, but are included in this report as another means that growers and companies might find useful to help assess differences in forage quality between trial entries.

Results and Discussion

There were significant differences in yield among the 16 orchardgrass varieties for all three cuttings, as well as the annual yield totals (Table 2). First-cutting yields ranged from 2.3 to 3.1 ton/acre, with a mean of 2.7 ton/acre. Second-cutting yields ranged from 0.9 to 1.3 ton/acre, with a mean of 1.1 ton/acre. Third-cutting yields ranged from 1.6 to 2.0 ton/acre, with a mean of 1.8 ton/acre. Total yields ranged from 5.3 to 6.1 ton/acre, with a mean of 5.6 ton/acre. The lowest-yielding varieties had a similar total yield in 2004 and 2005, but the yields of the highest yielding varieties were clearly lower in 2005. This difference was mainly due to the lower second cutting yields in 2005. Growing conditions were nearly ideal for cool-season grasses in 2004, especially in mid-summer, whereas the hotter mid-summer weather typically seen (as was experienced in 2005) tends to reduce biomass production at that time.

As in 2004, the lowest yielding entries tended to be late-maturing types, and except for Amba, these late-maturing types occupied the lowest 9 ranks in total yield. As in 2004, the early and medium types tended to have higher yields, and occupied the top six ranks in 2005. There were not as many dramatic changes in rank from 2004 to 2005 as there had been the previous year, but there were a few interesting trends. Stampede continued its relative improvement, moving up 4 ranks in 2005 after improving by 5 ranks in 2004. Satin also continued to improve. After producing the lowest yield in the entire trial in 2003, it improved by 6 ranks in 2004 and another 3 in 2005, becoming the highest yielding of the late-maturing group of varieties in 2005. In contrast, Amba continued its slide, dropping by 7 ranks in 2005 in addition to the drop of 3 it exhibited in 2004. Pennlate also continued to fall relative to the others, dropping 7 ranks in 2005 after dropping 2 in 2004. Two varieties (Mammoth and Potomac) have consistently yielded well all 3 years, whereas Sparta continues to remain near the bottom of the list for the third year in a row.

Significant variety differences were observed in CP for the second cutting only (Table 3). For every variety, CP values increased as the season progressed to the second and third cuttings. Due to maturity and other variety differences, it is unusual for a particular variety to have a higher CP than the others for all three cuttings. The relative ranking values indicate Sparta, Amba, and Quantum were the only varieties to rank among the top half in CP value for all three cuttings, but as was shown previously, those were also the three lowest yielding varieties in the entire trial in 2005. At the other extreme, Pizza was the only variety with below-average CP for all three cuttings. All entries were below premium grade (less than 13 percent CP) for the first cutting, but were above 13 percent for the second cutting, and well above 13 percent CP by the third cutting. The main difference between 2004 and 2005 occurred at the second cutting, where the 2004 mean was 17.6 percent, compared to the 2005 mean of 13.8 percent.

There was a significant difference between variety means for ADF, NDF, and RFV on the second cutting date only (Tables 4-6). As in the case of yield and CP, this response indicates some differential response of varieties to their growing conditions between May 27 and July 20.

Unlike the RFV results, RFQ results did show a significant difference between varieties for all three cutting dates (Table 7). Although RFV and RFQ calculations are both designed to differentiate between hay of different quality grades, they do not use the same factors in the calculation. RFV is derived from ADF and NDF, whereas RFQ is a more complicated calculation derived from nonfibrous carbohydrate, CP, fatty acids, nitrogen-free NDF, 48-hour *in vitro* digestibility, and NDF (Undersander and Moore 2002). Because RFQ uses additional factors representing animal assimilation (e.g., digestible fiber and nonfibrous carbohydrate), it is thought by some to be a more accurate predictor of actual animal performance on a particular forage. This improved ability to predict animal performance is thought to be especially true for grass forages. Thus, in most cases RFV and RFQ will provide similar predictions of forage quality, but when they do not, it is helpful to remember how the two values are calculated and therefore how they might best be used by hay growers and buyers, depending on the planned end-use of the forage.

As was true for CP, most varieties had relatively high ADF, NDF, RFV, and RFQ values for one or two cuttings, but not all three. Exceptions to that pattern included Comet and Mammoth (consistently high ADF and NDF, but low RFV), Orion (consistently low ADF), Satin and Amba (consistently low NDF, but high RFV), Athos (consistently high RFQ), and Comet (consistently low RFQ).

The consistently high ADF and NDF and low RFV for Mammoth is not too surprising given its consistently high yield for all cutting dates, indicating a maximizing of biomass production and advanced maturity for this early-maturing variety by the time of each harvest.

A comparison of the annual yield of each entry for all years of the study, as well as the cumulative total yield, is shown in Table 8. The relative persistence and production of each entry over time can be observed and compared. A few varieties produced very good yields relative to the other entries every year of the study, including Mammoth, Hallmark, and Potomac, and thus they were among the highest in total cumulative yield for the trial. In contrast, Pizza and Sparta produced low yields every year of the study, and thus their total cumulative yields were the lowest in the trial. Some entries dramatically increased or decreased their relative performance during the course of the trial. Icon had a relatively low yield the first year, but improved dramatically to the first or second position for the last two years, resulting in a second place cumulative yield. On the other hand, Quantum had the highest yield the first year, but then dropped to near the bottom the last 2 years.

References

Undersander, D., and J.E. Moore. 2002. Relative forage quality. Focus on Forage, Vol. 4, No. 5. Univ. of Wisconsin Extension, Madison. 2 pp.

Table 1. USDA quality guidelines for grass hay[1].

Quality Grade[2]	Crude Protein %
Premium	>13
Good	9-13
Fair	5-9
Low	<5

[1]For the latest hay market report contact: USDA Livestock and Grain Market News, 1498 S. Pioneer Way, Moses Lake, WA 98837; Phone: 509/765-3611; Fax: 509/765-0454.

[2]Hay quality designation--physical description.

Supreme	Very early maturity, prebloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
Premium	Early maturity, preheading, extra leafy and fine stemmed. Factors indicative of high nutritive content. Hay is green and free of damage.
Good	Early to average maturity, early head, leafy, fine to medium stemmed, free of damage other than slight discoloration.
Fair	Late maturity, head, moderate or below leaf content, generally coarse stemmed. Hay may show light damage.
Utility	Hay in very late maturity, mature head, coarse stemmed. Includes hay with excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

Table 2. 2005 yield results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1 May 27	Cut 2 July 20	Cut 3 Aug 26	Total yield	2005 rank	Rank change from 2004
		ton/acre					
Mammoth	early	3.1	1.1	1.8	6.1	1	2+
Icon	medium	2.9	1.1	2.0	6.1	2	1-
Stampede	early/med	3.0	1.2	1.9	6.0	3	4+
Hallmark	early	2.9	1.1	1.8	5.8	4	2-
Comet	medium	2.9	1.1	1.8	5.8	5	1+
Potomac	early	2.8	1.1	1.8	5.7	6	2-
Satin	late	2.7	1.0	2.0	5.6	7	3+
Baridana	late	2.7	1.0	1.9	5.6	8	3+
Latar	late	2.7	1.1	1.7	5.5	9	6+
Pizza	late	2.5	1.3	1.7	5.5	10	3+
Orion	late	2.7	0.9	1.8	5.5	11	3-
Pennlate	late	2.7	1.0	1.8	5.5	12	7-
Athos	late	2.3	1.3	1.8	5.4	13	1-
Quantum	late	2.5	1.2	1.8	5.4	14	=
Sparta	late	2.6	0.9	1.8	5.3	15	1+
Amba	early	2.7	1.0	1.6	5.3	16	7-
Mean		2.7	1.1	1.8	5.6		
P value		0.004	0.002	0.017	0.008		
LSD (0.05)		0.3	0.2	0.2	0.5		
CV (%)		8.7	12.0	7.2	5.7		

Table 3. 2005 crude protein results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Crude protein %					
Comet	medium	11.8	16	13.6	12	17.6	5
Hallmark	early	12.0	13	14.2	3	17.3	12
Orion	late	12.0	9	14.0	6	17.6	6
Potomac	early	12.2	3	12.7	16	17.3	14
Icon	medium	12.3	1	13.6	11	17.2	15
Pizza	late	12.0	10	13.1	15	17.5	10
Latar	late	12.0	11	13.6	10	17.5	7
Pennlate	late	12.0	14	13.6	9	17.9	2
Satin	late	11.8	15	13.7	8	18.1	1
Sparta	late	12.2	5	14.9	1	17.5	8
Athos	late	12.2	2	13.5	13	16.9	16
Amba	early	12.2	6	14.4	2	17.7	4
Mammoth	early	12.0	12	14.2	4	17.4	11
Quantum	late	12.1	8	14.1	5	17.7	3
Stampede	early/med	12.1	7	13.4	14	17.3	13
Baridana	late	12.2	4	13.9	7	17.5	9
Mean		12.0		13.8		17.5	
P value		0.192		0.004		0.907	
LSD (0.05)		NS		0.9		NS	
CV (%)		6.0		4.4		4.4	

Table 4. 2005 acid detergent fiber results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Acid detergent fiber %					
Comet	medium	36.0	1	38.0	2	37.0	4
Hallmark	early	35.4	7	37.7	5	36.1	14
Orion	late	35.3	10	36.6	14	36.0	15
Potomac	early	35.1	12	37.3	10	36.8	5
Icon	medium	35.5	6	36.5	15	35.6	16
Pizza	late	35.5	5	37.5	8	36.8	6
Latar	late	35.6	3	37.2	12	36.4	10
Pennlate	late	35.6	4	36.8	13	36.5	9
Satin	late	34.9	14	37.2	11	36.8	7
Sparta	late	35.4	8	35.7	16	36.6	8
Athos	late	35.3	11	37.7	6	37.0	3
Amba	early	35.4	9	37.4	9	36.4	12
Mammoth	early	35.9	2	38.2	1	37.1	1
Quantum	late	35.0	13	37.9	4	37.0	2
Stampede	early/med	34.5	15	37.6	7	36.2	13
Baridana	late	34.2	16	38.0	3	36.4	11
Mean		35.2		37.3		36.5	
P value		0.088		0.008		0.295	
LSD (0.05)		NS		1.2		NS	
CV (%)		2.8		2.2		2.1	

Table 5. 2005 neutral detergent fiber results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Neutral detergent fiber %					
Comet	medium	61.2	1	60.7	3	59.3	2
Hallmark	early	60.4	2	60.6	4	58.1	8
Orion	late	60.3	3	58.5	13	57.8	13
Potomac	early	59.0	11	59.5	7	58.3	5
Icon	medium	59.2	9	58.3	15	58.1	10
Pizza	late	59.2	8	59.2	9	57.6	15
Latar	late	59.1	10	59.4	8	58.1	7
Pennlate	late	59.8	4	58.6	12	58.1	9
Satin	late	59.0	12	58.4	14	57.7	14
Sparta	late	59.4	5	57.7	16	58.3	6
Athos	late	59.3	7	60.1	5	58.7	3
Amba	early	58.7	13	59.0	11	57.6	16
Mammoth	early	59.3	6	61.2	2	59.6	1
Quantum	late	57.9	14	61.3	1	57.9	12
Stampede	early/med	56.4	16	59.2	10	58.5	4
Baridana	late	56.7	15	60.1	6	58.0	11
Mean		59.0		59.5		58.2	
P value		0.112		<0.001		0.181	
LSD (0.05)		NS		1.6		NS	
CV (%)		3.3		1.9		1.6	

Table 6. 2005 relative feed value results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
			Relative feed value				
Comet	medium	93	16	91	14	94	15
Hallmark	early	94	15	91	13	97	5
Orion	late	95	14	96	3	98	1
Potomac	early	97	6	94	10	96	13
Icon	medium	96	7	97	2	98	2
Pizza	late	96	10	94	8	97	6
Latar	late	96	9	94	7	97	9
Pennlate	late	95	13	96	4	97	8
Satin	late	97	4	95	5	97	4
Sparta	late	96	11	98	1	96	12
Athos	late	96	8	92	11	95	14
Amba	early	97	5	94	6	98	3
Mammoth	early	96	12	90	16	94	16
Quantum	late	99	3	90	15	96	11
Stampede	early/med	103	1	94	9	97	10
Baridana	late	102	2	92	12	97	7
Mean		97		94		97	
P value		0.094		0.001		0.475	
LSD (0.05)		NS		4		NS	
CV (%)		4.5		2.8		2.6	

Table 7. 2005 relative forage quality results for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Variety	Maturity rating	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Relative forage quality					
Comet	medium	120	16	117	14	93	15
Hallmark	early	124	12	123	11	106	1
Orion	late	125	10	126	5	100	7
Potomac	early	126	6	126	6	98	11
Icon	medium	124	14	130	2	104	2
Pizza	late	124	11	122	12	99	9
Latar	late	124	13	128	4	99	8
Pennlate	late	125	9	130	3	99	10
Satin	late	130	2	123	10	88	16
Sparta	late	129	4	131	1	95	14
Athos	late	130	3	125	7	102	4
Amba	early	126	7	124	9	101	6
Mammoth	early	123	15	117	15	101	5
Quantum	late	126	8	121	13	97	12
Stampede	early/med	129	5	125	8	103	3
Baridana	late	132	1	115	16	96	13
Mean		127		124		99	
P value		0.020		0.005		0.032	
LSD (0.05)		9		8		9	
CV (%)		5.0		4.6		6.1	

Table 8. 2003, 2004, 2005, and cumulative yield totals for the orchardgrass variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

		2003		2004		2005		Total	
Variety	Maturity rating	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank
Mammoth	early	4.3	2	6.5	3	6.1	1	16.9	1
Icon	medium	3.9	10	6.6	1	6.1	2	16.6	2
Hallmark	early	4.1	5	6.5	2	5.8	4	16.5	3
Potomac	early	4.2	3	6.5	4	5.7	6	16.4	4
Comet	medium	3.9	11	6.5	6	5.8	5	16.2	5
Pennlate	late	4.1	4	6.5	5	5.5	12	16.1	6
Stampede	early/med	3.8	12	6.2	7	6.0	3	16.0	7
Quantum	late	4.4	1	6.0	14	5.4	14	15.8	8
Baridana	late	4.0	8	6.1	11	5.6	8	15.7	9
Amba	early	4.0	7	6.2	9	5.3	16	15.5	10
Latar	late	4.1	6	5.9	15	5.5	9	15.5	11
Orion	late	3.7	13	6.2	8	5.5	11	15.4	12
Athos	late	4.0	9	6.0	12	5.4	13	15.4	13
Satin	late	3.6	16	6.1	10	5.6	7	15.3	14
Pizza	late	3.7	14	6.0	13	5.5	10	15.2	15
Sparta	late	3.7	15	5.5	16	5.3	15	14.5	16
Mean		4.0		6.2		5.6		15.8	
P value		0.775		0.003		0.008		0.003	
LSD (0.05)		NS		0.5		0.5		1.0	
CV (%)		13.9		5.6		5.7		4.5	

Mixed Grass/Alfalfa Variety Trial

Richard J. Roseberg and Jim E. Smith[1]

Introduction

The production of mixed grass and alfalfa hay is increasing in the Klamath Basin to meet increasing demand from horse owners and export markets willing to pay higher prices for products like this. This hay consists of cool-season grass and alfalfa mixtures (grass/alfalfa). Most of this hay is baled in two- or three-string bales (less than 100 lb each) that are easier to handle than the 0.5-ton or 1.0-ton round or square bales commonly used in alfalfa hay production. The predominant grass species in grass/alfalfa mixtures is orchardgrass. However, grass/alfalfa mixtures containing quackgrass, endophyte-free tall fescue, annual and perennial ryegrass, or timothy are also grown because each of these cool-season grasses is well adapted to Klamath Basin climatic conditions.

Orchardgrass-alfalfa mixtures are important for the horse industry due to their higher palatability and nutritional value compared to pure grass hay. Maturity differences between particular orchardgrass and alfalfa varieties can greatly affect the resulting hay quality when grass is grown in mixtures with alfalfa. Thus, the selection of an orchardgrass variety that would be in the early heading stage when the alfalfa is in early bloom would presumably allow maximum yields with high quality from both species without compromising stand persistence.

To learn more about how these grass/alfalfa variety mixes performed in the Klamath Basin, trials were established by Dr. Don Clark, the previous agronomist at the Klamath Experiment Station (KES), in the spring of 2002. This study evaluated 16 orchardgrass varieties grown in mixed stands with 2 alfalfa varieties. The objective of this trial was to determine whether any of the orchardgrass varieties were more closely matched in maturity with either of two selected alfalfa varieties, with the goal of identifying superior alfalfa/orchardgrass combinations.

Procedures

The mixed orchardgrass-alfalfa variety trial was established in June 2002 at KES on a Fordney loamy fine sand soil. The 2 alfalfa varieties included a typical fall dormancy (FD) 4 alfalfa variety (329), and a more drought resistant, spreader type, FD2 alfalfa variety (Renovator).

The field was ripped to a depth of 12-18 inches, followed by moldboard plowing, disking, and harrowing. A Brillion packer (Brillion Farm Equipment) was pulled behind the harrow on the last pass to form a smooth, firm seedbed. All plots were 4.5 ft wide and 20 ft long. Seed was planted at 0.25- to 0.5-inch depth, at a seeding rate of 5 lb/acre orchardgrass seed plus 15 lb/acre alfalfa seed in the grass/alfalfa trial. All plots were seeded with a Kincaid (Kincaid Equipment

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Manufacturing) experimental plot drill, which planted 9 rows at a 6-inch spacing per row. The grass/alfalfa trial was arranged as a complete factorial design with four replications of each orchardgrass-alfalfa variety combination.

As part of field preparation, the trial area received preplant incorporated additions of elemental (popcorn) sulfur (S) at 300 lb/acre S, and 10-34-0 liquid at 400 lb/acre to supply phosphorus at 136 lb/acre P_2O_5 and nitrogen (N) at 40 lb/acre N. At planting, the area also received 310 lb/acre of 16-20-0-13, (supplying 50 lb/acre N, 62.5 lb/acre P_2O_5, and 41 lb/acre S). No additional fertilizers were applied to the grass/alfalfa trial area during 2002-2005. The trial area did not receive any herbicide during 2002-2005.

Irrigation water deliveries to KES were not interrupted for any significant time periods in 2005. All forage trials were irrigated with solid-set sprinklers to meet crop needs based upon crop evapotranspiration (ET), and were monitored with Watermark (Irrometer Co, Inc.) moisture sensors at 6-, 12-, and 24-inch soil depth. Water was applied when tensiometer readings were at 50 kPa for the 12-inch depth sensor. This generally coincided with ET requirements for irrigation. Irrigation rate for all forage trials was based upon alfalfa needs since most of the field was devoted to alfalfa test plots, and there was no practical way to irrigate the alfalfa trials separate from the orchardgrass or grass/alfalfa plantings. The trial area received one irrigation in April (0.64 inch), none in May, five irrigations between first and second cutting (4.45 inch total), five irrigations between second and third cutting (6.15 inch total), and five irrigations between third cutting and the end of September (4.24 inch total), for a seasonal total of 15.48 inches of irrigation water applied in 2005.

In addition to irrigation, a total of 4.51 inches of precipitation fell during the April-September growing season. This amount was greater than typical, due to an unusually wet spring, where 1.80 inches of precipitation fell during April, and another 2.24 inches fell from May 1 to May 18. Thus only one small irrigation (in April) was needed before the first cutting on June 2. Only 0.47 inches of precipitation fell the remainder of the season (May 19- September 30). No rain fell in August, and only 0.02 inches fell in July. After the unusually wet spring, the 2005 growing season was warmer than 2004 (especially in mid-summer), and was fairly typical for the Klamath Basin, providing good growing and excellent harvest conditions for most of the summer (see the Weather and Crop Summary section of this annual report for further weather details).

The grass/alfalfa variety trial was harvested three times, on June 2, July 19, and August 26. Prior to each harvest, 5.5-ft strips were cut between plot rows for separation. Forages were harvested with a Carter (Carter Manufacturing Co., Inc.) power take-off powered flail harvester with a 3-ft-wide cutting width. Residue in border areas was removed with a Mathews (Mathews Co.) flail chopper after plot harvests. After the cut material from each plot was weighed, random samples were collected from the chopped plot material, weighed, and then oven dried to determine dry matter content and calculate dry matter yield. Dried samples were ground to pass a 2-mm sieve in a Wiley Mill (Arthur H. Thomas Co.) and then to pass a 1-mm-sieve size in a Udy Mill (Udy Corp.).

The ground samples were then analyzed in a near infrared spectrophotometer (NIRS, NIRSystems) to determine forage quality expressed as crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV), and relative forage quality (RFQ), with equations developed by FOSS North America, Minneapolis, Minnesota; the NIRS Consortium, Madison, Wisconsin; or by KES. Statistics on yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level.

To assist interpretation of forage quality data, the USDA grass hay quality guidelines are included in this report (Table 1). KES grass hay quality ratings are reported on 100 percent dry matter and are based upon USDA guidelines. Ratings for total digestible nutrients (TDN), ADF, NDF, etc., are not included in USDA grass hay quality grading guidelines at this time. Grass/alfalfa quality guidelines follow either grass or alfalfa ratings. Alfalfa USDA grading guidelines use additional parameters for quality judgments, including ADF, NDF, CP, TDN at both 90 and 100 percent dry matter (DM), and RFV (Table 2). Relative forage quality is a newer parameter used in some regions to rate forage quality, but is not yet included in the official USDA guidelines (Undersander and Moore 2002). RFQ values were calculated for these trials as another quality comparison that some growers and companies may find useful.

Results and Discussion

In 2005, overall yields ranged from 5.3 to 7.3 ton/acre, with a mean of 6.6 ton/acre (Table 3). These yields were lower than those in 2004, but were similar to yields observed in 2003, confirming the presence of excellent growing conditions in 2004 as was suggested in the previous annual report. Significant yield differences between alfalfa varieties were not observed any cutting, although the *P* value was not much greater than 0.05 for the second cutting. No significant differences between orchardgrass varieties were observed for any cutting or for the total annual yield, although the *P* value was not much greater than 0.05 for the first and second cuttings, as well as for the annual total yield values. There was no significant interaction between alfalfa and orchardgrass variety for any cutting, indicating that orchardgrass varieties did not perform differently when mixed with one alfalfa variety compared to the other.

Change in total yield rank compared to 2004 illustrated the relative change in performance in 2005 (third full production year) compared to 2004 (second full production year) (Table 3). Unlike 2004, there were very few large changes in rank in 2005. The largest change was for Icon + 329, which had improved by 13 ranks between 2003 and 2004, but fell by 24 ranks between 2004 and 2005.

Quality measurements (CP, ADF, NDF, RFV, and RFQ) are presented in Tables 4-8. There were significant differences between alfalfa varieties for second-cutting CP and NDF, third-cutting ADF and RFQ, and both second- and third-cutting RFV. In the case of RFV, it is interesting to note that the entries with 329 alfalfa had better quality for the second cutting, but the entries with Renovator alfalfa had better quality for the third cutting, pointing out the difficulty in finding one variety or mixture that is best for all times during the growing season.

There were no significant differences between orchardgrass varieties on any cutting date for CP, NDF, RFV, or RFQ, although the *P* value for RFV and RFQ was just slightly greater than 0.05 for the first cutting. There was a significant difference between orchardgrass varieties for ADF on the first cutting date only. There was no significant interaction between alfalfa and orchardgrass varieties for any of the quality parameters at any cutting date, indicating that orchardgrass varieties did not exhibit different quality characteristics when mixed with one alfalfa variety compared to the other. This lack of interaction was also observed in 2004.

Using alfalfa standards, most entries were rated “Low” based on RFV, although some made it into the “Fair” grade. The same pattern of quality also held true using ADF and NDF values and the alfalfa standards. These results were similar to those observed in 2004. Considering that this trial involved mixtures of lower quality grass with higher quality alfalfa, the pattern of relatively low quality evaluated using standards developed for pure alfalfa is not too surprising. On the basis of CP standards for alfalfa, entries ranged from “Fair” to “Premium”, but when using the rating scale developed for grasses, all entries were rated as “Premium” on all cutting dates.

As was seen in 2004, most entries exhibited high quality relative to the other entries at one or two cuttings, but not for all three cuttings. There were a few exceptions to this pattern, however. Quantum + 329 was the only entry that had consistently high CP on all three cutting dates (Table 4). That entry also had consistently high CP on all cutting dates in 2004, indicating this combination will consistently produce hay with high CP over more than one season. Hallmark + Renovator and Mammoth + Renovator had consistently low CP on all three cutting dates. Hallmark + Renovator also had consistently low CP in 2004, indicating it is a consistently poor combination in terms of CP.

Stampede + 329, Comet + Renovator, Sparta + Renovator, and Amba + Renovator had consistently low ADF in 2005, a pattern none exhibited in 2004. Quantum + 329, Icon + Renovator, and Amba + Renovator had consistently low NDF in 2005, a pattern only Quantum + 329 had exhibited in 2004. Latar + 329 and Hallmark + Renovator had consistently high ADF and NDF on all three cutting dates (Tables 5 and 6). For Hallmark + Renovator this repeats the pattern observed in 2004.

Amba + Renovator was the only entry to consistently exhibit high RFV values compared to other entries in all three cuttings, which it did not do in 2004 (Table 7). Quantum + 329 consistently had a very high RFV for all three cuttings in 2004, and it exhibited the same general pattern in 2005, although its relative performance was not as strong as the year before. Low RFV values were consistently observed at all cuttings for Latar + 329, Hallmark + Renovator, and Mammoth + Renovator. This repeats the pattern seen in 2004 for Latar + 329 and Hallmark + Renovator.

In 2004, no entry had a consistently high RFQ value, but in 2005, Stampede + 329, Sparta + Renovator, and Amba + Renovator exhibited consistently high RFQ (Table 8). In 2005, Potomac + 329, Latar + 329, Baridana + 329, and Hallmark + Renovator had consistently low RFQ values. Only Hallmark + Renovator exhibited a similar result in 2004.

As noted, RFV and RFQ do not always give the same relative results since they are two distinct calculations using different formulas. An examination of the RFV and RFQ rankings for this study demonstrates how certain entries can have a relatively high RFV score, but not RFQ, and vice versa. It is important for growers and purchasers of hay to understand the parameters that are important for their particular uses, and to base their growing, purchasing, and feeding decisions on those characteristics.

The alfalfa portion of mixed grass/alfalfa stands usually contributes greatly towards yield and quality in a stand's early years, but we typically expect the orchardgrass portion to contribute progressively more towards the total production over time, especially if N fertilizer is applied. However, we noted last year that the overall mean yields in 2004 were 6.2 tons/acre in the orchardgrass variety trial (where N fertilizer was applied) compared to 7.2 tons/acre in the mixed grass/alfalfa study (where no fertilizer was applied in 2004). A similar pattern was observed in 2005, where the orchardgrass variety trial (where N fertilizer was applied) had a mean yield of 5.6 tons/acre compared to the mixed grass/alfalfa trial (no fertilizer applied) with a mean yield of 6.6 tons/acre. In 2005 both trials were cut three times. These results suggest that the financial gain of producing mixed grass/alfalfa stands compared to pure grass hay stands could be significant due to differences in yield, forage quality, and fertilizer costs.

A comparison of the annual yield of each entry for all years of the study thus far is shown in Table 9. This table illustrates how some combinations produced high yields early in the stand life, whereas others started off lower but increased their relative production through time.

Based on 3 years' results for the grass and alfalfa varieties included in this study, it appears that no one single orchardgrass/alfalfa combination resulted in consistently superior yield and quality. Thus, growers should choose variety mixes based on their goals of high yield or high quality, and further determine if they want their best yield and/or quality performance from earlier or later in the growing season. The projected stand life should also be considered when deciding which combination of alfalfa and orchardgrass to plant.

References

Undersander, D., and J.E. Moore. 2002. Relative forage quality. Focus on Forage, Vol. 4, No. 5. Univ. of Wisconsin Extension, Madison. 2 pp.

Table 1. USDA quality guidelines for grass hay[1].

Quality Grade[2]	Crude Protein %
Premium	>13
Good	9-13
Fair	5-9
Low	<5

[1]For the latest hay market report contact: USDA Livestock and Grain Market News, 1498 S. Pioneer Way, Moses Lake, WA 98837; Phone: 509/765-3611; Fax: 509/765-0454.

[2]Hay quality designation--physical description.

Supreme	Very early maturity, prebloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
Premium	Early maturity, preheading, extra leafy and fine stemmed. Factors indicative of high nutritive content. Hay is green and free of damage.
Good	Early to average maturity, early head, leafy, fine to medium stemmed, free of damage other than slight discoloration.
Fair	Late maturity, head, moderate or below leaf content, generally coarse stemmed. Hay may show light damage.
Utility	Hay in very late maturity, mature head, coarse stemmed. Includes hay with excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

Table 2. USDA quality guidelines for alfalfa hay[1].

Quality grade[2]	RFV[3]	ADF %	NDF %	TDN-100%[4]	TDN-90%	Crude protein %
Supreme	>185	<27	<34	>62	>55.9	>22
Premium	170-185	27-29	34-36	60.5-62	54.5-55.9	20-22
Good	150-170	29-32	36-40	58-60	52.5-54.5	18-20
Fair	130-150	32-35	40-44	56-58	50.5-52.5	16-18
Low	<130	>35	>44	<56	<50.5	<16

[1]For the latest hay market report contact: USDA Livestock and Grain Market News, 1498 S. Pioneer Way, Moses Lake, WA 98837; Phone: 509/765-3611; Fax: 509/765-0454.

[2]Hay quality designation--physical description.

Supreme	Very early maturity, prebloom, soft fine stemmed, extra leafy. Factors indicative of very high nutritive content. Hay is excellent color and free of damage.
Premium	Early maturity, prebloom, extra leafy and fine stemmed. Factors indicative of high nutritive content. Hay is green and free of damage.
Good	Early to average maturity, early to mid-bloom, leafy, fine to medium stemmed, free of damage other than slight discoloration.
Fair	Late maturity, mid- to late-bloom, moderate or below leaf content, generally coarse stemmed. Hay may show light damage.
Utility	Hay in very late maturity, mature seed pods, coarse stemmed. Includes hay with excessive damage and heavy weed content or mold. Defects will be identified in market reports when using this category.

[3]RFV calculated using the AFGC formula.

[4]TDN calculated using the western formula.

Table 3. 2005 yield results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1 June 1	Cut 2 July 19	Cut 3 Aug 26	Total yield	Rank	Rank change from 2004
		ton/acre					
Satin	329	3.3	2.2	1.8	7.3	1	14+
Hallmark	Renovator	3.3	2.2	1.7	7.2	2	17+
Baridana	Renovator	3.2	2.1	1.7	7.0	3	14+
Pennlate	329	2.9	2.2	1.8	7.0	4	3+
Potomac	Renovator	3.3	2.0	1.7	7.0	5	4+
Latar	329	3.1	2.2	1.7	6.9	6	5-
Hallmark	329	3.1	2.1	1.7	6.9	7	5-
Stampede	Renovator	3.2	1.9	1.7	6.8	8	5-
Latar	Renovator	2.9	2.1	1.7	6.7	9	13+
Athos	329	3.0	2.0	1.7	6.7	10	1+
Pizza	Renovator	3.0	2.2	1.6	6.7	11	3-
Orion	Renovator	3.1	1.9	1.6	6.7	12	2+
Athos	Renovator	2.9	2.1	1.6	6.7	13	3+
Pennlate	Renovator	3.0	2.0	1.6	6.6	14	7+
Comet	Renovator	2.9	2.0	1.7	6.6	15	11+
Comet	329	2.9	2.2	1.6	6.6	16	6-
Pizza	329	2.9	2.0	1.7	6.6	17	11-
Potomac	329	2.8	2.1	1.7	6.5	18	5-
Mammoth	329	2.8	2.1	1.7	6.5	19	14-
Orion	329	3.1	1.9	1.5	6.5	20	8+
Amba	Renovator	2.9	2.0	1.6	6.5	21	9-
Quantum	329	2.9	2.0	1.6	6.5	22	10+
Baridana	329	2.8	2.0	1.6	6.4	23	5-
Amba	329	2.6	2.1	1.7	6.4	24	=
Mammoth	Renovator	2.7	2.0	1.6	6.4	25	2-
Stampede	329	2.7	2.0	1.6	6.4	26	6-
Satin	Renovator	2.6	2.0	1.8	6.4	27	2-
Icon	329	2.4	2.1	1.8	6.3	28	24-
Sparta	Renovator	2.7	1.9	1.6	6.2	29	2+
Icon	Renovator	2.6	1.9	1.6	6.1	30	=
Sparta	329	2.2	2.0	1.6	5.8	31	4-
Quantum	Renovator	2.0	1.9	1.5	5.3	32	3-
Mean		2.9	2.0	1.7	6.6		
CV (%)		17.7	8.0	8.2	13.8		
P (alfalfa)		0.564	0.092	0.174	0.581		
LSD (0.05)-alfalfa		NS	NS	NS	NS		
P (orchardgrass)		0.067	0.094	0.140	0.088		
LSD (0.05)-orchardgrass		NS	NS	NS	NS		
P (alfalfa X orchardgrass interaction)		0.3	0.5	0.3	0.4		

Table 4. 2005 crude protein results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Crude protein %					
Comet	329	16.7	30	17.5	28	20.8	7
Hallmark	329	17.4	21	19.1	5	19.5	30
Orion	329	16.9	26	19.0	6	20.7	10
Potomac	329	17.0	25	18.4	13	20.5	13
Icon	329	17.4	19	18.7	8	20.3	17
Pizza	329	17.0	24	19.5	2	20.4	16
Latar	329	16.6	31	17.7	25	20.6	12
Pennlate	329	19.2	3	18.1	18	19.2	32
Satin	329	18.7	5	18.0	20	20.5	14
Sparta	329	18.3	10	18.4	15	20.1	25
Athos	329	17.5	17	17.7	24	20.3	21
Amba	329	18.2	11	19.4	3	20.8	8
Mammoth	329	17.8	14	18.2	17	19.8	28
Quantum	329	20.0	1	20.1	1	21.2	4
Stampede	329	19.3	2	18.6	9	20.7	11
Baridana	329	16.2	32	18.5	11	20.1	24
Comet	Renovator	18.8	4	18.1	19	20.3	18
Hallmark	Renovator	17.1	23	17.2	31	19.9	27
Orion	Renovator	17.7	16	18.9	7	20.8	6
Potomac	Renovator	16.9	27	18.6	10	20.0	26
Icon	Renovator	17.4	20	18.4	14	19.5	29
Pizza	Renovator	17.8	13	17.7	26	21.5	3
Latar	Renovator	17.7	15	19.2	4	19.4	31
Pennlate	Renovator	18.5	7	18.4	16	20.2	22
Satin	Renovator	18.5	8	17.9	21	20.3	20
Sparta	Renovator	18.0	12	17.9	22	21.6	2
Athos	Renovator	18.5	6	17.1	32	21.9	1
Amba	Renovator	17.4	18	18.5	12	20.8	9
Mammoth	Renovator	16.8	29	17.6	27	20.2	23
Quantum	Renovator	17.2	22	17.2	30	20.5	15
Stampede	Renovator	16.9	28	17.8	23	20.3	19
Baridana	Renovator	18.3	9	17.3	29	20.9	5
Mean		17.7		18.3		20.4	
CV (%)		8.9		7.0		5.3	
P (alfalfa)		0.878		0.012		0.405	
LSD (0.05)-alfalfa		NS		0.4		NS	
P (orchardgrass)		0.358		0.573		0.159	
LSD (0.05)-orchardgrass		NS		NS		NS	
P (alfalfa X orchardgrass interaction)		0.113		0.164		0.281	

Table 5. 2005 acid detergent fiber results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Acid detergent fiber %					
Comet	329	35.1	14	40.0	1	34.7	18
Hallmark	329	35.9	4	37.1	27	35.6	2
Orion	329	34.9	15	36.2	32	34.7	17
Potomac	329	35.5	10	38.4	14	35.0	12
Icon	329	34.8	16	37.4	26	35.0	13
Pizza	329	35.9	3	37.0	28	35.5	5
Latar	329	35.8	6	39.2	6	35.1	9
Pennlate	329	34.2	24	39.0	9	36.6	1
Satin	329	34.0	25	39.6	4	35.6	3
Sparta	329	32.1	32	37.5	23	34.8	16
Athos	329	35.6	9	38.8	12	35.0	14
Amba	329	34.3	18	36.6	29	34.8	15
Mammoth	329	33.6	28	38.2	16	35.1	10
Quantum	329	33.0	30	36.5	31	35.2	8
Stampede	329	33.4	29	37.5	24	34.3	24
Baridana	329	35.4	11	38.5	13	35.1	11
Comet	Renovator	34.3	22	37.6	22	34.2	26
Hallmark	Renovator	35.8	7	39.0	8	35.4	6
Orion	Renovator	35.3	12	38.2	17	34.3	25
Potomac	Renovator	36.1	2	37.7	21	34.4	23
Icon	Renovator	34.0	26	37.8	19	34.5	22
Pizza	Renovator	36.4	1	38.8	11	33.9	30
Latar	Renovator	35.2	13	36.5	30	35.6	4
Pennlate	Renovator	34.3	20	38.4	15	34.5	21
Satin	Renovator	34.2	23	38.9	10	35.3	7
Sparta	Renovator	32.7	31	37.8	20	33.0	32
Athos	Renovator	34.3	21	40.0	2	34.0	27
Amba	Renovator	33.8	27	37.5	25	33.5	31
Mammoth	Renovator	35.8	5	39.1	7	34.6	20
Quantum	Renovator	34.4	17	38.1	18	34.0	28
Stampede	Renovator	35.7	8	39.4	5	33.9	29
Baridana	Renovator	34.3	19	39.9	3	34.6	19
Mean		34.7		38.2		34.7	
CV (%)		4.9		4.5		4.2	
P (alfalfa)		0.516		0.132		0.003	
LSD (0.05)-alfalfa		NS		NS		0.5	
P (orchardgrass)		0.006		0.120		0.531	
LSD (0.05)-orchardgrass		1.7		NS		NS	
P (alfalfa X orchardgrass interaction)		0.658		0.116		0.965	

Table 6. 2005 neutral detergent fiber results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Neutral detergent fiber %					
Comet	329	49.7	8	52.1	5	45.2	12
Hallmark	329	50.5	3	49.5	21	46.6	5
Orion	329	48.5	15	47.1	31	43.6	28
Potomac	329	49.7	9	49.7	19	45.0	14
Icon	329	49.0	13	49.5	20	44.9	18
Pizza	329	50.0	5	47.6	30	45.3	11
Latar	329	51.3	1	51.9	6	45.4	9
Pennlate	329	47.5	22	49.9	17	47.2	1
Satin	329	47.6	20	50.7	12	45.0	13
Sparta	329	45.1	32	48.9	26	45.6	8
Athos	329	48.2	17	50.8	10	46.6	4
Amba	329	47.9	18	47.9	29	43.7	27
Mammoth	329	46.9	26	49.4	22	46.3	7
Quantum	329	45.4	31	48.2	28	44.7	22
Stampede	329	46.3	29	49.2	25	44.9	19
Baridana	329	50.1	4	50.1	15	45.4	10
Comet	Renovator	46.3	28	49.9	18	44.9	15
Hallmark	Renovator	49.2	12	52.1	4	46.5	6
Orion	Renovator	49.4	11	49.9	16	44.3	26
Potomac	Renovator	50.5	2	49.4	23	44.9	17
Icon	Renovator	47.1	25	48.8	27	44.8	20
Pizza	Renovator	49.8	6	51.0	9	43.1	30
Latar	Renovator	48.8	14	46.8	32	47.1	2
Pennlate	Renovator	46.8	27	50.7	11	44.4	25
Satin	Renovator	47.8	19	50.5	13	44.5	24
Sparta	Renovator	46.3	30	50.4	14	42.2	31
Athos	Renovator	47.1	24	53.8	1	41.7	32
Amba	Renovator	47.3	23	49.3	24	43.1	29
Mammoth	Renovator	49.6	10	51.1	8	46.7	3
Quantum	Renovator	48.3	16	51.2	7	44.9	16
Stampede	Renovator	49.8	7	52.2	3	44.5	23
Baridana	Renovator	47.6	21	52.7	2	44.8	21
Mean		48.3		50.1		44.9	
CV (%)		6.0		5.8		6.0	
P (alfalfa)		0.817		0.037		0.099	
LSD (0.05)-alfalfa		NS		1.0		NS	
P (orchardgrass)		0.120		0.462		0.486	
LSD (0.05)-orchardgrass		NS		NS		NS	
P (alfalfa X orchardgrass interaction)		0.502		0.244		0.701	

Table 7. 2005 relative feed value results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Relative feed value					
Comet	329	116	22	116	6	116	32
Hallmark	329	112	30	113	11	124	26
Orion	329	119	17	121	1	133	5
Potomac	329	115	25	111	16	129	18
Icon	329	118	18	113	12	128	19
Pizza	329	114	28	118	4	126	24
Latar	329	111	32	105	28	127	21
Pennlate	329	122	11	109	20	120	31
Satin	329	122	12	107	26	127	20
Sparta	329	133	1	114	7	126	23
Athos	329	118	19	108	25	123	28
Amba	329	121	15	118	3	132	6
Mammoth	329	124	6	111	14	124	25
Quantum	329	130	2	117	5	129	13
Stampede	329	127	4	114	8	129	16
Baridana	329	115	26	110	19	126	22
Comet	Renovator	125	5	111	15	130	11
Hallmark	Renovator	117	21	104	29	123	29
Orion	Renovator	116	23	110	18	131	7
Potomac	Renovator	112	31	112	13	129	14
Icon	Renovator	124	7	114	9	129	15
Pizza	Renovator	114	29	108	24	135	4
Latar	Renovator	117	20	120	2	121	30
Pennlate	Renovator	124	9	109	21	130	9
Satin	Renovator	121	14	108	22	129	17
Sparta	Renovator	128	3	110	17	140	1
Athos	Renovator	123	10	100	32	139	2
Amba	Renovator	124	8	113	10	136	3
Mammoth	Renovator	116	24	107	27	123	27
Quantum	Renovator	120	16	108	23	130	10
Stampede	Renovator	114	27	104	30	131	8
Baridana	Renovator	122	13	102	31	129	12
Mean		119.8		110.4		128.6	
CV (%)		8.1		8.1		7.7	
P (alfalfa)		0.957		0.046		0.046	
LSD (0.05)-alfalfa		NS		3.2		3.5	
P (orchardgrass)		0.053		0.354		0.545	
LSD (0.05)-orchardgrass		NS		NS		NS	
P (alfalfa X orchardgrass interaction)		0.575		0.265		0.759	

Table 8. 2005 relative forage quality results for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

Orchardgrass variety	Alfalfa variety	Cut 1	Rank	Cut 2	Rank	Cut 3	Rank
		Relative forage quality					
Comet	329	155	16	155	1	155	17
Hallmark	329	144	32	137	8	150	30
Orion	329	153	18	142	3	156	12
Potomac	329	151	26	132	20	154	21
Icon	329	156	13	138	6	153	22
Pizza	329	147	28	142	4	152	25
Latar	329	146	29	126	30	153	23
Pennlate	329	155	14	131	23	144	32
Satin	329	160	7	127	28	152	24
Sparta	329	165	1	134	13	154	19
Athos	329	152	21	131	22	154	20
Amba	329	153	19	138	5	155	16
Mammoth	329	160	6	133	18	154	18
Quantum	329	157	10	135	11	150	29
Stampede	329	162	4	135	10	158	7
Baridana	329	152	22	130	25	149	31
Comet	Renovator	157	9	134	14	157	10
Hallmark	Renovator	153	20	130	26	151	28
Orion	Renovator	152	23	131	21	160	5
Potomac	Renovator	145	30	134	16	156	14
Icon	Renovator	161	5	134	12	159	6
Pizza	Renovator	144	31	134	15	162	3
Latar	Renovator	152	24	143	2	151	27
Pennlate	Renovator	158	8	130	24	156	13
Satin	Renovator	156	12	133	19	151	26
Sparta	Renovator	164	2	136	9	163	2
Athos	Renovator	155	15	126	31	157	11
Amba	Renovator	163	3	138	7	164	1
Mammoth	Renovator	152	25	129	27	155	15
Quantum	Renovator	154	17	133	17	158	8
Stampede	Renovator	148	27	125	32	162	4
Baridana	Renovator	157	11	127	29	158	9
Mean		154.4		133.0		155.0	
CV (%)		6.7		6.9		5.9	
P (alfalfa)		0.938		0.393		0.003	
LSD (0.05)-alfalfa		NS		NS		3.2	
P (orchardgrass)		0.065		0.485		0.585	
LSD (0.05)-orchardgrass		NS		NS		NS	
P (alfalfa X orchardgrass interaction)		0.730		0.253		0.976	

Table 9. Annual and cumulative yield totals for 2003-2005 for the mixed orchardgrass/alfalfa variety trial planted in spring 2002 at the Klamath Experiment Station, Klamath Falls, OR.

		2003		2004		2005		3-Year total	
Orchardgrass variety	Alfalfa variety	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank	Yield ton/acre	Rank
Comet	329	6.3	29	7.4	10	6.6	16	20.2	22
Hallmark	329	6.5	23	7.7	2	6.9	7	21.2	3
Orion	329	6.4	28	6.7	28	6.5	20	19.6	30
Potomac	329	6.6	21	7.3	13	6.5	18	20.4	18
Icon	329	6.8	17	7.5	4	6.3	28	20.6	13
Pizza	329	6.1	32	7.5	6	6.6	17	20.2	24
Latar	329	6.5	26	7.8	1	6.9	6	21.2	4
Pennlate	329	6.3	30	7.4	7	7.0	4	20.6	12
Satin	329	6.8	14	7.3	15	7.3	1	21.3	1
Sparta	329	6.7	19	6.7	27	5.8	31	19.2	32
Athos	329	6.6	22	7.3	11	6.7	10	20.6	14
Amba	329	7.1	2	7.1	24	6.4	24	20.5	15
Mammoth	329	7.1	3	7.5	5	6.5	19	21.2	6
Quantum	329	6.9	11	6.5	32	6.5	22	19.9	27
Stampede	329	6.8	13	7.1	20	6.4	26	20.3	21
Baridana	329	6.9	10	7.1	18	6.4	23	20.5	16
Comet	Renovator	6.5	24	6.8	26	6.6	15	19.9	26
Hallmark	Renovator	6.8	18	7.1	19	7.2	2	21.1	7
Orion	Renovator	6.8	16	7.3	14	6.7	12	20.7	11
Potomac	Renovator	6.8	12	7.4	9	7.0	5	21.2	5
Icon	Renovator	7.0	5	6.6	30	6.1	30	19.7	29
Pizza	Renovator	6.2	31	7.4	8	6.7	11	20.2	23
Latar	Renovator	7.0	6	7.1	22	6.7	9	20.8	8
Pennlate	Renovator	6.4	27	7.1	21	6.6	14	20.2	25
Satin	Renovator	7.0	8	7.0	25	6.4	27	20.3	20
Sparta	Renovator	7.0	7	6.6	31	6.2	29	19.7	28
Athos	Renovator	6.5	25	7.2	16	6.7	13	20.3	19
Amba	Renovator	6.9	9	7.3	12	6.5	21	20.8	9
Mammoth	Renovator	7.0	4	7.1	23	6.4	25	20.5	17
Quantum	Renovator	7.2	1	6.6	29	5.3	32	19.2	31
Stampede	Renovator	6.8	15	7.6	3	6.8	8	21.2	2
Baridana	Renovator	6.6	20	7.1	17	7.0	3	20.8	10
Mean		6.7		7.2		6.6		20.4	
CV (%)		9.0		7.9		13.8		4.9	
P (alfalfa)		0.185		0.109		0.581		0.781	
LSD (0.05)-alfalfa		NS		NS		NS		NS	
P (orchardgrass)		0.102		0.058		0.088		0.033	
LSD (0.05)-orchardgrass		NS		NS		NS		0.995	
P (alfalfa X orchardgrass interaction)		0.998		0.330		0.368		0.623	

Using Selenium Fertilizer to Improve Forage Nutrition

Richard J. Roseberg, Jim E. Smith, and Ronald L. Hathaway[1]

Introduction

Forage in the Pacific Northwest is often deficient in selenium (Se) due to an abundance of low-Se soils. Se deficiency in livestock is well documented in southern Oregon and northern California (Hathaway 1987). Acute deficiencies result in nutritional myopathy, commonly called “white muscle disease”. Less severe deficiencies contribute to reduced weight gain in cattle, increased diarrhea, lower conception rates, and other reproductive problems.

Selenium supplementation by oral salts and injections has resulted in increased weight gain and general health of ruminants on low-Se diets, and this practice has been widely adopted by ranchers. However, injections are expensive and require frequent handling of livestock. Uniform dosing with mineral salt supplements is not easily administered and free-choice feeding of mineral salt supplements often results in uneven doses, with some animals inevitably receiving insufficient Se.

Given these drawbacks, it would be preferable for animals to receive the appropriate amount of Se in their consumed forage. Research in Australia and New Zealand indicates that Se fertilizer can be applied to pasture so that forage Se concentration is sufficient for animal nutrition, while still remaining low enough to avoid animal toxicity or problems with leaching and runoff. Research has shown that forage containing 2-5 mg/kg Se poses a marginal threat to livestock, who may experience chronic Se toxicity if fed such forage continually. Forage above 5 mg/kg Se can cause acute toxic conditions in livestock and should be avoided. Most livestock species require Se at a concentration of at least 0.1 mg/kg in the total diet. Therefore, there is a significant safety factor between the level needed in the diet and that which is toxic.

The effectiveness of soil-applied Se in relieving Se deficiency in tall fescue and intermediate wheatgrass in southern Oregon was evaluated at the Klamath Experiment Station (KES) in 1996-1997, using the sodium selenate product Selcote® (Crop Care Holdings Ltd., New Zealand) (Dovel and Hathaway 1999). Off-station tests of various Se formulations were conducted on grass pasture and alfalfa fields in 2003 (Hathaway and Smith 2004). Attempts to repeat that trial in 2004 were hampered by complications due to grower management changes and communication.

To better document the effects of Se fertilization under controlled conditions, including immediate changes in forage concentration as well as the persistence of increased Se over time, a trial was initiated at KES in 2005. The objective of this study was to measure the increased Se concentration in pure alfalfa or pure orchardgrass hay

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immediately after fertilizer application, as well as persistence of the Se fertilizer's effect over time. In this study we used the only commercially available form of Se fertilizer (Selcote Ultra®), which contains a combination of highly soluble sodium selenate with the more slowly soluble barium selenate form.

Procedures

The orchardgrass portion of this trial was established in an area of bulk Potomac orchardgrass planted in 2002 that was previously used as a border area between two forage trials. This area was a good example of uniform management with no previous Se fertilization. The alfalfa portion of this trial consisted of an area of two varieties planted as a seed-treatment evaluation in 2002. Because seed-treatment differences had long since ceased to be noticeable in yield or quality, this area was also an example of uniform management without previous Se fertilization. The two alfalfa varieties were Rampage (a fall dormancy 3 variety), and Rebel (a fall dormancy 4 variety). Plots for both orchardgrass and alfalfa were 5.5 ft by 20 ft.

Immediately after first cutting, all orchardgrass plots received ammonium sulphate fertilizer at 337 lb/acre (supplying 71 lb/acre nitrogen [N]). After second cutting, the orchardgrass plots all received ammonium sulphate at 405 lb/acre (supplying 85 lb/acre N). The alfalfa plots did not receive any fertilizer except the Se treatments. For orchardgrass, the Se treatments (either receiving Se or not) were laid out as a randomized complete block design with eight replications. For alfalfa, the Se treatments (either receiving Se or not) were laid out on the two alfalfa varieties as a complete factorial design. Each Rampage by Se treatment had five replications, while each Rebel by Se treatment had seven replications. For orchardgrass, the plots assigned to the Se treatment received Selcote Ultra (mixed with the other fertilizer) at 1.5 lb/acre on June 2. For alfalfa, the plots assigned to the Se treatment received Selcote Ultra at 1.5 lb/acre on June 16.

The orchardgrass portion was harvested three times, on May 27, July 20, and August 26. The alfalfa portion was also harvested three times, on June 1, July 19, and August 26. Prior to each harvest, 5.5-ft strips were cut between plot rows for separation. Forages were harvested with a Carter (Carter Manufacturing Co., Inc.) power take-off powered flail harvester with a 3-ft-wide cutting width. Residue in border areas was removed with a Mathews (Mathews Co.) flail chopper after plot harvests. After the cut material from each plot was weighed, random samples were collected from the chopped plot material, weighed, and then oven dried to determine dry matter content and calculate dry matter yield. Dried samples were ground to pass a 2-mm sieve in a Wiley Mill (Arthur H. Thomas Co.) and then to pass a 1-mm-sieve size in a Udy Mill (Udy Corp.). The ground samples were then analyzed for Se using inductively coupled plasma (ICP) at the University of California–Division of Agriculture and Natural Resources Analytical Lab.

Statistics on yield and Se concentration data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software, using either PROC ANOVA or PROC GLM depending on whether there was an equal number of replications or not. Treatment significance was based on the

F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level.

Results and Discussion

Alfalfa

Overall, the alfalfa trial yielded 3.1 ton/acre, 2.1 ton/acre, 1.5 ton/acre, and 6.7 ton/acre for the three cuttings and annual total. There was no significant difference in yield for any of the cuttings or for annual total between the Se treatment and the no-Se treatment. While Se is a required animal nutrient, it is not considered a required plant nutrient, thus deficiencies in plants are not expected to cause decreases in forage yield, so we did not expect the Se treatment to affect yield.

Se concentration was not significantly different between Se treatments at first cutting, as this occurred before the Se fertilizer was applied. However, there was a significant difference in Se concentration between plots receiving Se and those that did not for both the second and third cuttings (Table 1). There was also a significant difference between alfalfa varieties, and a significant interaction between alfalfa variety and Se treatment for the second cutting only. This interaction indicates that the two alfalfa varieties responded differently to Se fertilization on the second cutting date (the first harvest made after Se fertilizer was applied).

Orchardgrass

Overall, the orchardgrass trial yielded 2.7 ton/acre, 1.4 ton/acre, 1.7 ton/acre, and 5.7 ton/acre for the three cuttings and annual total. There was no significant difference in yield for any of the cuttings or for annual total between the Se treatment and the no-Se treatment. As with the alfalfa, Se concentration in orchardgrass was not significantly different between Se treatments at first cutting, as this occurred before the Se fertilizer was applied. However, there was a significant difference in Se concentration between plots receiving Se and those that did not for both the second and third cuttings (Table 2).

The fact that there was still a significant difference in Se concentration between the treated and untreated alfalfa and orchardgrass for the last cutting suggests that increased Se levels in forage may persist for more than one season. In all cases, Se concentration did not exceed a safe range for ruminant nutrition, indicating applied rates were not excessive. Measurements will be continued in 2006 to determine how long the effects of the one-time Se application in 2005 will persist. If it turns out that a single application of Se fertilizer results in forage containing sufficient Se for more than one growing season, it will lend further evidence towards recommending this practice as a more dependable and cost-effective way to ensure proper Se nutrition in livestock.

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Table 1. Selenium concentration for both alfalfa varieties on all three cutting dates in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Alfalfa variety	Selenium treatment	Cut 1 June 1	Cut 2 July 19	Cut 3 Aug 26
			mg/kg	
Rampage	Yes	0.02	0.70	0.23
Rampage	No	0.03	0.03	0.06
Rebel	Yes	0.02	0.47	0.25
Rebel	No	0.03	0.04	0.02
Mean		0.03	0.30	0.14
CV (%)		59.8	33.1	31.7
P (alfalfa)		0.421	0.013	0.922
LSD (0.05)-alfalfa		NS	0.09	NS
P (selenium)		0.276	<0.001	<0.001
LSD (0.05)-selenium		NS	0.09	0.04
P (alfalfa X selenium interaction)		0.851	0.010	0.095

Table 2. Selenium concentration for orchardgrass on all three cutting dates in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Selenium treatment	Cut 1 May 27	Cut 2 July 20	Cut 3 Aug 26
		mg/kg	
Yes	0.01	0.20	0.17
No	0.01	0.01	0.02
Mean	0.01	0.11	0.09
CV (%)	23.5	56.1	71.8
P (selenium)	0.351	<0.001	0.004
LSD (0.05)-selenium	NS	0.07	0.08

Cereal Forage Trial, 2005

Richard J. Roseberg and Jim E. Smith[1]

Introduction

In the Klamath Basin, annual cereal forages produce one cutting and typically result in a high biomass yield of hay suitable for feeding many types of livestock. Cereal hay prices are generally lower than those of higher quality hay such as alfalfa, perennial grass, and grass/alfalfa mixtures. Cereal forages are useful because they can fill a crop rotation need (e.g., coming out of alfalfa, grow one cereal crop for forage or grain, then rotate back into alfalfa). In addition, cereal crops are commonly planted following potatoes and are harvested for either grain or forage, thus utilizing some of the nutrients that may remain in the soil following potatoes.

To test the yield and quality potential of several cereal hay species and varieties, a trial was planted in 2005 on the Henzel farm, about 10 miles south of the Klamath Experiment Station (KES), near the intersection of Lower Lake Road and Cross Road. This trial was done in cooperation with Winema Elevators, Tulelake, California, and was planted there to evaluate variety response to the high organic matter lake bottom soil. The 2005 trial included two beardless barley varieties, one beardless wheat variety, two triticale varieties (one bearded and one beardless), and four oat varieties. The entries were similar to those included in our 2003 and 2004 trials, but those two trials were conducted on the mineral soil at KES.

Procedures

The trial was planted on the Henzel farm on an Algoma silt loam soil following wheat grown the previous season. Seedbed preparation included plowing, disking, spring-tooth cultivating, and rolling. The trial was arranged in nonreplicated strips, with separate varieties or species in each strip. Most entries were planted at 2 or more rates, ranging from 30 seed/ft^2 up to 105 seed/ft^2 in one case (Table 1). Due to differences in seed size between species, these rates ranged from 78 to 413 lb/acre. This arrangement resulted in four replications of each variety/seeding rate combination, but the treatments were not randomized. All entries were drilled using a modified Kincaid (Kincaid Equipment Manufacturing) planter on May 25. Individual plots were 4.5 by 20 ft, with 3 by 15.5 ft harvested. All plots received 16-20-0-13 fertilizer at 310 lb/acre banded at planting (supplying nitrogen [N] at 50 lb/acre N, phosphorus at 63 lb/acre P_2O_5, and sulfur [S] at 41 lb/acre S. During the season, the farmer followed his normal fertilizer and weed control practices for the entire field including our plot area. Irrigation was applied with an overhead linear irrigation system as part of the farmer's normal small grain production operations.

The crop was harvested on August 16-18, when heads were in the milk or soft dough stages. This is quite a bit later than the harvest date in 2004

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(July 20), when a similar trial was conducted on the mineral soil at KES. The delay in 2005 was probably due to the greater water-holding capacity of the high organic matter soil delaying maturity in 2005.

Plots were harvested with a Carter (Carter Manufacturing Co. Inc.) tractor-mounted flail harvester with a 3-ft-wide header. A sample of about 1.0 lb of chopped forage was taken from each plot and oven dried to determine dry matter yield. Dried samples were ground to 2-mm-sieve size in a Wiley Mill (Arthur H. Thomas Co.) and to 1-mm-sieve size in a Udy Mill (Udy Corp.) before being analyzed in a near infrared spectrophotometer (NIRS) (NIRSystems) to determine forage quality. Because the entries were laid out in nonreplicated strips, we could not calculate analysis of variance statistics as we commonly do for variety trials. We did harvest multiple plots within each variety strip, and thus were able to calculate a variance for each entry's mean value, providing a measure of how variable the results were.

Results and Discussion

Yields across varieties in this spring-planted cereal forage trial ranged from 3.1 to 6.1 tons/acre (Table 1). In general, yields were somewhat less in 2005 than in 2004, but as was noted in the 2004 annual report, growing conditions at KES in 2004 were ideal for grain crops, resulting in unusually high yields for both the small grain forage and grain experiments. In general, the triticale entries produced the highest yield, although Charisma oat also produced 5 ton/acre. In contrast, Cayuse oat had the lowest yield.

For a given entry, increasing the seeding rate from 30 to 45 seed/ft^2 tended to increase forage yield, but increasing the seeding rate beyond 45 seed/ft^2 did not have an obvious effect on forage yield.

The quality analysis data were not deemed reliable. It appeared that the samples were too contaminated by the high organic matter soil, and thus the soil material was mixed with the forage during grinding. These high organic matter soils are easily dislodged and subject to wind erosion, as can happen during harvest with a flail chopper, or during any dry, windy weather period. Future studies on these soils will have to take this effect into consideration to allow accurate sampling for quality parameters.

Table 1. 2005 yield results for the grain hay variety trial planted in high organic matter soil 10 miles south of Klamath Experiment Station, Klamath Falls, OR. Harvested on August 16-18, 2005.

Species	Variety	Head type	Seeding rate (seed/ft^2)	Seeding rate (lb/acre)	Yield ton/acre	Variance (s^2)
Barley	Sara	Beardless	30	118	4.0	0.70
	Sara	Beardless	45	177	4.6	0.51
	Sara	Beardless	60	236	4.1	0.28
	Sara	Beardless	75	295	4.2	0.28
	Sara	Beardless	90	354	3.9	0.29
	Sara	Beardless	105	413	4.4	1.06
	Belford	Beardless	30	112	4.1	1.41
	Belford	Beardless	45	168	4.5	0.34
Oat	Cayuse	Hulled	30	92	3.1	0.15
	Charisma	Hulled	30	104	5.0	0.74
	Everleaf	Forage Oat	30	81	4.2	0.46
	Everleaf	Forage Oat	45	121	4.3	1.72
	Ajay	Hulled	30	78	4.5	0.65
	Ajay	Hulled	45	117	3.6	0.01
Triticale	Trical OLT6042	Beardless	30	127	5.1	0.11
	Trical OLT6042	Beardless	45	190	5.2	0.14
	Trical 2700	Bearded	30	138	6.1	0.05
	Trical 2700	Bearded	45	207	5.4	0.19
Wheat	Twin	Beardless	30	112	4.3	0.06
	Twin	Beardless	45	169	4.3	0.05
	Twin	Beardless	60	225	4.6	0.07
	Twin	Beardless	90	337	4.4	0.13

Spring Wheat and Barley Variety Screening in the Klamath Basin

Richard J. Roseberg and Jim E. Smith[1]

Introduction

Grain is produced on about 100,000 acres in the Klamath Basin and 60,000 acres within the Klamath Reclamation Project. Susceptibility to late spring frosts has historically limited winter cereal production, and spring cereals have accounted for the majority of production. Starting in 2003, a significant shift to production of hard red winter wheat was observed. With few late spring frosts and a frost-free summer in 2005, most of the winter wheat crops produced good yields and quality. Klamath Experiment Station (KES) cereal variety evaluation efforts have focused on spring cereal varieties, although a small winter wheat variety test was planted in fall 2004 for harvest in summer 2005. A much larger set of winter grain variety trials including wheat, barley, and triticale were planted in fall of 2005 for harvest in 2006.

In 2005, small grain variety trials were conducted on-site at KES on a mineral soil, and at a Lower Klamath Lake (LKL) site on a silty clay loam muck (high organic matter) soil. The Western Regional Spring Barley Trial, Soft Spring Wheat Trial, and Hard Spring Wheat Trial were planted at both the KES and LKL sites. The Oregon State University (OSU) Elite Spring Barley Trial and Elite Spring Wheat Trial were also planted at both the KES and LKL sites. The OSU Elite Winter Wheat Trial was planted only at the KES site.

Procedures

KES Site

KES spring grain variety trials were conducted on a Poe fine sandy loam soil following 2004 potato experiments. All trials were arranged in a randomized complete block design with four replications, except for the OSU Elite Spring Wheat Trial and the OSU Elite Winter Wheat Trial, which had three replications each. Seed was planted 1 inch deep at 30 seeds/ft^2, with a Kincaid (Kincaid Equipment Manufacturing) plot planter on October 9, 2004 for the winter wheat trial, and on May 3, 2005 for the spring trials. Plots were 20 by 4.5 ft wide, (9 rows at 6-inch spacing), with a harvested area of 14.5 by 4.5 ft.

All plots received 16-20-0-13 fertilizer at 310 lb/acre banded at planting (supplying nitrogen [N] at 50 lb/acre N, phosphorus at 63 lb/acre P_2O_5, and sulfur [S] at 41 lb/acre S. An additional 50 lb/acre N was applied as Solution 32 in a tank mix with the broadleaf herbicide Rhomene® (MCPA,

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Aventis) at 1.0 pt/acre (0.5 lb a.i./acre) on June 7 with a conventional ground sprayer.

At KES, irrigation was applied with solid-set sprinklers arranged in a 30- by 40-ft pattern. Irrigation was applied to meet crop needs based on Agricultural Meteorological (AgriMet) crop water use estimates from the KES AgriMet weather station. Irrigation was applied on 13 occasions during the season, for a total of 13.3 inches. In addition to irrigation, rainfall totaled 1.80 inch in April, 2.27 inch in May, 0.19 inch in June, 0.02 inch in July, and no rain fell in August. Grain was harvested with a Hege (Hans-Ulrich Hege) plot harvester with a 4.5-ft-wide header on August 11 for the winter wheat trial, and August 26 and 29 for the spring trials.

LKL Site

LKL spring grain variety trials were conducted on Algoma silt loam soil in a continuous grain rotation. The field was flooded during the winter to replenish moisture to the entire soil profile. All trials at LKL were arranged in a randomized complete block design with four replications except for the OSU Elite Spring Wheat Trial, which had three replications. Trial plots were planted with a Kincaid plot planter as was done at KES (above) on May 25, 2005. All plots were fertilized with 50 lb/acre N shanked in before planting as anhydrous ammonia, followed by 50 lb/acre N, 63 lb/acre P_2O_5, and 41 lb/acre S banded at planting, (applying 16-20-0-13 fertilizer at 320 lb/acre). Herbicides applied included a tank mix of Buctril® (Bromoxynil, Aventis) at 1.5 pt/acre (0.5 lb a.i./acre) and Rhomene at 1.0 pt/acre (0.5 lb a.i./acre) on June 10 with a conventional ground sprayer. The field was irrigated during the growing season with an overhead linear move system according to the grower's schedule. Grain was harvested on September 14-16 with a Hege plot combine as was done at the KES site.

KES and LKL Sites

For both sites, data collected included grain yield, test weight, lodging percentage, plant height, and maturity (date of 50 percent heading). Percent plumps (percent above 6/64 and 5.5/64 sieves) and thins (pan) were also measured for the barley trials. For all trials, grain moisture was measured and used to adjust yield to industry standards (12 percent moisture by weight). All measured parameters were analyzed statistically using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level.

Results and Discussion

Soil moisture was good during seedbed preparation, and resulting germination and stand density were very good. Good availability of irrigation water, lack of frost, relatively few hot days during the season, and good weed control all contributed to very good yields in 2005. However, yields in 2005 were generally not as high as were observed in 2004 at KES, which was an unusually ideal year for grain production at that site. In contrast, yields at LKL generally were higher in 2005 than they were in 2004.

Western Regional Spring Barley Variety Trial

Thirty-five entries were included in the 2005 trial. This trial included 12 feed varieties, 14 malting varieties (or selections), and 9 varieties that could be used for both feed and malting. At the KES site, yields ranged from 4,470 to 7,560 lb/acre with a mean of 6,230 lb/acre (Table 1). Yields at KES in 2005 were lower than in 2004, which was an unusually outstanding year, as noted above. At the LKL site, yields in 2005 ranged from 6,110 to 8,230 lb/acre with a mean of 7200 lb/acre (Table 2). Unlike the situation at KES, yields were higher overall at LKL in 2005 as compared to 2004. Moisture status appeared better for the full growing season at LKL in 2005 compared to 2004, perhaps contributing to the improved yield.

Comparing results for the two sites clearly demonstrated how some varieties are better-suited for more specific growing conditions, while others are more widely adapted to various growth environments. For example, 01ST1587, 2B99-2771-1, 99Ab11073, and Sellar yielded very well at both sites, while Morex, Harrington, 2B99-2039, 2B99-2657, and WA10701-99 had relatively low yields at both sites. Most varieties did somewhat better at one site or the other, but in 2005 there were no entries that were near the top at one site, but near the bottom at the other.

Some entries exhibited lodging at one or both locations (Tables 1 and 2). In general, lodging was slightly worse at KES, but individual entries varied greatly at the two locations, as indicated by the very large coefficient of variation (CV) value at both sites.

Bushel (bu) weights were well above the 48 lb/bu standard for all entries at both sites, indicating good moisture, fertility, and weather conditions during the seed-filling phase. This was especially true at the LKL site, where the percent of seed retained on the 6/64 screen (the plumpest seed) was very high (trial mean of 97.7 percent, Table 2). The trial mean of seed retained on the 6/64 screen at KES was 90.7 percent, still an acceptable value. This pattern is the opposite of what was observed in 2004, where the percent of seed retained on the 6/64 screen was 6.0 percent higher at the KES site.

Multiple-year yield means for all entries that were planted in the 2003-2005 trials at KES were calculated (Table 3). Only the five named varieties were planted all 3 years. For those entries the yields clearly demonstrated the excellent growing conditions in 2004, good conditions in 2005, and poor conditions in 2003. Despite this variation, Baronesse and Stander demonstrated outstanding performance, both having either the highest or second highest 2-year and 3-year mean yield. The old standard variety Steptoe had the third highest 2-year and 3-year mean yield. The multi-year yields of the numbered varieties were not outstanding.

OSU Elite Spring Barley Variety Trial

This trial examined some of the elite breeding lines from Dr. Pat Hayes' breeding program at OSU, as well as numbered lines from the University of California breeding program with which Dr. Hayes cooperates. This trial was planted at both the KES and LKL sites. Entries from these programs had not been evaluated at KES for the past several years before 2005.

There were five experimental lines in this trial, including two potential malting types, one six-row feed type, and two hull-less (naked seed) types. Significant differences were found for bushel weight and percent seeds passing over the 6/64 screen, the 5.5/64 screen, and percent fallen through to the pan (Tables 4 and 5). As in the Western Regional Spring Barley Variety Trial, bushel weights were well above the 48 lb/bu standard for all entries at both sites, indicating good moisture, fertility, and weather conditions during the seed-filling phase. This was especially true at the LKL site, where a mean of 95.3 percent of seeds were larger than the 6/64 screen. There were significant differences between entries for yield and heading date at the LKL site only. There was no lodging at LKL, and only one entry exhibited lodging at KES. There were significant differences in height at KES, but heights were not measured at LKL.

At KES, yields ranged from 6,050 to 7,640 lb/acre with a mean of 6,600 lb/acre. At LKL, yields ranged from 6,320 to 8,820 lb/acre with a mean of 7,780 lb/acre. UC1047 had the second highest yield at both locations, but other entries had variable performance (e.g., UC1135 had the highest yield at KES, but the second lowest at LKL).

Western Regional Soft White Spring Wheat Variety Trial

Four standard named varieties and 12 numbered selections were included in the 2005 trial at both the KES and LKL sites. Fifteen of the entries were soft white spring types, and one was a club type. Yields ranged from 6,250 to 9,770 lb/acre at KES, with a mean of 7,670 lb/acre, and they ranged from 5,440 to 8,260 lb/acre at LKL, with a mean of 6,850 lb/acre (Tables 6 and 7). There was no lodging for any entry at either site. There were significant differences in yield, bushel weight, plant height, and maturity (day of the year when heading reached 50 percent) at both sites. The only variety to have consistently high yields at both sites was Alturas. WA007960 was the only entry to have consistently low yields at both sites. Yield for some entries was quite different at the two sites (e.g., IDO642 had the highest yield at LKL, but had the second-lowest yield at KES).

Bushel weights were well above the industry standard of 60 lb/bu for all entries at KES, and were above 60 lb/bu for all but four entries at LKL (Tables 6 & 7). Bushel weights overall were slightly higher in 2005 compared to 2004 at KES, with a mean of 64.5 lb/bu. Bushel weights at LKL in 2005 overall were similar to those observed in 2004. Variation between entries was not large in most cases. In 2004, entry IDO610 had exhibited the highest bushel weight of all entries at both sites. In 2005, IDO610 again was the best overall in terms of bushel weight, exhibiting the highest weight at KES and the third highest at LKL.

As was done for the Western Regional Barley Trial, multiple-year yield means for all soft white spring wheat entries that were planted in the 2003-2005 trials at KES were calculated (Table 8). Three-year comparisons are meaningless, as only Alpowa was planted all 3 years. IDO610 had an excellent yield at KES in 2004, but was only slightly above the mean in 2005, yet still had the second highest 2-year mean yield.

Western Regional Hard Spring Wheat Variety Trial

This trial evaluated both hard white spring (HWS) and hard red spring

(HRS) wheat experimental lines and named varieties at both the KES and LKL sites. The trial included 8 HRS and 10 HWS entries. At both sites, there were significant differences between entries for yield, bushel weight, plant height, and maturity (Tables 9 and 10). No lodging was observed for any entry at either site. Grain yield ranged from 5,380 to 7,780 lb/acre at KES, with a mean of 6,490 lb/acre. At LKL, grain yield ranged from 5,330 to 8,330 lb/acre, with a mean of 6,590 lb/acre. The only entry that had relatively high yield at both locations was IDO377S, repeating a similar performance in 2004. Entries with relatively low yield at both locations included UC1418, UC1419, and OR4201104. Entries with high yield at one location, but low yield at the other included OR4201027 and OR4990115, which had the unusual distinction of having the top yield at KES, but the lowest yield at LKL.

Bushel weights were well above 60 lb/bu for all entries at KES, and for all but three entries at LKL. The mean at KES was very high at 64.3 lb/bu, while the LKL mean was an acceptable 61.5 lb/bu, both values similar to 2004. Entries with high bushel weights at both locations included IDO377S, OR4201019, and UC1296. IDO377S had also exhibited high bushel weights at both locations in 2004. Other entries did not have a dramatically different bushel weight performance at one location compared to the other.

In the multiyear rankings, IDO377S had the highest grain yield for both the 2-year and 3-year means (Table 11). This entry achieved the same result for the 2002-2004 time period (as was described in the 2004 annual report).

OSU Elite Spring Wheat Variety Trial

Twelve named varieties and 13 experimental lines were included in the trial planted at LKL. At KES, 13 named varieties and 17 experimental lines were planted. The five entries missing from the LKL trial were not planted due to lack of sufficient seed, and included Jubilee and the four numbered varieties beginning with the letters “ML”. Significant differences were found for yield, bushel weight, and height at KES (Table 12). Entries did not exhibit a significant difference in maturity date. Due to an accident involving the sample bags after harvest, we were only able to collect data for one replication from the LKL site, preventing any statistical analysis of the LKL data for this trial.

Yields ranged from 3,230 to 7,780 lb/acre at KES, with a mean of 5,050 lb/acre. At LKL, yields ranged from 4,790 to 10,260 lb/acre from the one surviving replication, with a mean of 7,310 lb/acre (Table 13). No entries exhibited any observable lodging at either location. Bushel weights were excellent overall, ranging from 61.5 to 65.3 lb/bu at KES, with a mean of 63.6 lb/bu. At LKL, bushel weights ranged from 60.0 to 64.0, with a mean of 62.1 lb/bu. WA007952 had the highest bushel weight at both locations, and was also among the highest yielding entries at both locations. B. Pronto had relatively poor yield at both locations. B. Grande had the highest yield at KES, but the lowest yield at LKL.

OSU Elite Winter Wheat Variety Trial

KES had not done a winter wheat trial in many years, but due to the increased interest of growers in planting winter wheat, we tested entries from Jim

Peterson's OSU winter wheat breeding program during the 2004-2005 growing season. This trial had 40 entries, including 15 named varieties and 25 numbered experimental lines. Significant differences were found between entries for test weight and height only (Table 14). Maturity date was not measured. No lodging was observed for any entry. Yields ranged from 4,160 to 7,620 lb/acre, with a mean of 5,900. Test weights were very good. Stephens was the only entry below 60 lb/bu, but all but eight of the remaining entries were greater than 62 lb/bu. Three of the entries were among the top quarter in both yield and bushel weight (e.g., OR3970965, ORH010917, and OR2010241).

Summary

Trial results for 2005 exhibited more typical grain yield and grain size characteristics at both locations compared to 2004, which was an unusually ideal year at KES and a poorer than typical year at LKL. Production at the LKL site was better in 2005 than 2004, with improved yields likely due to improved moisture status throughout the entire growing season at LKL in 2005. Comparisons among entries in 2004 and 2005 demonstrate how entries can respond differently depending on how the overall growing conditions vary from year to year. Comparing the performance of a particular variety at the two locations indicates how the different soil types can affect grain production in some cases.

Table 1. 2005 Western Regional Spring Barley Nursery, planted in mineral soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Row	Use	Yield lb/acre	Bu wt lb/bu	6/64%	5.5/64%	Pan %	Lodge %	Height inch	50% Heading day of the year
01ST1587	2 row	feed, RWA rest.[1]	7560	54.1	92.9	5.0	2.1	6	31.5	182
ND21863	2 row	malting	7120	55.1	98.1	1.2	0.7	0	37.4	182
WA 8569-99	2 row	feed/malting	7030	54.7	88.7	8.3	3.0	1	30.5	182
2B99-2771-1	2 row	malting	6790	54.8	93.3	4.9	1.8	0	34.4	182
YU501-385	2 row	feed	6730	55.1	91.5	6.4	2.1	0	37.4	182
99Ab11073	2 row	malting	6680	53.2	90.6	6.1	3.3	1	38.4	180
Sellar (ND16301)	6 row	malting	6680	53.5	95.8	3.1	1.1	0	42.3	180
WA 15279-00	2 row	feed	6640	53.6	89.9	7.0	3.1	24	33.5	182
2B99-2763-10	2 row	malting	6630	54.1	92.8	5.4	1.8	3	36.4	182
01ST1758	2 row	feed, RWA rest.	6620	54.8	91.4	5.9	2.7	6	32.5	182
MT000125	2 row	feed/malting	6600	54.5	93.4	4.2	2.4	19	35.4	183
99NZ102	6 row	feed/malting	6430	54.6	88.3	9.2	2.5	0	36.4	182
YU 597-432	2 row	feed	6390	54.6	90.5	7.4	2.1	0	34.4	182
2B99-2316	2 row	malting	6310	54.5	88.7	7.7	3.6	5	37.4	182
98Ab11993	2 row	malting	6310	52.5	90.6	6.3	3.0	23	34.4	182
ND19854	2 row	malting	6270	54.5	97.0	2.1	0.9	0	32.5	181
YU501-163	2 row	feed	6250	55.2	95.4	3.3	1.3	0	34.4	182
Stander	6 row	malting	6240	54.3	92.2	5.3	2.5	0	41.3	180
PB1-97-2R-7010	2 row	feed/malting	6240	55.1	94.3	4.1	1.6	0	34.4	184
MT000138	2 row	feed/malting	6200	54.5	96.0	2.7	1.3	4	38.4	182
MT000047	2 row	feed/malting	6110	55.0	93.2	5.2	1.6	0	36.4	182
Steptoe	6 row	feed	6100	53.0	87.5	8.2	4.3	27	37.4	181
96RWA1222	6 row	malt, RWA rest.	6100	52.7	93.0	5.4	1.6	0	37.4	181
WA 10429-00	2 row	feed	6000	54.3	85.4	10.5	4.0	21	31.5	182
UT99B1669-3243	6 row	feed	5960	52.4	91.7	5.7	2.7	5	39.4	181
Baronesse	2 row	feed	5920	52.4	83.3	11.7	5.0	25	34.4	182
2B99-2657	2 row	malting	5880	53.0	88.4	8.1	3.5	26	36.4	182
WA 7330-00	2 row	feed	5830	51.8	83.2	11.4	5.4	19	33.5	182
01NZ392	6 row	feed/malting	5790	53.0	89.0	8.1	2.9	0	38.4	182
2B99-2039	2 row	malting	5740	54.8	95.0	3.7	1.3	1	37.4	183
Harrington	2 row	malting	5690	53.7	89.6	7.2	3.2	4	35.4	182
UT99B1670-3458	6 row	feed	5630	53.7	93.9	4.5	1.7	19	37.4	181
01NZ706	6 row	feed/malting	5620	52.9	89.9	7.8	2.3	6	40.4	182
WA 10701-99	2 row	feed/malting	5580	50.9	81.7	12.0	6.3	15	33.5	183
Morex	6 row	malting	4470	50.3	82.3	13.4	4.3	28	43.3	180
Mean			6230	53.7	90.7	6.6	2.7	8	36.2	182
LSD (0.05)			1230	2.3	5.7	3.8	2.3	NSD	4.3	1
CV (%)			14.0	3.1	4.5	41.1	60.1	231.1	8.4	0.5
P value			0.038	0.002	<0.001	<0.001	<0.001	0.291	<0.001	<0.001

[1]Russian wheat aphid resistant.

Table 2. 2005 Western Regional Spring Barley Nursery, planted in organic soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Row	Use	Yield lb/acre	Bu wt lb/bu	6/64%	5.5/64%	Pan %	Lodge %	Height inch	50% Heading day of the year
UT99B1669-3243	6 row	feed	8230	53.7	99.2	0.6	0.2	0	NA	196
99Ab11073	2 row	malting	8060	52.4	98.1	1.6	0.4	0	NA	188
01ST1758	2 row	feed, RWA rest.[1]	8050	54.0	98.4	1.0	0.6	0	NA	201
98Ab11993	2 row	malting	8010	53.5	99.0	0.7	0.3	18	NA	201
YU 597-432	2 row	feed	7940	54.1	98.2	1.4	0.4	0	NA	199
YU501-163	2 row	feed	7720	54.7	99.1	0.7	0.2	10	NA	201
99NZ102	6 row	feed/malting	7600	52.8	98.1	1.5	0.4	3	NA	200
Sellar (ND16301)	6 row	malting	7590	52.4	99.0	0.7	0.2	0	NA	197
2B99-2771-1	2 row	malting	7580	54.0	98.8	0.9	0.3	10	NA	201
UT99B1670-3458	6 row	feed	7550	52.4	99.0	0.8	0.3	0	NA	196
YU501-385	2 row	feed	7540	52.8	95.8	3.2	1.0	24	NA	200
Baronesse	2 row	feed	7370	53.3	97.8	1.7	0.5	19	NA	201
96RWA1222	6 row	malt, RWA rest.	7350	53.3	97.1	2.2	0.7	20	NA	200
Steptoe	6 row	feed	7310	52.5	98.2	1.2	0.5	10	NA	196
01ST1587	2 row	feed, RWA rest.	7260	54.0	99.2	0.6	0.2	0	NA	199
2B99-2316	2 row	malting	7180	52.8	94.0	4.3	1.7	51	NA	199
MT000047	2 row	feed/malting	7140	54.7	98.1	1.5	0.4	13	NA	201
WA 8569-99	2 row	feed/malting	7110	52.1	95.6	3.2	1.3	51	NA	201
WA 15279-00	2 row	feed	7110	52.8	99.1	0.7	0.2	0	NA	201
ND19854	2 row	malting	7090	53.8	99.2	0.5	0.3	3	NA	195
Stander	6 row	malting	7060	53.0	98.7	1.0	0.3	0	NA	199
MT000125	2 row	feed/malting	6970	54.3	98.3	1.1	0.6	15	NA	201
01NZ706	6 row	feed/malting	6960	51.6	96.1	3.1	0.9	13	NA	200
WA 7330-00	2 row	feed	6880	52.4	96.3	2.8	0.9	36	NA	199
WA 10429-00	2 row	feed	6880	52.5	94.7	4.4	0.9	38	NA	200
01NZ392	6 row	feed/malting	6860	53.0	97.5	1.8	0.7	15	NA	201
WA 10701-99	2 row	feed/malting	6750	51.0	96.0	2.9	1.1	49	NA	200
ND21863	2 row	malting	6720	54.3	99.2	0.6	0.2	5	NA	200
Harrington	2 row	malting	6710	53.0	97.7	1.9	0.4	41	NA	201
2B99-2657	2 row	malting	6680	52.6	96.0	3.0	1.0	30	NA	201
2B99-2039	2 row	malting	6670	53.7	97.7	1.7	0.6	31	NA	201
PB1-97-2R-7010	2 row	feed/malting	6630	54.0	99.1	0.6	0.3	4	NA	201
2B99-2763-10	2 row	malting	6600	53.5	98.9	0.9	0.2	0	NA	201
MT000138	2 row	feed/malting	6560	54.8	99.4	0.4	0.1	3	NA	200
Morex	6 row	malting	6110	51.5	93.8	5.0	1.2	50	NA	198
Mean			7200	53.2	97.7	1.7	0.6	16		199
LSD (0.05)			NSD	1.4	2.1	1.6	0.6	34		4
CV (%)			14.5	1.9	1.5	66.9	72.2	152.6		1.4
P value			0.567	<0.001	<0.001	<0.001	<0.001	0.004		<0.001

[1]Russian wheat aphid resistant.

Table 3. Three-year summary, Western Regional Spring Barley Nursery, planted in mineral soil, Klamath Experiment Station, Klamath Falls, OR, 2003-2005.

		Yield			2-yr mean		3-yr mean	
Variety	Row	2003	2004	2005	Yield	Rank	Yield	Rank
		lb/acre					lb/acre	
Malting Varieties								
Morex	6	2320	8740	4470	6605	5	5177	5
Stander	6	1790	10800	6240	8520	1	6277	2
Harrington	2	2320	8270	5690	6980	4	5427	4
WA 8569-99	2		4210	7030	5620	6		
Sellar (ND16301)	6		3670	6680	5175	12		
99NZ102	6		4690	6430	5560	7		
2B99-2316	2		4060	6310	5185	11		
98Ab11993	2		3250	6310	4780	15		
ND19854	2		4470	6270	5370	9		
PB1-97-2R-7010	2		4170	6240	5205	10		
2B99-2657	2		4910	5880	5395	8		
WA 10701-99	2		4200	5580	4890	13		
Feed Varieties								
Steptoe	6	2290	9660	6100	7880	3	6017	3
Baronesse	2	2560	10810	5920	8365	2	6430	1
YU 597-432	2		3380	6390	4885	14		
Mean		2256	5953	6103	6028		5865	

Table 4. 2005 OSU Elite Spring Barley Nursery, planted in mineral soil (ranked by yield), Klamath Experiment Station Klamath Falls, OR.

Variety	Row	Use	Yield lb/acre	Bu wt lb/bu	6/64%	5.5/64%	Pan %	Lodge %	Height inch	50% Heading day of the year
UC 1135	6-row hull-less	0	7640	53.8	91.5	6.1	2.3	0	27.6	180
UC 1047	6-row feed	0	6960	52.0	89.1	7.9	3.0	0	37.4	180
UC 1136	2-row hull-less	0	6290	60.8	79.4	15.4	5.2	0	31.5	183
T/S//E 11-18	6-row potential malting type	0	6060	52.5	64.0	24.9	11.1	28	40.4	180
T/S//E 11-33	6-row potential malting type	0	6050	54.3	65.8	25.5	8.7	0	36.4	181
Mean			6600	54.7	77.9	16.0	6.1	6	34.7	181
LSD (0.05)			NSD	2.0	9.2	7.0	3.0	NSD	2.6	NSD
CV (%)			17.1	2.4	7.6	28.6	31.9	297.8	4.8	0.9
P value			0.269	<0.001	<0.001	<0.001	<0.001	0.124	<0.001	0.318

Table 5. 2005 OSU Elite Spring Barley Nursery, planted in organic soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Row	Use	Yield lb/acre	Bu wt lb/bu	6/64%	5.5/64%	Pan %	Lodge %	Height inch	50% Heading day of the year
T/S//E 11-18	6-row potential malting type	0	8820	55.4	96.8	2.5	0.8	0	NA	199
UC 1047	6-row feed	0	8700	53.0	96.7	2.7	0.6	0	NA	195
T/S//E 11-33	6-row potential malting type	0	8460	55.0	94.8	4.2	1.0	0	NA	198
UC 1135	6-row hull-less	0	6590	57.5	95.1	3.6	1.4	0	NA	195
UC 1136	2-row hull-less	0	6320	61.8	93.0	5.4	1.6	0	NA	205
Mean			7780	56.5	95.3	3.7	1.1	0		198
LSD (0.05)			1300	1.7	2.3	1.8	0.6	NA		1
CV (%)			10.8	2.0	1.6	31.2	36.7	NA		0.3
P value			0.002	<0.001	0.024	0.022	0.024	NA		<0.001

Table 6. 2005 Western Regional Soft Spring Wheat Nursery, planted in mineral soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
Alpowa	SWS	9770	64.3	0	41.3	186
Alturas	SWS	8630	63.2	0	39.4	186
WA007964	SWS	8460	63.1	0	43.3	188
WA007952	SWS	8260	65.0	0	36.4	158
Louise	SWS	8180	63.6	0	41.3	184
WA007963	SWS	8040	65.0	0	39.4	186
IDO645	SWS	7860	65.3	0	39.4	182
IDO610	SWS	7850	65.8	0	37.4	183
Nick	SWS	7700	65.6	0	35.4	181
IDO630	SWS	7490	64.0	0	37.4	186
IDO629	SWS	7240	63.9	0	39.4	188
WQL7PENWX-2	SWS	7230	64.8	0	35.4	185
IDO609	SWS	6750	64.4	0	34.4	180
IDO632	SWS	6720	64.2	0	31.5	180
IDO642	SWS	6290	65.1	0	34.4	180
WA007960	SWC	6250	65.1	0	36.4	185
Mean		7670	64.5	0	37.6	184
LSD (0.05)		1320	1.5	NA	2.9	2
CV (%)		12.1	1.6	NA	5.5	0.9
P value		<0.001	0.009	NA	<0.001	<0.001

[1]SWS = soft white spring; SWC = soft white club.

Table 7. 2005 Western Regional Soft Spring Wheat Nursery, planted in organic soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
IDO642	SWS	8260	62.3	0	30.5	199
WQL7PENWX-2	SWS	7890	61.6	0	31.5	201
Alturas	SWS	7770	62.3	0	32.5	201
WA007963	SWS	7500	61.3	0	33.5	201
IDO632	SWS	7390	62.8	0	25.6	194
WA007952	SWS	7360	63.2	0	30.5	199
IDO610	SWS	7130	63.0	0	33.5	199
IDO630	SWS	6800	59.0	0	34.4	203
IDO609	SWS	6770	63.5	0	31.5	198
IDO629	SWS	6590	57.5	0	38.4	203
Louise	SWS	6400	61.3	0	35.4	199
WA007960	SWC	6360	62.0	0	31.5	200
WA007964	SWS	6150	58.9	0	36.4	202
Nick	SWS	6110	62.7	0	33.5	199
IDO645	SWS	5770	62.0	0	34.4	200
Alpowa	SWS	5440	58.7	0	33.5	201
Mean		6850	61.4	0	32.9	200
LSD (0.05)		1230	2.4	NA	3.0	2
CV (%)		12.6	2.8	NA	6.4	0.5
P value		<0.001	<0.001	NA	<0.001	<0.001

[1]SWS = soft white spring; SWC = soft white club.

Table 8. Three-year yield summary, Western Regional Soft Spring Wheat Nursery, planted in mineral soil Klamath Experiment Station, Klamath Falls, OR, 2003-2005.

Variety	Type[1]	Yield 2003	Yield 2004	Yield 2005	2-yr mean Yield	2-yr mean Rank	3-yr mean Yield	3-yr mean Rank
		lb/acre	lb/acre	lb/acre	lb/acre		lb/acre	
Alpowa	SWS	3500	8380	9770	9075	1	7217	1
IDO609	SWS		8580	6750	7665	4		
WA007952	SWS		6050	8260	7155	5		
IDO610	SWS		9580	7850	8715	2		
IDO629	SWS		8440	7240	7840	3		
Mean		3500	8480	8260	8370		7217	

[1]SWS = soft white spring.

Table 9. 2005 Western Regional Hard Spring Wheat Nursery, planted in mineral soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
OR4990115	HRS	7780	68.0	0	35.4	185
Hank	HRS	7700	64.0	0	35.4	181
ML455-533-2	HWS	7640	64.6	0	39.4	192
UC1296	HWS	7010	64.9	0	35.4	180
IDO377S	HRS	6930	67.2	0	37.4	182
OR4201080	HWS	6850	63.8	0	32.5	186
OR4201019	HRS	6690	66.1	0	34.4	184
OR4990114	HRS	6550	64.1	0	34.4	181
WA007957	HWS	6520	63.5	0	41.3	183
IDO626	HRS	6350	65.1	0	30.5	181
OR4990092	HWS	6330	62.5	0	29.5	186
IDO612	HRS	6210	65.8	0	36.4	181
OR4201104	HWS	6090	62.8	0	35.4	187
OR4201027	HRS	6060	62.4	0	30.5	185
Clear White	HWS	5690	64.6	0	30.5	181
UC1419	HWS	5630	62.6	0	27.6	187
ML316-Maya74-2	HWS	5470	61.4	0	36.4	184
UC1418	HWS	5380	63.5	0	23.6	181
Mean		6490	64.3	0	33.7	183
LSD (0.05)		1030	2.7	NA	2.3	2
CV (%)		11.2	2.9	NA	4.9	0.7
P value		<0.001	<0.001	NA	<0.001	<0.001

[1]HRS = hard red spring; HWS = hard white spring.

Table 10. 2005 Western Regional Hard Spring Wheat Nursery, planted in organic soil (ranked by yield), Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
IDO377S	HRS	8330	63.5	0	36.4	199
WA007957	HWS	7880	62.1	0	37.4	200
IDO626	HRS	7650	62.4	0	30.5	198
OR4201027	HRS	7150	61.3	0	28.5	202
OR4990092	HWS	7080	59.5	0	26.6	203
Clear White	HWS	6740	63.6	0	31.5	199
Hank	HRS	6680	62.8	0	32.5	198
ML316-Maya74-2	HWS	6630	61.2	0	32.5	199
OR4990114	HRS	6600	61.8	0	31.5	197
IDO612	HRS	6450	62.0	0	31.5	197
UC1296	HWS	6390	63.0	0	30.5	198
OR4201019	HRS	6240	65.0	0	31.5	199
ML455-533-2	HWS	6140	56.0	0	33.5	208
UC1418	HWS	6100	60.4	0	23.6	199
UC1419	HWS	5890	59.0	0	24.6	205
OR4201080	HWS	5730	61.6	0	26.6	202
OR4201104	HWS	5620	61.5	0	34.4	205
OR4990115	HRS	5330	61.1	0	31.5	201
Mean		6590	61.5	0	30.8	200
LSD (0.05)		1230	2.4	NA	2.5	2
CV (%)		13.1	2.8	NA	5.8	0.6
P value		<0.001	<0.001	NA	<0.001	<0.001

[1]HRS = hard red spring; HWS = hard white spring.

Table 11. Three-year yield summary, Western Regional Hard Spring Wheat Nursery, planted in mineral soil, Klamath Experiment Station, Klamath Falls, OR, 2003-2005.

Variety	Type[1]	Yield 2003	Yield 2004	Yield 2005	2-yr mean Yield	2-yr mean Rank	3-yr mean Yield	3-yr mean Rank
		lb/acre	lb/acre	lb/acre	lb/acre		lb/acre	
IDO377S	HRS	4080	10820	6930	8875	1	7277	1
OR4990092	HWS	4000	10120	6330	8225	2	6817	2
OR4201019	HRS		4910	6690	5800	6		
OR4201080	HWS		5480	6850	6165	4		
OR4201104	HWS		5000	6090	5545	7		
OR4201027	HRS		5830	6060	5945	5		
OR4990114	HRS		6070	6550	6310	3		
UC1419	HWS		5370	5630	5500	8		
Mean		4040	6700	6391	6546		7047	

[1]HRS = hard red spring; HWS = hard white spring.

Table 12. 2005 OSU Elite Spring Wheat Nursery, planted in mineral soil, Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
B. Grande	HW	7780	65.3	0	27.6	186
BZ998-447W	HW	7450	62.3	0	35.4	187
WA007952	SW	5890	65.3	0	31.5	187
WA007964	SW	5630	63.0	0	38.1	292
Lolo	HW	5580	65.0	0	35.4	189
Alturas	SW	5570	62.7	0	31.5	191
IDO632	SW	5570	63.1	0	28.9	186
IDO597	HW	5400	62.3	0	32.8	188
IDO593	HR	5360	62.0	0	31.5	186
Louise	HW	5320	63.0	0	36.7	187
Jerome	HR	5300	64.3	0	32.8	186
Jubilee		5210	63.4	0	35.4	188
OR4870532	SW	5160	63.5	0	30.2	190
Alpowa	SW	5090	63.3	0	36.7	192
WA007931	HW	5040	65.2	0	36.7	187
OR4201262	HW	5040	65.2	0	31.5	189
Macon	HW	4920	64.4	0	36.7	186
OR4201261	HW	4920	64.2	0	31.5	191
Jefferson	HR	4900	63.4	0	35.4	186
Winsome	HW	4850	62.0	0	28.9	189
Nick	SW	4730	64.3	0	31.5	186
ML1007225	HW	4700	62.6	0	32.8	192
OR4201219	HR	4680	63.2	0	31.5	189
ML042-37A	SW	4640	61.5	0	31.5	189
IDO377S	HW	4290	64.7	0	32.8	190
B. Pronto	HR	4170	63.7	0	35.4	186
Hank	HR	3960	63.2	0	32.8	188
ML04115A98	SW	3650	64.0	0	34.1	190
ML2-24spc5	HW	3520	63.3	0	31.5	192
OR4990115	HR	3230	64.2	0	32.8	190
Mean		5050	63.6	0	33.1	192
LSD (0.05)		1630	2.0	NA	3.2	NSD
CV (%)		19.8	1.9	NA	5.9	16.5
P value		<0.001	0.003	NA	<0.001	0.388

[1]HW = hard white; SW = soft white; HR = hard red.

Table 13. 2005 OSU Elite Spring Wheat Nursery, planted in organic soil, Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
WA007952	SW	10260	64.0	0	34.1	199
OR4870532	SW	9310	63.0	0	32.8	200
Alpowa	SW	8500	63.0	0	35.4	202
Alturas	SW	8060	63.0	0	34.1	200
OR4201262	HW	7990	63.0	0	27.6	204
BZ998-447W	HW	7740	60.0	0	35.4	199
IDO377S	HW	7680	64.0	0	34.1	199
IDO593	HR	7650	63.1	0	31.5	198
Hank	HR	7560	64.0	0	31.5	199
Macon	HW	7560	62.0	0	31.5	199
Lolo	HW	7520	63.0	0	35.4	199
WA007931	HW	7520	63.2	0	42.0	199
Louise	HW	7430	62.0	0	36.7	199
WA007964	SW	7290	62.3	0	34.1	202
OR4990115	HR	7200	62.0	0	32.8	201
Nick	SW	7150	63.0	0	31.5	198
OR4201261	HW	7090	62.0	0	28.9	205
Jerome	HR	7050	62.0	0	31.5	164
Winsome	HW	6960	61.0	0	32.8	205
Jefferson	HR	6690	62.0	0	32.8	199
OR4201219	HR	6270	60.5	0	30.2	203
IDO632	SW	5990	63.0	0	26.2	195
IDO597	HW	5770	62.0	0	31.5	199
B. Pronto	HR	5690	63.0	0	31.5	196
B. Grande	HW	4790	62.0	0	27.6	195
Mean		7309	62.1	0	33.0	199

[1]HW = hard white; SW = soft white; HR = hard red.

Note: Data represent one replication only, therefore no statistics are available to make comparisons between entries.

Table 14. 2005 OSU Elite Winter Wheat Nursery, planted in mineral soil, Klamath Experiment Station, Klamath Falls, OR.

Variety	Type[1]	Yield lb/acre	Bu wt lb/bu	Lodge %	Height inch	50% Heading day of the year
OR3970965	SW	7620	63.7	0	40.7	NA
ID92-16004A	SW	7540	63.0	0	39.4	NA
ID92-22407A		7030	62.7	0	34.1	NA
Gene	SW	6770	60.7	0	36.7	NA
ORH010917		6760	64.3	0	38.1	NA
Coda	SW	6700	62.0	0	36.7	NA
OR2010241	SW	6580	64.0	0	38.1	NA
ORH010085		6550	63.0	0	38.1	NA
Dune	SW	6520	63.0	0	32.8	NA
Tubbs	SW	6460	61.7	0	39.4	NA
ORH010920		6440	63.7	0	36.7	NA
Brundage96	SW	6390	64.7	0	34.1	NA
OR2010239	SW	6320	64.3	0	38.1	NA
Finch	SW	6210	64.0	0	42.0	NA
ARS99123		6120	62.7	0	35.4	NA
Rod	SW	6000	62.7	0	39.4	NA
ORCF-102	SW	5990	62.7	0	35.4	NA
OR9900553	SW	5990	62.3	0	34.1	NA
ORI202183C		5980	60.3	0	32.8	NA
IDO587CL		5930	60.3	0	32.8	NA
ORH012183		5920	64.0	0	32.8	NA
Masami		5840	63.0	0	32.8	NA
OR9901887	SW	5730	63.3	0	34.1	NA
Simon	SW	5720	63.0	0	36.7	NA
ORH010918		5710	61.7	0	32.8	NA
OR9901619	SW	5700	61.3	0	34.1	NA
OR2010007-05C		5680	62.3	0	36.7	NA
Mohler	SW	5630	65.0	0	32.8	NA
ORH011481		5500	62.0	0	35.4	NA
ORCF-101	SW	5490	65.0	0	34.1	NA
Chukar	CL	5310	62.3	0	35.4	NA
Westbrd528		5230	61.7	0	32.8	NA
Weatherford	SW	5200	63.0	0	38.1	NA
Madsen	SW	5190	62.7	0	31.5	NA
BZ 6W93-901a		4970	63.3	0	32.8	NA
ORH010083		4960	62.7	0	35.4	NA
IDO620		4830	62.3	0	35.4	NA
OR 941611	SW	4810	61.7	0	38.1	NA
Stephens	SW	4550	58.7	0	30.2	NA
ORSS-1757	SW	4160	62.7	0	42.0	NA
Mean		5900	62.7	0	35.7	
LSD (0.05)		NDS	2.6	NA	4.0	
CV (%)		21.1	2.5	NA	6.9	
P value		0.314	0.003	NA	<0.001	

[1]SW = soft white; CL = club.

Yield and Quality of Teff Forage as a Function of Varying Rates of Applied Irrigation and Nitrogen

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Introduction

(Background information is adapted from Stallknecht [1997] and Ketema [1997])

Background

Teff (*Eragrostis tef* [Zucc.], *Poaceae)* is a C4 annual tropical grass. It has a large crown, many tillers, and a shallow diverse root system. Teff is traditionally harvested for grain in Ethiopia, where it was first domesticated between 4000–1000 BC. Teff flour is preferred in the production of enjera, a major food staple in Ethiopia. Teff flour is also eaten as porridge or used as an ingredient of home-brewed alcoholic drinks. Teff is grown on a limited basis for livestock forage in other parts of Africa, India, Australia and South America. In the United States, small acreages of teff are grown for grain production (Caldwell, ID) and sold to Ethiopian restaurants throughout the United States, or used as a late-planted livestock forage (Larson, MN). The nutritional value of teff grain is similar to traditional cereals. Teff is considered to have an excellent amino acid composition, lysine levels higher than wheat or barley, and slightly less than rice or oats. Teff is also higher in several minerals, particularly iron. Teff contains very little gluten and is being evaluated in gluten-free food systems. Approximately 1 million Americans suffer from Celiac disease (gluten sensitivity) and teff may provide a niche for meeting these dietary requirements.

Teff germplasm is characterized by a wide variation of morphological and agronomic traits. Typical maturity for grain varies from 93 to 130 days. Grain color ranges from pale white to ivory white, very light tan to deep brown to reddish-brown purple. Teff seed is very small with l000-seed weight averaging 0.3–0.4 g, similar to timothy. Teff is adapted to environments ranging from drought-stressed to water-logged soil conditions. In its native habitat, maximum production occurs at elevations of 5,900 – 6,900 ft, growing season rainfall of 17–22 inches, with a temperature range of 50–85°F. Teff is day length sensitive and flowers best at 12 hours of daylight. Tests at higher latitudes showed reduced flowering and seed formation for both short day (8

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hours of light) and long day (16 hours of light) conditions. However, genetic diversity is wide for this species and grain production using selected landraces has been successful in some cases at temperate latitudes.

Several improved varieties have been selected for grain production and released in Ethiopia, South Africa, and the United States (Wayne Carlson, pers. comm., 2006). While the primary emphasis has been on grain qualities, some consideration of forage use has also occurred. Much of the teff seed available in commerce are common landraces, not released varieties, and thus have varying degrees of uniformity and unknown performance.

Past Work at Klamath Falls

In 2003 and 2004 teff was grown on a quasi-commercial scale at KES using the best available information and expertise of the station staff. We planted seed of an unnamed cultivar whose seed had been increased for grain production by James Van Leeuwen in the Willamette Valley. Its designation is VA-T1-Brown. This seed was not of a released variety, but had reportedly come directly from Ethiopia. We have continued to use it due to its favorable performance compared to limited plantings we made using seed samples from the USDA Germplasm Repository in Pullman, Washington. Future studies should include a more rigorous comparison of released varieties and unreleased landraces of common types to determine characteristics and performance of the various types.

Due to the reports of teff's frost intolerance, we delayed planting until early June each year. At KES the soils are sandy loams containing about 1.5 percent organic matter. The fields where teff was planted have a pH of 6.5-7.0. We applied 60 lb/acre nitrogen (N) at planting and another 60 lb/acre N after first cutting using 15-15-15 fertilizer. From these nonreplicated bulk plantings we made the following observations:

1. With a fine, firm seed bed, seedlings emerged in about 3 days both years.
2. Stands were poor when seed was planted deeper than 0.5 inch. Seed left on the surface did germinate given sufficient continuous surface moisture. A safe compromise seems to be planting seed around 0.125-0.25 inch deep.
3. Thick vigorous stands were achieved by seeding at 8-9 lb/acre. The plant tillered extensively. We suspected we could have reduced the seeding rate to 5-6 lb/acre without sacrificing yield.
4. Early growth was vigorous when daytime maximum air temperatures were consistently in the 80-90° F range after emergence in 2003, but the teff grew very slowly when daytime maximum air temperatures remained in the 60-75° F range after emergence in 2004.
5. Under good conditions, it was about 50-55 days from planting to first cutting, and another 40-45 days from first cutting to second cutting.
6. After cutting, regrowth was vigorous if cutting height was kept at 3-4 inches (leaving more leaf area for photosynthesis). If teff was cut at a 1- to 2-inch height it regrew much slower.
7. The root system was not strong and plants were easily pulled from the ground if the swather glide plate was dragging on the ground too much. We suspect this would also be true if

animals were allowed to graze the teff, especially before first cutting.
8. Crude protein ranged from 12 to 17 percent depending on the cutting time.
9. Teff seems to accumulate fairly high levels of potassium (K), which may be of concern in some feed rations. We commonly saw K concentrations around 3 percent by dry weight.
10. Teff was more prone to lodge if cutting was delayed until after seedhead emergence.
11. Teff took about a day longer than orchardgrass to cure sufficiently in the field for baling.
12. Informal taste tests suggested horses considered teff to be very palatable compared to orchardgrass. Informal testing with cattle has been less conclusive.
13. Mature teff was 100 percent killed when temperatures dipped slightly below 32^{o}F.

Objectives

1. We sought to evaluate teff's yield and forage quality response to varying levels of N fertilizer and irrigation at three locations representing different climate regimes and possible production areas in Oregon.
2. We also wanted to make additional observations on seeding rate and other agronomic factors where possible at least at one location.

Procedures

Klamath Falls

Approximately 2.6 acres of teff was planted on a Poe fine sandy loam soil containing about 1.5 percent organic matter on June 6 using a John Deere grain drill with a grass seed attachment. The previous crop was a uniform area of bulk teff for forage in 2004. A portion of the field was used for the irrigation rate by N rate study. Half of that area was seeded at a 3 lb/acre rate, and the other half was seeded at 6 lb/acre. These two areas were separated by an irrigation line that provided a "line source" for variable irrigation rates during the season. The response to available moisture was evaluated by harvesting small plots laid out at various distances from the line source. The plots closer to the line source received the higher irrigation rates (Table 1). Nitrogen rates were applied at planting and after first cutting (Table 2). Due to an error, the N rate by irrigation study at Klamath Falls did not include a true N_0 (no nitrogen) treatment. In another portion of the field, an area used for a separate N rate study did include a true N_0 treatment. This area was grown under uniform irrigation. In all cases, the N rates were applied in a randomized complete block design with four replications. An herbicide tank mix of 2,4-D amine at 0.54 lb a.i./acre plus dicamba at 0.19 lb a.i./acre was applied on July 7 to control broadleaf weeds.

The first teff cutting was made on August 8 and second cutting was made on September 13. The first cutting occurred perhaps a week later than ideal in order to demonstrate the teff trial at a public field day, resulting in seed heads that were almost completely emerged. At the time of second cutting, seedheads were just beginning to emerge. Forage fresh weights were measured immediately in the field and samples were collected from each plot for drying to correct yields to a dry weight basis as well as to perform forage quality analysis. After drying and weighing, samples were ground to 2-mm-sieve size in a Wiley Mill (Arthur H. Thomas Co.) and to 1-mm-sieve size in a Udy Mill

(Udy Corp.) before being analyzed in a near infrared spectrophotometer (NIRS) (NIRSystems) to determine forage quality. Quality testing at KES is accomplished using the NIRS and equations developed by the NIRS Consortium, Madison, Wisconsin. Calculated forage quality parameters included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and relative forage quality (RFQ). We used NIRS equations developed for other grasses due to the limited data available for teff.

Medford

Approximately 0.5 acre of teff was planted on May 13 on a Central Point sandy loam containing about 5 percent organic matter using a John Deere grain drill with a grass seed attachment. The previous crop had been sugar beets for seed. Due to the crude adjustment of seeding rate on that machine, the first pass seeded only about 1.2 lb/acre. After making a slight adjustment, the second run seeded about 9.2 lb/acre for a total seeding rate of 10.4 lb/acre. The irrigation line source was set up down the middle of the plot area to provide the various irrigation rates (Table 1). Nitrogen rates were laid out perpendicular to the irrigation line across the width of the field. N rate treatments were applied in a randomized complete block design with four replications (Table 2). The first cutting was made on July 22 and second cutting was made on September 3. In both cases the plots were cut when seedheads were just beginning to emerge. Samples were dried from each plot for moisture correction and quality analysis was done as at the other sites.

To control broadleaf weeds that emerged with the teff, a tank mix of 2,4-D at 0.7 lb a.i./acre plus dicamba at 0.25 lb a.i./acre was applied on June 23, resulting in no visible damage to the teff. Weed competition after the herbicide application was minimal due to the vigorous teff stand.

Ontario

Approximately 0.5 acre of teff was planted on June 23 on a Nyssa silt loam containing about 1.5 percent organic matter. The field was fallow the previous year. Seed was broadcast by hand using an Earthway Hand Spreader at a uniform rate of 3 lb/acre, and was incorporated only by irrigation droplet impact on the bare soil. As at the other locations, irrigation treatments were imposed by installing an irrigation line source and harvesting plots at different distances from the line source (Table 1). N rates were applied in a randomized complete block design with four replications (Table 2). Small broadleaf weeds were controlled with an application of bromoxynil at 0.25 lb a.i./acre shortly after crop and weed emergence, with no visible damage to the teff. Harvests occurred when seed heads were beginning to emerge. First cutting was on August 15 and the second cutting was on September 12. Further details on the Ontario trial can be found in the 2005 Malheur Experiment Station Annual Report.

Statistical Analysis

Statistics on yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level. For this report, the N rate x irrigation rate studies were analyzed as a split-block design, with irrigation rate as the main plot and N rate as subplot. Because of the inherent design limitations of line-source irrigation systems, irrigation rate treatments could not be randomized, so that a strictly valid error term could not be calculated for the main plot irrigation rate effect. Thus, while caution must be exercised in interpreting the irrigation rate results, the large responses observed in this study should be valid even with this less robust statistical method. Because the N rates were randomized, the N rate and irrigation by N rate interaction error terms are completely valid for interpretation in these studies.

Results and Discussion

Klamath Falls Nitrogen Rate under Uniform Irrigation

For the first cutting, there was a significant difference between N rate treatments only for yield and CP (Table 3). The biggest effect was the difference between the N_0 treatment and the two higher N rates. For the second cutting, however, there was a significant treatment effect for all yield and quality factors except RFQ (Table 3). Yield and quality were greatest at the highest N rate and lowest for the N_0 rate for all but RFQ, although the largest difference tended to be between the N_0 treatment and the two higher N rates, which were only significantly different from one another for CP, NDF, and RFV.

Klamath Falls Irrigation by N rate

Germination and emergence were good, except at the farthest reaches from the irrigation line, where very slight differences in moisture resulted in obvious stand differences.

3 lb/acre Seeding Rate

Irrigation treatments had a significant effect on all yield and quality parameters for the first cutting (Table 4). The most obvious effect was the lack of measurable yield at the low irrigation rate treatment (plants existed, but were too small and stunted to be harvested normally). Ignoring the low irrigation treatment, teff yield and quality tended to be better at the medium irrigation rate than at the high rate, although differences between the two were not always significant.

For first cutting, N rates had a significant effect on yield and all quality parameters except RFQ (Table 4). Looking at just the N rate effects within the high and medium irrigation rates, the N_2 treatment was significantly better than the N_1 treatment for CP, ADF, NDF, and RFV, but was significantly worse than the N_1 treatment for yield. This N rate response illustrates a classic tradeoff between yield and quality, but it is uncertain why the yield would be lower for the N_2 treatment.

The irrigation results were less obvious at the second cutting, as there was a significant irrigation treatment effect only for CP (Table 5). However, there was a significant N rate effect for CP, ADF, NDF, and RFV. Yield was not significantly affected by either irrigation or N rate. The higher N rate resulted in significantly greater CP and RFV within each irrigation treatment, as well as significantly lower ADF and NDF. Thus the trade-off between yield and quality that was observed for first cutting was also observed for second cutting at the 3 lb/acre seeding rate, although the obvious beneficial effects of irrigation observed at first cutting were not significant for the second cutting.

6 lb/acre Seeding Rate

There was a significant response to the irrigation treatments for all yield and quality parameters measured for first cutting (Table 6). The low irrigation treatments had significantly lower yields than the medium and high treatments. For all the quality parameters, quality tended to decrease as irrigation increased, although not all differences between irrigation rates were significant.

Nitrogen rates had a significant effect on CP, but not on yield or other quality parameters at first cutting. At all irrigation rates, the N_2 treatment had higher CP than the N_1 treatment.

By the second cutting, teff planted at the 6 lb/acre rate exhibited a significant response to irrigation only in terms of CP, ADF, and RFV (Table 7). The trends in quality were not as obvious as they had been for first cutting. Yields tended to increase with increasing irrigation, but the differences were not significant.

There were no significant differences between N rates for any of the yield or quality parameters, although the trend was for increased yield at the higher N rate. There was a significant interaction between irrigation rate and N rate in some cases, indicating that the response to N rate was not the same at different irrigation rates.

Comparison of 3 lb/acre vs 6 lb/acre Seeding Rates

Due to nonrandomization of the seeding rate, statistical comparisons between the 3 lb/acre and 6 lb/acre seeding rates cannot be made. In general, however, it appeared that yield and protein were more sensitive to differences in N rate at the 3 lb/acre seeding rate than at the 6 lb/acre seeding rate. Yield tended to be higher for the 6 lb/acre seeding rate at first cutting, but the reverse tended to be true at second cutting. In general, under good conditions of irrigation and N nutrition, there was little obvious difference in total yield, although quality seemed to be somewhat better at first cutting for teff seeded at the higher rate.

Medford

Teff emergence was good. Rainfall soon after planting initially resulted in a uniform stand across all treatments. There was a significant irrigation effect on all yield and quality parameters at first cutting (Table 8). The largest difference was between the low irrigation rate and the other two rates, but the differences between the medium and high irrigation rates were significant in some cases. As was seen in Klamath Falls, there was often a trade-off between yield and quality as a function of irrigation rate.

At first cutting there was not a significant yield response to N rate, but the quality parameters were significantly affected by N rate, especially within the medium and low irrigation rate zones. Interestingly, at the time of first cutting it was difficult to visually distinguish the various N rate treatments. The N_0 treatment area was only slightly shorter and a slightly lighter shade of green than the other two treatments for a comparable irrigation rate. Because the soil in Medford is a sandy loam containing about 5 percent organic matter, it is hypothesized that sufficient N mineralization occurred in the early summer to supply most of the plants' N requirements before first cutting. For first cutting, the visual nonresponse to added N confirmed the measured yield data, but not the quality data, illustrating the potential error that can occur when evaluating forage quality by visual information only (Table 8).

At second cutting there was a significant irrigation treatment effect on yield and all quality parameters, similar to results observed at first cutting (Table 9). Unlike first cutting, however, there were significant differences in yield between the high and medium irrigation rates for both the N_2 and N_1 treatments at second cutting. The quality parameters followed a pattern similar to that observed elsewhere, with increased irrigation rate producing greater yield, but lower quality.

By the second cutting, the different N rate treatments were visually very obvious by differences in color and plant height. Unlike first cutting, N rates at second cutting had a significant effect on yield and CP, but none of the other quality parameters. For yield, the largest difference was between the N_1 and N_0 treatments, whereas the largest difference for CP was between the N_2 and N_1 treatments. Like first cutting, the visual response to added N at second cutting confirmed the N rate effect on yield data, but did not predict the lack of response of forage quality other than CP, once again illustrating the potential error that can occur when evaluating forage quality by visual information only (Table 9).

Ontario

Teff emergence at Ontario was less uniform than at the other locations. Emergence was very poor where the soil remained driest due to the lack of moisture availability. However, where moisture was adequate the surface-seeded teff at Ontario germinated well and produced solid stands.

Irrigation treatments did not have a significant effect on first cutting yield or RFQ, although the yield did tend to decrease somewhat under the very low irrigation treatment (Table 10). The irrigation treatment effect was significant for the other quality parameters. Hay quality generally increased as irrigation rate decreased, although not all differences were significant.

There was a significant effect of N rate treatments only for yield, CP, and ADF for first cutting. Although the N_2 treatment had the highest yield in all but the high irrigation rate zone, the largest consistent difference in yield was between the N_0 rate and the other two rates. For CP, within each irrigation zone the highest CP was the N_1 treatment, whereas the lowest CP was the N_2 treatment, although the differences were only sometimes significant. This result does not seem to have a ready explanation. A similar pattern was observed for ADF.

For the second cutting, there was a significant irrigation treatment effect for all yield and quality parameters (Table 11). Although the yields were quite a bit lower than at first cutting due to the much shorter growth period, the yield clearly was reduced for the low and very low irrigation treatments. The pattern observed at the other sites where higher irrigation rates resulted in reduced quality, but higher yields, was also observed at Ontario.

Unlike first cutting, the N rate treatments did not have a significant effect on any of the quality parameters at second cutting, although the effect on yield was significant. There tended to be only small differences and no observable pattern between values of a given parameter for the three N rates under a particular irrigation regime. The effect on yield was unexpected, with the N_0 treatment producing the highest yield within a given irrigation zone.

Conclusion

Teff grew well and produced good yields and quality at all three locations that represent different climate types in Oregon. Although the responses to irrigation and N rates varied somewhat at the different locations and varied between first and second cuttings, in general there were consistent responses. The lowest rate of irrigation and lack of added fertilizer N clearly reduced yields. However, the highest rate of irrigation and N fertilizer often did not improve yield or quality compared to a moderate rate of both N and irrigation. Thus, under the range of conditions examined here, it appeared that teff responded to some added N, but that N fertilization greater than about 80-90 lb N/acre during the growing season was probably not justified. Teff also responded to a moderate level of irrigation. Using automated weather data collected at the three trial sites, it appears that yield and quality did not improve when irrigation exceeded about 0.5-0.6 of calculated Kimberly-Penman evapotranspiration rate (data not shown), but a more detailed examination of this conclusion is beyond the scope of this report. If teff is planted to a well-prepared seedbed, and adequate moisture is present after planting, it appears that a 3 lb/acre seeding rate may be sufficient to result in a good stand and optimal yield, although it also appears teff might be more sensitive to nonideal conditions at the lower seeding rate.

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Table 1. Planting date, harvest dates, and irrigation plus precipitation treatments for teff forage production at three Oregon sites, 2005.

Location	Planting date	1st Cutting date	2nd Cutting date	Irrigation treatment	Irrigation plus precipitation from planting to 1st cutting	Irrigation plus precipitation from 1st cutting to 2nd cutting
					—— inches	——
Klamath Falls	June 6	Aug 8	Sept 13	High	9.87	8.2
				Medium	4.41	3.58
				Low	0.19	0.00
Medford	May 13	July 22	Sept 3	High	14.88	15.4
				Medium	8.64	8.09
				Low	2.93	1.39
Ontario	June 23	Aug 15	Sept 12	High	13.25	3.75
				Medium	10.42	2.96
				Low	7.65	2.19
				Very Low	4.68	1.36

Table 2. Treatment labels assigned to rates of nitrogen (N) applied during entire season at three Oregon locations, 2005. N applications were split, with approximately half applied at planting, and half after first cutting.

Location	Treatment N_0	Treatment N_1	Treatment N_2
	——	lb N/acre	——
Klamath Falls	0	91	195
Medford	0	84	168
Ontario	0	80	160

Table 3. Teff forage yield and quality response to different rates of nitrogen grown under uniform irrigation at the Klamath Experiment Station, Klamath Falls, OR in 2005.

Cutting	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
First	N_2	1.74	16.6	35.2	59.5	96	99
	N_1	1.72	14	36.5	60.7	93	100
	N_0	1.02	11.9	34.9	59	97	113
P value		0.012	0.014	0.459	0.302	0.37	0.084
$LSD_{(0.05)}$		0.44	2.6	NS	NS	NS	NS
Second	N_2	2.68	16	35.4	57.4	100	101
	N_1	2.62	13.6	36.6	59.5	95	110
	N_0	2.26	9.1	38.8	60.8	90	108
P value		0.01	<0.001	0.005	0.015	0.004	0.271
$LSD_{(0.05)}$		0.24	1.3	1.6	2	4	NS

Table 4. Teff forage yield and quality response to different rates of irrigation and nitrogen at first cutting. Results are shown for teff planted at the 3 lb/acre seeding rate in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	2.6	16.2	31.4	56.8	106	125
	N_1	2.9	13.5	34.7	60.9	94	119
Medium	N_2	2.64	17.2	30.1	56.3	108	128
	N_1	3.2	14.1	32.6	58.7	101	123
Low	N_2	0	0	0	0	0	0
	N_1	0	0	0	0	0	0
P value (irrig)		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		0.37	1.6	0.8	0.8	2	8
P value (N rate)		0.028	<0.001	0.001	<0.001	<0.001	0.165
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		0.25	0.9	0.9	0.8	2	NS
P (irrig x N rate interaction)		0.162	0.017	0.024	0.003	0.006	0.584

Table 5. Teff forage yield and quality response to different rates of irrigation and nitrogen at second cutting. Results are shown for teff planted at the 3 lb/acre seeding rate in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	1.22	19.2	30.6	54.3	111	108
	N_1	1.41	16.1	32.9	56.2	105	115
Medium	N_2	1.06	19.2	29.8	54	113	112
	N_1	1.14	16.4	31.2	55.6	108	120
Low	N_2	1.26	17.1	29.3	55.1	112	119
	N_1	1.48	13.8	32.1	57.2	104	122
P value (irrig)		0.43	0.037	0.498	0.403	0.643	0.083
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		NS	1.9	NS	NS	NS	NS
P value (N rate)		0.141	<0.001	0.002	0.023	0.007	0.066
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		NS	1.3	1.1	1.6	4	NS
P (irrig x N rate interaction)		0.864	0.935	0.55	0.962	0.845	0.751

Table 6. Teff forage yield and quality response to different rates of irrigation and nitrogen at first cutting. Results are shown for teff planted at the 6 lb/acre seeding rate in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	3.08	15	32	58.1	102	125
	N_1	3.15	12.9	34.3	60.7	95	123
Medium	N_2	2.82	16.6	28.5	54.1	115	142
	N_1	3.1	15.1	29.8	55.1	111	139
Low	N_2	1.58	17.1	27.9	55	114	141
	N_1	1.06	15.4	28	54.8	114	145
P value (irrig)		0.007	0.029	<0.001	0.002	<0.001	0.038
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		0.97	1.6	1.3	2.1	5	15
P value (N rate)		0.733	0.048	0.116	0.266	0.220	0.934
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		NS	1.7	NS	NS	NS	NS
P (irrig x N rate interaction)		0.214	0.948	0.483	0.515	0.593	0.569

Table 7. Teff forage yield and quality response to different rates of irrigation and nitrogen at second cutting. Results are shown for teff planted at the 6 lb/acre seeding rate in 2005 at the Klamath Experiment Station, Klamath Falls, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	1.07	19.7	29.6	53.2	115	113
	N_1	0.97	16.1	32.5	56.1	106	117
Medium	N_2	0.82	17.5	28.9	53.7	115	136
	N_1	0.72	20.9	27.6	52.8	119	116
Low	N_2	0.6	14.4	32	55.4	108	124
	N_1	0.3	12.9	31.1	55.8	108	133
P value (irrig)		0.106	0.007	0.008	0.103	0.029	0.051
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		NS	2.8	1.7	NS	6	NS
P value (N rate)		0.306	0.485	0.57	0.212	0.354	0.429
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		NS	NS	NS	NS	NS	NS
P (irrig x N rate interaction)		0.838	0.014	0.008	0.095	0.046	0.007

Table 8. Teff forage yield and quality response to different rates of irrigation and nitrogen at first cutting, 2005, when grown at the Southern Oregon Research and Extension Center, Medford, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	2.39	8.2	41.2	71	74	86
	N_1	2.16	8.1	40.3	69.7	77	90
	N_0	1.89	7.4	42	72.2	72	86
Medium	N_2	2.03	10.5	36.4	66.2	86	111
	N_1	1.92	7.8	39.4	68.9	79	94
	N_0	1.96	7	40.4	70.5	76	89
Low	N_2	0.3	14.6	27.7	55	114	169
	N_1	0.22	12.3	29.4	56.6	109	156
	N_0	0.22	9.2	35.4	65.8	89	120
P value (irrig)		<0.001	0.004	0.002	0.002	0.001	<0.001
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		0.65	1.9	4.2	4.5	10	19
P value (N rate)		0.44	0.002	0.028	0.008	0.013	0.033
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		NS	1.6	3.1	3.4	8	18
P (irrig x N rate interaction)		0.821	0.196	0.334	0.15	0.164	0.193

Table 9. Teff forage yield and quality response to different rates of irrigation and nitrogen at second cutting, 2005, when grown at the Southern Oregon Research and Extension Center, Medford, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	2.04	10.5	39.6	67.4	80	98
	N_1	2.06	7	39.6	68	80	97
	N_0	0.8	5.9	39.3	64.9	84	96
Medium	N_2	1.58	13.6	32.9	61	97	126
	N_1	1.42	9	33	61.6	96	125
	N_0	0.84	7.2	35.2	62.2	92	112
Low	N_2	0.1	14.7	29.8	60.2	102	150
	N_1	0.06	13.5	30	60.5	101	144
	N_0	0.25	12.6	31.3	59.8	101	139
P value (irrig)		<0.001	0.006	0.003	0.019	0.012	<0.001
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		0.13	2.8	3.7	4.2	11	13
P value (N rate)		<0.001	0.001	0.369	0.497	0.92	0.151
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		0.25	2.1	NS	NS	NS	NS
P (irrig x N rate interaction)		<0.001	0.534	0.78	0.446	0.672	0.782

Table 10. Teff forage yield and quality response to different rates of irrigation and nitrogen at first cutting, 2005, when grown at the Malheur Experiment Station, Ontario, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	1.9	12.6	39	63.3	86	101
	N_1	2.02	15.5	36.8	61.8	91	103
	N_0	1.58	13	38	62.8	88	103
Medium	N_2	2.24	17	35.4	60.2	95	104
	N_1	2.12	18.1	33.2	58.4	101	108
	N_0	1.61	17.8	34	58.9	99	106
Low	N_2	2.32	17.7	33	58.6	100	110
	N_1	2.11	18.9	32	57	104	112
	N_0	1.97	18.8	32.4	57.4	104	110
Very Low	N_2	1.29	17.8	32.1	57.3	105	111
	N_1	1.23	21.6	28.5	53.3	117	110
	N_0	1.16	20.6	29.3	54.3	113	114
P value (irrig)		0.059	<0.001	<0.001	<0.001	<0.001	0.134
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		NS	2.1	2.3	2.4	6	NS
P value (N rate)		0.01	0.034	0.042	0.083	0.07	0.772
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		0.24	1.6	1.8	NS	NS	NS
P (irrig x N rate interaction)		0.66	0.795	0.958	0.956	0.956	0.98

Table 11. Teff forage yield and quality response to different rates of irrigation and nitrogen at second cutting, 2005, when grown at the Malheur Experiment Station, Ontario, OR.

Irrigation treatment	Nitrogen treatment	Yield (ton/acre)	Crude protein (%)	ADF	NDF	RFV	RFQ
High	N_2	1.09	14.2	34.5	56.9	101	121
	N_1	1.08	15.3	34	56.8	102	118
	N_0	1.24	14	35	57.5	100	120
Medium	N_2	1.1	18.4	30.8	55	110	116
	N_1	1.11	18.1	30.9	54.6	111	118
	N_0	1.46	17.6	31.2	55.4	109	119
Low	N_2	0.82	17.6	30.1	53.6	114	123
	N_1	0.58	18.4	28.7	52.9	117	126
	N_0	1.08	18	30.4	55.3	110	117
Very Low	N_2	0.38	16.9	28.1	53	118	140
	N_1	0.27	16.7	29	54.1	114	139
	N_0	0.52	16.7	28	52.7	118	142
P value (irrig)		<0.001	0.001	<0.001	0.04	0.008	<0.001
$LSD_{(0.05)}$ between irrig rates (for a given N treatment)		0.32	1.5	2.2	2.6	8	8
P value (N rate)		0.003	0.664	0.672	0.413	0.531	0.983
$LSD_{(0.05)}$ between N treatments (at a given irrig rate)		0.17	NS	NS	NS	NS	NS
P (irrig x N rate interaction)		0.771	0.956	0.688	0.393	0.43	0.488