

**Washington Grain Commission**  
**Wheat and Barley Research Annual Progress Reports and Final Reports**

**PROJECT No.: 30109-6601**

**Progress report year:** Final: 3 of 3 (*maximum of 3 year funding cycle*)

**Title: CLUB WHEAT BREEDING**

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**Executive summary:**

We focused club wheat development on two major goals: 1) Development of competitive club wheat cultivars for the < 15 inch rainfall zone with excellent resistance to snow mold, eyespot, stripe rust, sprouting and good emergence and winter hardiness and 2) Development of competitive early maturing club wheat for the > 15 inch rainfall zone with excellent resistance to eyespot, cephalosporium stripe, stripe rust, aluminum toxicity and good straw strength, and excellent test weight.

The new club wheat cultivar, Pritchett, jointly developed by the USDA-ARS and WSU winter wheat breeding programs, was released in 2015, because of its superior agronomic productivity in the targeted region, and superior end use quality combined with resistance to multiple diseases and abiotic stress. This cultivar was available to growers in the fall of 2018. Foundation seed of Pritchett, was produced. Pritchett is targeted to the traditional club wheat growing region in the dry precipitation zones.

ARS Castella (ARS20060123-31C) developed by the USDA-ARS and WSU was released in 2018 as an early maturing club wheat with good performance, excellent stripe rust resistance, aluminum tolerance and tolerance to low falling numbers. Castella has performed better in lower rainfall trials where lodging due to its height has not been a problem.

New club wheat breeding lines have been highly competitive with soft white wheat cultivars in multiple rainfall zones during the past three harvest seasons. In the Washington State Extension Dry Trials the three year yields of Pritchett averaged 6% more than ARS-Crescent and Bruehl in the < 12 inch rainfall zone; equal to ARS-Crescent and 4% better than Bruehl in the 12-16 inch rainfall zone (Table 1). ARS Castella was entered into the WAVT dry trials where yields were 2% better than Bruehl, 8% better than ARS-Crescent and 5% better than Bruehl <12 inch rainfall zones. Castella was equal to Pritchett, and ARS-Crescent and 3% better than Bruehl in the 12-16 inch rainfall zone.

The club wheat ARS Crescent is a complement to Pritchett in the higher rainfall regions (Table 2). ARS Crescent maintained acceptable falling numbers in almost all environments in 2016-2017 and has achieved stable high performance across rainfall zones over multiple years.

**Table 1. Three-Year WSU Variety Testing Data from 2016-2018**

Variety *club	<12"	12"-16"	TEST WT (LB/BU)	PROTEIN (%)
	YIELD (BU/A)	YIELD (BU/A)		
<i>Castella</i>	67	108	60.3	10.0
<i>Pritchett</i> *	66	109	59.5	
<i>ARS-Crescent</i> *	62	109	59.8	10.0
<i>Bruehl</i> *	62	105	58.6	10.3
<b>Curiosity CL+</b>	64	101	60.5	9.9
<b>Norwest Duet</b>	67	116	60.7	10.1
<b>Otto</b>	62	101	60.1	10.6
<b>SY Banks</b>	64	111	59.7	10.3
<b>Xerpha</b>	68	112	60.2	9.9
<b>CV %</b>	9	8	1.5	6.7
<b>LSD (.05)</b>	2	3	0.3	0.3

<12" Precip (Connell, Harrington, Horse Heaven, Lind) 2016-2018, (Ritzville, St. Andrews) 2017-2018, (Bickelton) 2018, 17 loc/years. (Smallgrains.wsu.edu)

12"-16" Precip (Almira, Creston) 2016-2018, (Anatone) 2016-2018, (Lamont) 2016, 2018, (Reardan) 2016-2018, 14 loc/years. (Smallgrains.wsu.edu)

**Table 2. Five-Year WSU Variety Testing Data from 2014-2018**

Variety *club	16-20"	>20"	TEST WT (LB/BU)	PROTEIN (%)
	YIELD (BU/A)	YIELD (BU/A)		
<i>ARS-Crescent</i> *	103	122	59.5	10.2
<b>Bobtail</b>	110	121	58.0	10.3
<b>LCS Art Deco</b>	110	118	59.5	10.1
<b>Puma</b>	109	118	60.2	10.5
<b>Rosalyn</b>	115	128	58.7	9.9
<b>SY Ovation</b>	109	115	60.4	10.5
<b>Xerpha</b>	108	123	60.1	10.4
<b>CV %</b>	7	6	1.1	4.9
<b>LSD (.05)</b>	2	2	0.2	0.2

16-20" Precip (Dayton, Mayview, St. John, Walla Walla) 2014-2018, 19 loc/years. (Smallgrains.wsu.edu)

> 20" Precip Colton, Fairfield, Farmington, Pullman) 2014-2018, 18 loc/years. (Smallgrains.wsu.edu)

The USDA-ARS Wheat breeding program managed field testing locations at Central Ferry, Lind, Harrington, Pullman, and Farmington WA and at Pendleton OR and Genesee ID. We also evaluated breeding lines at Walla Walla, St. Andrews, Mansfield, Ritzville, and Kahlotus, WA and Corvallis OR in collaboration with the WSU Winter Breeding program, the WSU Cereal Variety Testing Program, OSU-CBARC, the OSU Wheat Breeding program, the University of Idaho and Syngenta. The overall goal of this project has been to remove the agronomic constraints that make club wheat less attractive to growers than soft white wheat.

For the 2017 WA State Extension trials for the dry rainfall zones, we entered two lines: ARS20060123-31C (was in the 2015-16 trials) is derived from a cross between NY89066-7131/B980696//CHUKAR; a tall, early maturing, awnless club that has been very resistant to stripe rust in USDAARS trials; ARSDH08028-111C, and ARSDH08028-44C were derived from a cross between Cara/Xerpha, an awned club that has performed well, where Xerpha is adapted but with better adult plant resistance to stripe rust and excellent milling quality.

For the 2017 WA State Extension trials for the high rainfall zones, we entered two lines: ARSDH08028-44C is an awnless club and new entry for 2017 derived from the Cara/Xerpha cross with excellent stripe rust resistance and moderately early maturity that has performed well in early maturing and higher rainfall regions. ARS20040150-2C is also a new entry for 2017 derived from a cross between Chukar/Cayuga/2\*Chukar. Cayuga is a source of preharvest sprouting resistance from NY. This entry was selected to have that resistance. We still need further testing to confirm but the line has performed well on the Palouse with good stripe rust resistance and maturity similar to Chukar.

We entered the following breeding lines into 2018 trials: ARSDH08X117-83C in the WAVT Dry, North Idaho, and Oregon Wheat Elite Yield Trial (OWEYT); ARSWA2J100065C in the WAVT Dry; ARSDH08X103-102C and ARS06132-45C in the WAVT-Wet; ARSDH08X028-9C in the WA/OR cooperative trials and OWEYT; ARSDH08X142-11L, ARSDH08X103-102C, DH08X028-9C, and ARS2J100065-C in the Western Regional Nurseries.

We entered two lines into the 2019 trials: ARSDH08X117-83C and ARS09X492-6CBW.

These club breeding lines are all products of crossing with soft wheat from the Eastern US as additional sources of resistance to rusts, cold tolerance, Hessian Fly and BYDV. We have added an additional head row purification and selection step to the breeding program in order to provide Washington Foundation Seed with quality Breeder seed in a timely manner.

We have greatly expanded our use of genotyping and are in the process of genotyping all our the entries in all of our yield trials using resequencing approaches through North Carolina State University and targeted amplicon sequencing in the USDA Western Small Grains Genotyping laboratory. We are implementing genomic selection for end use quality and cold tolerance and end use quality. Marker assisted selection was conducted using KASP and SSR markers to select for resistance to low falling number, BYDV, eyespot, stripe rust, dough strength, cold tolerance and reduced height.

We evaluated several hundred doubled haploid lines and advanced several to our elite replicated trials. Early generation quality testing using the micro-mill, the polyphenol oxidase assay, and solvent retention capacity tests was performed. Coleoptile testing and survival from freezing was assayed on all breeding lines. All breeding lines were selected for resistance to stripe rust, eyespot, cephalosporium stripe, and Fusarium in inoculated nurseries at Central Ferry and Pullman WA.

We expanded our selection in single row plots to additional locations at Lind WA Pendleton OR and near Waterville. These small plots allow us to select among large populations for emergence, snow mold resistance, and adaptation to early spring green-up. Our expansion into these locations was made possible by the new deep furrow no-till drill that is shared with the WSU Winter wheat project.

Our plot and head row totals for 2019 are listed below:

Total Locations: 13 in the Pacific Northwest plus 2 additional sites in Colorado

Total Winter Plots: = 4315

Spring Plots= 646

Total Headrows: 34,992 individual rows

\* includes stripe rust screening rows that we conduct for collaborators

Spring HR= 416

## **Impact**

Club wheat acreage represents a small but significant part of the total WA wheat market. The excellent disease resistance of the club wheat is a built-in premium for growers because the reduced need for fungicides. Because of their disease resistance, club wheat cultivars have been used to incorporate stripe rust resistance and eyespot resistance into other wheat classes. The combination of excellent end use quality, disease resistance, and cold tolerance of new club wheat cultivars allows growers to make planting decisions based on market demands and to maximize choice in marketing strategy. The club wheat breeding program works collaboratively with several other WGC funded projects including the Winter and spring wheat breeding projects, the disease resistance and quality projects, and the drought and preharvest sprouting projects to integrate their results and methods into production of quality cultivars for PNW growers.

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## **Presentations:**

- a. Report of Progress: Washington Grains Commission Research Review, “Club Wheat Breeding”, Pullman WA, Feb. 2016, 2017, 2018.

- b. Invited by R. Higginbotham to present at plot and field day tours speaking to approximately 35-50 growers and industry representatives per tour during May, June and July: Connell WA, 2016; Harrington WA, 2016, 2017, 2018; Lacrosse, WA, 2017; Lind WA, 2016, 2018; St. Andrews WA, 2016, 2017; St. John WA, 2017;
- c. Invited by Planning Committee, Edgar Mcfadden Symposium to speak on, "Learning from the Daleks and the Silurians to Control Stripe Rust in the Great Plains" at Joint Edgar McFadden Symposium-Hard Winter Wheat Workers Workshop, April 19, 2016. San Antonio TX

**Selected refereed manuscripts with applications to this project.**

1. Garland-Campbell, K, Carter, AH, Jones, SS, Chen, XM, DeMacon, P, Higginbotham, R, Engle, D, Guy, SO, Mundt, CC, Murray, TD, Morris, CF, See, D, 2017. Registration of "Pritchett" Soft White Winter Club Wheat. *J. Plant Reg.* 11. DOI: 10.3198/jpr2016.04.0018crc
2. Gizaw, S.A., Garland-Campbell, K., Carter, A.H., 2016. Evaluation of agronomic traits and spectral reflectance in Pacific Northwest winter wheat under rain-fed and irrigated conditions. *Field Crops Res.* <http://dx.doi.org/10.1016/j.fcr.2016.06.018>
3. Gizaw, S.A., Garland-Campbell, K., Carter, A.H. 2016. Use of spectral reflectance for indirect selection of yield potential and stability in Pacific Northwest winter wheat. *Field Crops Res.* Available online 21 July 2016. <http://www.sciencedirect.com/science/article/pii/S0378429016302088>
4. Campbell KG. Errors in statistical decision making. 2017. In Glaz, B., Yeates, K (Eds.) *Applied statistics in agricultural, biological, and environmental sciences.* American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. Online first: doi:10.2134/appliedstatistics.2016.0007
5. Jernigan KL, Morris CF, Zemetra R, Chen J, Garland-Campbell K, Carter AH. 2017. Genetic analysis of soft white wheat end-use quality traits in a club by common wheat cross. *Journal of Cereal Science.* 76:148-56. <https://doi.org/10.1016/j.jcs.2017.06.005>
6. Martinez SA, Godoy J, Huang M, Zhang Z, Carter AH, Garland Campbell KA, Steber CM. 2018. Genome-wide Association Mapping for Tolerance to Preharvest Sprouting and Low Falling Numbers in Wheat. *Frontiers in Plant Science.* 2018;9:141. doi.org/10.3389/fpls.2018.00141

**WGC project number:**

**WGC project title:** Club wheat breeding

**Project PI(s):** Kimberly Garland-Campbell and Arron Carter

**Project initiation date:** 7/1/16

**Project year:** 3

Objective	Deliverable	Progress	Timeline	Communication
1. Develop agronomically competitive club wheat cultivars targeted to the diversity of rainfall and production zones of the PNW. These cultivars will possess the excellent end use quality characteristic of club wheat. They will also possess excellent resistance to stripe rust. Specific other characteristics will be targeted to individual rainfall regions	Club cultivar releases	The club wheat cultivar Pritchett was available to growers in fall 2018. ARS-Castella was planted as breeders seed in fall 2018.	Sept 2016- June 2019. Cultivar releases are targeted as one every three years per rainfall zone.	Report of Progress: Washington Grains Commission Research Review, "Club Wheat Breeding", Pullman WA, Feb. 2017. Garland-Campbell, K, Carter, AH, Jones, SS, Chen, XM, DeMacon, P, Higginbotham, R, Engle, D, Guy, SO, Mundt, CC, Murray, TD, Morris, CF, See, D, 2017. Registration of "Pritchett" Soft White Winter Club Wheat. J. Plant Reg. 11. DOI: 10.3198/jpr2016.04.0018crc
2. Develop club breeding lines for the <15 inch rainfall zone with improved resistance to snow mold and fusarium crown rot, improved emergence and winter survival	Germplasm identified with resistance, used to introgress new resistance genes into existing club wheat germplasm. Better combination of traits in club wheat targeted to the <15 in. rainfall zone.	We entered two lines into the 2019 trials: ARSDH08X117-83C and ARS09X492-6CBW.	Sept 2016- June 2019.	Plot and field day tours speaking to approximately 15-30 growers and industry representatives per tour during June, 2018, Harrington, Lind
3. Develop club breeding lines for the > 15 inch rainfall zone with improved resistance to eyespot, cephalosporium stripe, aluminum toxicity, and cereal cyst nematodes.	Germplasm identified with resistance, used to introgress new resistance genes into existing club wheat germplasm. Better combination of traits in club wheat targeted to the >15 in. rainfall zone.	We entered two lines into the 2019 trials: ARSDH08X117-83C and ARS09X492-6CBW.	Sept 2016- June 2019.	"Club Wheat" Drew Lyon interviewed K. Campbell for Wheat Beat Podcast, summer 2018.

<p>4. Release a club wheat cultivar with early maturity targeted to SE Washington and NE Oregon.</p>	<p>Club wheat cultivars with early maturity (2-5d earlier than Pritchett) combined with excellent stripe rust resistance.</p>	<p>Head rows were planted in Pendleton in the fall of 2017 so that earlier maturing selections can be made in that environment.</p>	<p>Sept 2016-June 2019. Our next club wheat release after Pritchett will be targeted to this growing environment</p>	<p>Invited talk, 'Falling Numbers' Northwest Grain Growers Meeting, June 21, 2017. Walla Walla WA</p>
<p>5. Release germplasm with improved resistance to low falling number</p>	<p>Club wheat breeding lines with stable falling numbers above 300 in all but extreme environments.</p>	<p>All elite lines in the breeding program were assayed for LMA using field testing and PHS using spike wetting tests. Lines that were susceptible were not advanced.</p>	<p>Sept 2016-June 2019.</p>	<p>Presentation at grower meetings, Wheat commission meetings, field days, plot tours, Wheat Life and Research Review.</p>
<p>6. Identify an early generation method to assess cake baking quality</p>	<p>Early generation prediction equation for cake baking quality, the key trait for club wheat.</p>	<p>Association mapping and genomic selection for improved baking quality is underway.</p>	<p>Sept 2016-June 2019.</p>	<p>Jernigan KL, Morris CF, Zemetra R, Chen J, Garland-Campbell K, Carter AH. 2017. Genetic analysis of soft white wheat end-use quality traits in a club by common wheat cross. <i>Journal of Cereal Science</i>. 76:148-56. <a href="https://doi.org/10.1016/j.jcs.2017.06.005">https://doi.org/10.1016/j.jcs.2017.06.005</a></p>