USDA-ARS Club Wheat Breeding in Oregon

Jeron Chatelain, Kimberly Garland Campbell, Chris Hoagland, and Steve Petrie

Abstract

Club wheat is commonly grown in Washington and northeastern Oregon and usually marketed as a mixture with soft white wheat called 'Western White'. The goal of the USDA-Agriculture Research Service Club Wheat Breeding Program is to improve club wheat cultivars, especially to increase yields and disease resistance, and to maintain the excellent end-use quality that characterizes the class. The objective of this research was to evaluate preliminary and advanced winter club wheat breeding lines in northeastern Oregon to develop competitive winter club cultivars suited for these growing conditions. Four locations were used to evaluate 16 breeding and 4 Western Regional Cooperative nurseries for early spring growth, winter damage, heading date, height, disease, grain yield, test weight, and quality. A seeding rate study trial was conducted to compare how varying seeding rates affect overall yield in club wheat varieties compared to soft white common varieties. Coleoptile length measurements were taken on preliminary breeding lines to identify genotypes with long coleoptiles to improve deep planting emergence.

Key words: club wheat, coleoptile length, Western White, wheat breeding

Introduction

In the United States club wheat is grown only in the Pacific Northwest and it is used almost exclusively in blends with soft white wheat, called 'Western White', for export markets in Asia. Due to its characteristically weak-gluten, low-protein flour with high break flour extraction, club wheat is sought by the milling and baking industry for cakes, pastries, crackers, and flatbreads. The demand for Western White and club wheat remains extremely high and is important for our export markets and for use by local millers and bakers. This makes club wheat a vital part of the wheat industry in northeastern Oregon, as well as the entire PNW.

During the past several years there has been a steady decline in the club wheat acreage grown. In 2001, 54,000 acres of club wheat were grown in Oregon, which accounted for 6% of all wheat grown in the state. Then in 2008 and 2009 there were only between 10,000 and 11,000 acres, which is only 1% of all wheat grown. Likewise, for Washington in 2001 there were 230,000 acres grown, which was 9% of all wheat acreage in the state, and in 2009 there were 128,000 acres or 6% of all wheat grown. Part of the reason for the decline was the loss of a premium on the price for club wheat. Also, there is a perception among growers that club wheat varieties do not yield or compete as well as other common soft white varieties. This unfortunate perception is no longer true. Data from the past few years have shown that the current club wheat varieties such as 'Chukar', 'Coda', 'Cara', and 'Bruehl', will yield and perform just as well as the leading soft white winter varieties. Not only do these club wheat varieties have excellent quality, but all of the varieties possess superb disease resistance packages, with excellent stripe rust, cephalosporium stripe, and strawbreaker foot rot resistance.

The club wheat breeding program is coordinated from the USDA-Agricultural Research Service (ARS) Wheat Genetics, Quality, Physiology, and Disease Research Unit at Pullman, Washington under the direction of Dr. Kim Garland Campbell, with technical assistance provided by Jeron Chatelain at CBARC and Adrienne Burke, Chris Hoagland, and Lesley Murphy at Pullman. Administrative assistance in Oregon is provided by Dr. Steve Petrie. Dr. K. Garland Campbell is also coordinator of the Western Regional Cooperative Nurseries. The goal of the program is to improve emergence, cold tolerance, disease resistance, and yield potential of club wheat cultivars to reduce grower risk, as well as improve end-use quality. The objective of this research was to evaluate preliminary and advanced winter club wheat breeding lines at several locations in northeastern Oregon with the goal of developing competitive winter club cultivars suited for these growing conditions, with high genetic resistance to major disease and excellent end-use quality.

Materials and Methods

Four northeastern Oregon locations (Pendleton, Moro, Lexington, and Hermiston) were used for 16 breeding and 4 Western Regional nurseries, and one seeding rate study trial. All sites were dryland except Hermiston, which was pivot irrigated. The Pendleton nurseries and Moro nurseries were located at the Pendleton and Sherman Stations, respectively, of the Columbia Basin Agricultural Research Center. The other two locations were Madison Farms near Hermiston with cooperator Kent Madison, and Starvation Farms north of Lexington with cooperator Chris Rauch. Average annual precipitation at Pendleton is 17 inches, Moro receives 11 inches, and Lexington and Hermiston receive about 10 inches.

Pendleton

Replicated winter wheat nurseries were planted October 2, 2008 after conventional fallow. The winter yield trial nurseries evaluated were the USDA-ARS Oregon Elite and USDA-ARS Washington Elite, consisting of 30 entries replicated 4 times, and the USDA-ARS Preliminary 1, Preliminary 2, Preliminary 3, and Preliminary 4 nurseries, consisting of 36 entries each and replicated 3 times. Two cooperative regional nurseries were evaluated, the Western Regional Soft Winter Wheat Nursery and the Western Regional Hard Winter Wheat Nursery, comprised of 34 and 17 entries, respectively, with 3 replications. All replicated trials were arranged in a randomized complete block design. The ARS unreplicated yield trial (09 F6 Yield) was planted October 8, 2008 and included breeding lines from early generation material. Included in the unreplicated nursery were the check cultivars Chukar and 'Tubbs' alternately spaced about every 10 entries. All seed, excluding the ARS unreplicated 09 F6 Yield trial, was treated prior to planting with Dividend® at recommended label rates. The seeding rate was approximately 20 seeds/ft^2 and the plot size approximately 77.5 ft^2. Plots were dusted in or seeded at a depth of 0.5 inches and into no moisture, due to the lack of rain in the fall. This was done using a five-row Hege drill with double-disc openers on 12-inch spacing. Fifty four pounds of nitrogen (N)/acre as anhydrous ammonia and 20 lb of sulfur/acre as Nitrosul® were applied prior to planting. Broadleaf weeds were controlled by the application of 13 oz of Huskie®/acre the last week of

April. A spring nitrogen fertilizer application was made in mid April to the Western Regional Hard Winter Wheat Nursery as Solution 32 at a rate of 20 lb of N/acre. For the ARS unreplicated F6 Yield trial, 74 lb of N/acre as anhydrous ammonia and 20 lb of sulfur/acre as Nitrosul were applied prior to planting. The herbicide Hoelon® EC was applied at 2.66 pt/acre and incorporated into the soil prior to planting, and 10 oz Axiom® DF/acre and 3 oz Sencor® DF/acre were applied pre-emergence after planting. Spring weed control on this trial consisted of 13 oz of Huskie/acre.

All plots were evaluated for early spring growth, winter damage, disease, heading date, height, and lodging. Heading date was defined as days from January 1 until 50 percent of the plot had headed. Due to very low disease pressure or presence on the replicated nurseries, the only disease notes taken were for physiological leaf spot. The unreplicated ARS trial was evaluated for physiological leaf spot and for common bunt. Plots were harvested with a Hege small-plot combine July 27-28, 2009, except for the ARS unreplicated F6 Yield trial, which was harvested August 4-5, 2009. Grain samples were weighed to determine grain yield, cleaned using a small-sample Hege seed cleaner, and test weight was measured. An 800-g sample was saved from one replication for all trials, and lines to be used the following year were sent to the Western Wheat Quality Laboratory in Pullman, Washington for quality evaluation.

There was also a spring wheat High Temperature Adult Plant (HTAP) Yield nursery planted on March 27, 2009, with the objective of introgressing novel sources of stripe rust resistance into spring wheat. Plots were approximately 77.5 ft^2 and seeded at a rate of approximately 30 seeds/ft^2. Seed was planted about 0.5 - 1 inch deep using a five-row Hege drill with double-disc openers on 12-inch spacing. Plots were evaluated for heading date, height, grain yield, and test weight.

Moro

Nurseries evaluated at the Sherman Experiment Station included the USDA-ARS Oregon Elite and USDA-ARS Washington Elite yield trials, the USDA-ARS Preliminary 1, Preliminary 2, Preliminary 3, and Preliminary 4 nurseries, and the two cooperative regional nurseries (the Western Regional Soft Winter Wheat Nursery and the Western Regional Hard Winter Wheat Nursery). Trials were planted on October 13, 2008 with a Gaines tip, hoe-opener Hege drill, on 14-inch spacing, dusted in about ¼ - 1 inch deep with marginal moisture. All seed was treated with Dividend prior to planting and seeded at approximately 20 seeds/ft^2 in a 77.5 ft^2 plot. There were 61 lb N/acre in the soil and 80 lb N/acre was applied as anhydrous ammonia in early September. Broadleaf weeds were controlled in the spring by spraying Harmony® Extra at 0.5 oz/acre on May 10. The experimental design and data collected were the same as described for the Pendleton Station. Plots were harvested July 22-23, 2009 using a Hege small-plot combine.

Lexington

The USDA-ARS Oregon Elite yield trial was planted on October 7, 2008 into chemfallow ground using a four-row Hege 1000 drill with double-disc openers on 14-inch spacing, at approximately 20 seeds/ft^2. Seed was treated with Dividend and plot size was approximately 77.5 ft^2. Fertilizer and herbicide applications were managed by the grower. Experimental design and data collected were the same as described for Pendleton, except no quality samples were taken. Plots were harvested July 13, 2009.

Hermiston

On October 6, 2008 the USDA-ARS Oregon Elite yield trial was planted under pivot irrigation using a seven-row Hege 1000 drill with double-disc openers on 8-inch spacing. Fertilizer and herbicide applications were managed by the cooperator and the plots were harvested July 15, 2009. Experimental design and data collected were the same as described for Pendleton, except no quality-evaluation samples were taken.

Seeding Rate Study

The seeding rate study trial looked at 3 different rates of seeding to compare how varying rates affect overall yield in club wheat varieties compared to soft white common varieties. The trial consisted of six varieties, including club wheat cultivars Chukar, Cara, and Bruehl, and soft white common cultivars 'Eltan', 'Xerpha', and 'Brundage 96'. These entries were planted at a rate of 12, 18, and 24 seeds/ft^2 and replicated 4 times. Using a five-row Hege drill with double-disc openers on 12-inch spacing, the study was planted on October 16, 2008 about 0.5 inches deep into dry soil, and plots were approximately 40 ft^2 in size. Each plot was evaluated for stand counts, tillers per meter of row, heading date, height, yield and test weight.

Coleoptile Length Testing

Coleoptile lengths were measured for preliminary USDA-ARS club breeding lines. Multiple check varieties were included for comparison along with long-coleoptile checks 'Moro' and 'Edwin', and short-coleoptile check 'Hiller'. These were evaluated as described in Hakizimana et al. (2000) with a few modifications. Fifteen seeds were placed on a wet germination towel 1 cm apart with the germ end down across the middle of the towel. The towel was folded up, rolled loosely, secured with a rubber band, and placed upright in a plastic tray lined with wet germination towels. Samples were placed in a dark growth chamber at 4^{o}C for 4 days, then removed and placed in another dark growth chamber at 15^{o}C for 16 days. Coleoptile lengths were measured to the nearest millimeter and the average length of each cultivar was calculated after removing the highest and lowest value. This technique was used to identify genotypes with long coleoptiles that will readily emerge from deep planting.

Results

Weather in the fall of 2008 was extremely dry and prohibited planting into moisture at all locations except Hermiston. This resulted in all dryland location plantings to be dusted in or just put under the surface in dry soil. The first significant amount of rain didn't come until early November. As a result, most plot stands were variable and early spring growth differences were undetectable. Timely rains throughout the spring resulted in average yields for the locations of Pendleton and Moro. Once again test weights were lower than average at Pendleton at 56lb/bu. There were no major infestations of disease in the replicated nurseries, such as physiological leaf spot or stripe rust. There was however, considerable damage in the F6 Yield early generation nursery from common bunt, and contributed to poor yield data. This was due to seed not being treated with fungicide seed treatment, inoculum with the seed, and also disease pressure in the soil.

In the Washington-Elite nursery at Pendleton and Moro lines ARS960277L and ARS970075-3C, which are currently in breeder seed increase, yielded the same as soft white check varieties

Tubbs and ‘Finch’ and were better than the club wheat Chukar. Likewise, lines 98X458-C and 98X359-C also yielded the same or higher as the check varieties (Table 1). In the Oregon-Elite nursery lines X970042-2C, 97X230-1C, and 98X402-1C all yielded the same or higher as soft white check varieties Tubbs and Xerpha, and club wheat varieties Coda and Chukar at all Oregon locations (Table 2).

Table 1. Agronomic trait data for 2009 USDA-ARS Washington-Elite Nursery.

	Grain yield			Heading		Test
	Pendleton	Moro	Pullman[a]	date[b]	Height	weight
	------------------ bu/acre ------------------			from 1/1	in	lb/bu
Bruehl	78.7	58.9	80	160	32	56.07
Chukar	84.8	54.6	65	160	29	55.42
Finch	86.8	56.7	84	160	30	59.19
Tubbs	89.6	64.0	81	156	33	57.46
Xerpha	95.6	66.8	87	158	32	56.98
ARS960277L	86.5	56.0	87	158	30	57.20
ARS970071-1C	86.5	56.2	71	157	30	58.15
ARS970075-3C	92.1	59.2	63	158	29	56.79
ARS970163'-4C	81.4	58.0	72	160	30	56.82
ARS970170-2L	90.5	56.8	82	159	32	57.80
X00290-10L	76.2	54.0	64	160	32	56.81
X00290-4L	82.2	55.5	78	160	34	58.09
X00295-12C	74.0	54.3	67	159	31	59.19
X00295-14C	68.4	51.7	83	161	40	55.91
X00295-3L	79.3	50.4	67	158	36	55.53
X00295-6L	83.1	58.7	67	158	34	55.36
X00295-8L	90.6	56.1	68	156	32	57.68
X970161-2L	80.2	50.7	74	158	31	58.23
X970161-3L	84.9	52.9	78	158	30	58.62
X980336-5L	85.2	56.8	85	160	31	59.88
X980431-2C	92.1	50.1	67	158	29	56.97
X980440-2C	73.2	48.9	71	161	26	55.37
X980451-4C	81.7	59.1	74	158	31	59.37
97X358-8L	84.9	61.6	76	160	30	56.41
98X357-C	80.1	48.1	75	159	26	57.20
98X359-C	91.4	60.1	74	157	29	56.37
98X371-1C	91.4	64.2	69	159	28	53.28
98X371-3C	93.1	59.5	75	159	29	56.78
98X458-C	91.1	59.7	69	157	28	57.44
98X467-1C	86.1	58.2	72	156	27	59.77
Location Avg.	82.7	54.7	73.2			
CV	6.3	12.0	15.5			
$LSD_{(0.05)}$	6.3	8.0	13.5			

[a]Pullman, Washington yield data were reported for comparison.
[b]Heading date, height, and test weight data are the average over all locations.

Table 2. Agronomic trait data for 2009 USDA-ARS Oregon-Elite Nursery.

	Grain yield					Heading date[b]	Height	Test weight
	Lexington	Hermiston	Pendleton	Moro	Pullman[a]			
	bu/acre					from 1/1	in	lb/bu
Brundage96	29.7	102.8	90.9	52.8	83	153	30	58.05
Cara	28.3	112.1	94.7	49.1	86	156	29	56.40
Coda	31.9	86.4	93.4	56.9	81	155	32	58.46
Tubbs	32.4	109.3	97.7	57.7	88	153	33	57.73
Xerpha	32.3	110.1	98.8	54.4	92	155	33	57.59
ARS970168-2C	31.6	100.2	85.6	52.0	74	154	31	59.53
ARS970175-1L	32.7	105.1	94.3	58.2	92	153	31	56.98
ARS970175-4C	27.9	100.2	78.2	59.1	83	156	28	55.31
ARS970184-1C	28.8	101.7	98.4	56.2	86	153	30	57.79
X970038-2C	25.5	106.2	83.0	53.2	76	155	31	57.32
X970042-1C	29.7	110.0	93.7	54.8	81	154	30	57.07
X970042-2C	34.0	110.3	100.5	61.2	80	154	31	56.38
X970167-1-L	29.6	105.7	88.6	59.9	70	152	29	57.70
X980404-1C	30.3	103.4	88.9	55.3	70	154	29	57.16
X980404-4C	25.8	109.1	90.5	57.0	83	151	30	58.03
X980412-2C	31.5	101.3	90.4	48.8	78	153	28	56.37
X980421-1C	27.2	97.7	90.1	54.9	85	150	30	56.55
X980434-1L	31.5	103.9	92.4	58.8	83	151	29	59.78
X980436-1L	28.4	102.2	97.8	55.1	76	151	30	59.73
X980437-3L	28.9	92.2	88.7	53.5	86	152	31	59.22
X980495-2L	28.8	95.1	87.1	46.0	80	153	33	60.23
97X230-19C	30.5	111.4	92.9	62.3	81	153	30	58.12
97X230-1C	33.0	109.2	100.3	60.9	83	154	30	57.92
97X230-6C	35.2	112.9	92.4	59.4	81	154	29	58.36
98X356-2C	29.1	104.0	95.3	53.7	82	154	29	59.76
98X366-C	29.3	104.0	93.2	53.7	79	155	29	57.23
98X402-1C	30.7	111.8	98.3	63.1	85	155	30	57.50
98X471-2C	26.0	124.1	88.9	56.3	80	150	28	59.53
98X472-2C	31.1	103.9	86.2	50.8	79	154	27	58.30
98X472-4C	29.4	96.9	93.6	55.0	82	152	30	58.15
Location Avg.	29.5	102.8	90.5	55.3	80.2			
CV	10.4	7.7	5.3	11.9	9.4			
$LSD_{(0.05)}$	3.7	9.4	5.7	7.8	9.0			

[a]Pullman, Washington yield data were reported for comparison.
[b]Heading date, height, and test weight data are the average over all locations.

Early heading dates and spring vegetative growth are important traits for varieties to be well adapted to northeastern Oregon. Experimental lines in the Oregon-Elite nursery averaged just 1 day later than Tubbs for heading dates, and in the Washington-Elite nursery lines averaged 2 days later. Lines ARS960277L and ARS970075-3C from the Washington-Elite nursery averaged a day or two later than Tubbs and lines 98X458-C and 98X359-C headed out only a day later (Table 1). In the Oregon-Elite nursery line X980436-1L headed out 2 days earlier, on average, than Tubbs in Pendleton and Moro, and it also yielded the same as the check varieties and had good test weight (Table 2). Cultivars that come out of dormancy early in the spring and start producing vegetative growth can help improve yields in northeastern Oregon. This trait is seen in many varieties grown in the region, such as Tubbs and ‘Stephens’, and has been observed in some of the lines in the club nurseries like ARS970184-1C and 98X371-3C. Lines are continually being screened and developed to have earlier heading dates and early spring growth, and more emphasis is being placed on developing varieties with these traits so that club wheat will compete with the leading soft white winter varieties in northeastern Oregon.

Club wheat variety yields in the seeding rate study averaged the same as Brundage 96 and Eltan. All varieties were lower in yield than Xerpha. Seeding rate one (12 seeds/ft^2) was significantly lower in yield than rates two (18 seeds/ft^2) and three (24 seeds/ft^2) for all varieties except Xerpha and Brundage 96. Brundage 96 also had no significant difference in yield between all three seeding rates. There were more tillers per meter of row with each increase in rate, however this did not necessarily correlate to higher yields. The club wheat Cara was the only variety to show a significant difference in yield between rates two and three (Table 3). This difference in all the other varieties was not significant. While most of the varieties performed similarly, it does show that some club wheat varieties may benefit from higher seeding rates than normal, as was the case for Cara. This study will be continued to further look at seeding rates for club wheat to help improve yields that are competitive with other soft white varieties.

Table 3. Seeding rate study agronomic data.

Variety	Seeding Rate	Grain yield	Test weight	Tillers
	seeds/sq ft	bu/acre	lb/bu	tillers/m of row
Bruehl	12	73	51.79	112
Bruehl	18	81	51.87	115
Bruehl	24	81	51.38	121
Avg.		78	51.68	116
Cara	12	77	53.09	106
Cara	18	82	52.97	113
Cara	24	89	53.58	114
Avg.		83	53.21	111
Chukar	12	75	53.17	89
Chukar	18	85	53.68	99
Chukar	24	83	53.24	108
Avg.		81	53.36	99
Brundage96	12	81	55.61	120
Brundage96	18	84	53.13	134
Brundage96	24	82	53.77	143
Avg.		82	54.17	133
Eltan	12	72	56.02	125
Eltan	18	81	55.17	150
Eltan	24	82	54.81	154
Avg.		79	55.33	143
Xerpha	12	95	54.12	143
Xerpha	18	96	54.13	149
Xerpha	24	99	53.22	165
Avg.		97	53.82	152
	12	79	53.97	116
Seed Rate Avg.	18	85	53.49	127
	24	86	53.33	134
CV		5.3	1.8	11.3
$LSD_{(0.05)}$		3.5	0.7	11.3

Coleoptile lengths from the preliminary USDA-ARS club breeding lines measured an average of 3.5 inches. The longest coleoptile lengths were the checks Moro and Edwin at 4.2 and 4.8 inches, respectively. The experimental lines averaged the same or above Tubbs in length. A few lines such as X010761-5C and X010774-2C averaged 4.4 and 4.3 inches, respectively, which was longer than the check Moro. Compared to last year's preliminary lines which averaged 3.1 inches, there was an increase in coleoptile length. Coleoptile length can have a large impact on seedling emergence and overall stand. When seed has to be planted deep in the fall to reach moisture, a long coleoptile can help improve emergence from the soil and establish a better stand. This is true not only for wheat planted in conventional fallow, but especially for club wheat planted into no-till fallow ground. Using long-coleoptile varieties in crosses will help increase coleoptile length in breeding lines and improve deep seeding emergence. Selection for longer coleoptile length and emergence will continue to be a high priority in the USDA-ARS breeding program.

References

Hakizimana, F., S.D. Haley, and E.B. Turnipseed. 2000. Repeatability and genotype x environment interaction of coleoptile length measurements in winter wheat. Crop Science 40:1233-1237.