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

PROJECT #: 30109-3156

Progress report year: 3 of 3 Final report for current project

Title: Club wheat Breeding

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Cooperator: **Mike Pumphrey**

Executive summary:

The acres of the club wheat cultivar 'Pritchett' increased from 15,183 acres in 2020 to 49,934 in 2021. 'Castella' club wheat was available as registered seed in fall of 2020 and occupied 13,873 acres in 2021. Other club wheat cultivars included 'ARS Crescent' (23,330 acres), 'Bruehl '(15,104 acres), and 'Coda' (600 acres). A small amount of 'Cara' was grown in Idaho. The spring clubs 'Melba' (7306 acres) and 'JD' (3077 acres) rounded out the total club wheat which amounted to 105,224 acres, which was slightly reduced from total 2020 acreage (119,124). However, the winter club acreage in 2021 was increased significantly from 77,999 acres in 2020. Since spring wheat production was devastated by the drought in 2021, the winter club increase sustained the club wheat market. There is currently a shortage of club wheat grain, and the premium is high. White club bids were between $10.20 and $13.75 with an average of $12.12 in Portland on Jan 7, 2022 as compared to soft white wheat (maximum 10.5% protein) bids averaging $10.69. This approximately $1.50 premium is on the high side for sustainability for club wheat purchases. When the premiums are high, the markets shift to other classes. Unfortunately, the poor crop season and sowing conditions in 2021 also resulted in a shortage of club wheat seed for the future.

Our major goal is to develop club wheat cultivars with the excellent club wheat end use quality that is expected by markets in Asia, and with competitive crop performance. To that end, we released 'Cameo' in Feb. 2021. Although the main club wheat production region is central Washington in the < 15-inch rainfall zone, growers in the higher rainfall regions continue to grow the very old club wheat cultivars 'Cara' and 'Coda'. The spring club wheat cultivars 'J.D.' and 'Melba' are also popular. While spring club wheat will continue to be an important tool in rotations, there was a need for a new winter club targeted the Palouse region of Idaho, Oregon and Washington. As compared to other club wheat cultivars grown in the high rainfall region, Cameo has better agronomic performance than other clubs in trials on the Palouse, better stripe rust resistance than ARS Crescent, and tolerance to eyespot, soilborne wheat mosaic virus, acid soils and Hessian fly. Cameo has consistent high test weight, mid-season maturity, moderate height, excellent club wheat quality, moderate tolerance to low falling numbers, similar to that of ARS Crescent, and it consistently grades as white club. The pedigree of Cameo is ARSC96059-2/IL01-11934//ARSC96059-2-0-16.

Pritchett and Castella have been productive in the traditional club wheat growing region and Pritchett maintained grain yields as well as many soft white wheat cultivars, even under the severe drought conditions of 2021 (Tables 1 and 2). There is still a great need for new club wheat cultivars with the snow mold resistance and emergence of Bruehl, combined with the tolerance to low Falling Numbers that is more typical of ARS Crescent.

New entries with better resistance to snow-mold, ARSX12015-68CBW and WA8317, which also has two-gene IMI resistance, and ARS12097-8D were entered in the WA Cereal Variety trials in the dry zone in 2020 and 2021. Unfortunately, although they did well in 2020, the three lines were not better than existing cultivars for grain yield and suffered more than those cultivars in the 2021 drought (Tables 1 and 2). Therefore, they were not advanced. In the high rainfall zone, ARSX09500-17CBW performed well at Mayview and Walla Walla in 2021, likely due to relatively early maturity.

In 2022, the breeding lines, ARS12097-12C (X010679-1C/IL06-14262), ARS13659-4C (Bruehl///(J010049/Brundage 96/Mohler)-2), and ARS141114-64C (Xerpha/X06132-45C) were entered into the WA Cereal Variety Testing dry trials. All had previously been selected have some tolerance to snow mold, excellent club end use quality, and were competitive in the very dry year of 2021. In the high rainfall trials, ARSX09500-17CBW (ARSC96059-2/VA03W-412//ARSC96059-2-0-17) was repeated and ARS14DH1014-C (ARS-Amber/X010301-4-2C) with earlier maturity, excellent standability, excellent club wheat quality and resistance to stripe rust was entered for 2022.

Each year of the project, we made over 150 crosses to develop new club wheat populations. We evaluated mini-bulk breeding and speed breeding techniques in the greenhouse and discovered that we can save about 20 days off of normal winter wheat generations using these techniques which allows us to advance material through the greenhouse faster and serves as a cost-effective alternative to doubled haploids. Therefore, populations are being advanced in the WSU plant growth facility, and selected for height and club wheat head type prior to planting in the field at F4 headrows. Several populations were developed to introgress two-gene IMI resistant into club wheat. Since the soft white wheat cultivars ‘Curiosity’ and ‘Mela’ were used as resistance donors, these crosses will also be useful to incorporate better snow mold resistance. With our collaborators, we evaluated nurseries at 14 locations in Washington, Idaho and Oregon in all years of the project (Table 3). Since 2020, genotype data is generated for all lines in yield trails in the club wheat breeding program. These data are used for marker assisted selection, for cross prediction and to generate genomic selection models.

In 2020 we evaluated all of plots in our yield trials in Lind and Pullman for resistance to low falling number using spike wetting tests. We discovered that, although ARS Crescent performs well for falling number in grower fields as compared to Bruehl, it was rated as susceptible to sprouting in spike wetting tests conducted at the WSU Plant Growth Facility. We suspect that the resistance in ARS Crescent is enough to maintain falling number in grower fields but not enough to sustain resistance in under the pressure of the spike wetting test. While we could select for greater dormancy using the spike wetting test alone, we are concerned that this increased dormancy would negatively impact fall emergence in the dry locations. There are a few winter wheat lines such as Otto soft white winter wheat, that have good emergence and the

ability to maintain acceptable falling numbers in most environments. Therefore, we made several crosses between Otto and the club wheats to select for a moderate degree of tolerance to falling number and good emergence. We are evaluating molecular markers for association with falling number tolerance in our breeding program.

Pritchett was rated as resistant to soil borne mosaic virus over multiple years of testing by Dr. C. Hagerty of OSU. This resistance was originally present in Bruehl, and is associated with the SBMV-1 and SBMV-2 molecular markers indicating that we can select for resistance using marker assisted selection. Although soil borne mosaic virus has not emerged as a great threat to wheat production in the PNW, it is good to know that we have resistance present in adapted germplasm.

Each year we evaluate over 2500 breeding lines from breeding programs throughout the U.S. for resistance to stripe rust. This collaborative project has enabled us to made crosses to several good sources of Hessian fly and wheat barley dwarf virus resistance which are are being advanced for selection. In addition, several USDA-ARS developed cultivars possess resistance to local races of Hessian Fly, as tested at the Univ. of Idaho. These include ARS Selbu, Castella, Cameo and the breeding line ARSX09500-17CBW.

We were unable to visit with our collaborators of the Japanese Flour Miller's Association in person in 2020 and 2021 due to the pandemic but we were able to meet in virtual conferences. From that interaction, we started to investigate additional methods to measure cake quality including image analysis and texture classification. These trials are ongoing. Released club wheat cultivars continue to be listed as desirable or most desirable in the 'Preferred Varieties Brochure sponsored by the Washington, Oregon and Idaho Wheat commissions and the USDA-ARS Western Wheat Quality Laboratory.

Impact

The integration of genomic selection, speed breeding, doubled haploid breeding, and new methods of analyzing data enables us to continue to be efficient with grower dollars and produce club wheat cultivars that are competitive as well as additional soft wheat germplasm with specific useful traits for other breeders. Better resistance to low falling number will stabilize markets and reduce grower risk. The USDA-ARS club wheat breeding program is the only one with a primary focus on club wheat. Club wheat remains a highly desired product in the the PNW grain market giving growers additional choices in marketing strategy. The most significant measurable impact is the acreage devoted to club wheat cultivars developed from this project and the increase in acreage of winter clubs in 2021.

Table 1.

Summaries from 2020 WSU Cereal Variety Testing Program
By Rainfall Zone. Club Wheats are in Italics

	>20 in.					16-20 in.				
Name	Colton	Fairfield	Farmington	Pullman	Ave.	Dayton	Mayview	St John	Walla Walla	Ave.
ARS Crescent	130	135	137	124	131	127	104	130	132	123
ARS09X492-6CBW	125	137	139	144	136	124	98	128	132	121
ARSX12016-45CBW	129	125	132	147	133	120	97	115	124	114
Castella	125	130	131	145	133	123	57*	115	134	107
OR5170022	107	114	114	118	113	115	92	117	118	110
Pritchett	125	130	131	145	133	131	97	124	132	121
M-press	140	142	131	142	139	131	110	119	146	127
Norwest Duet	125	130	131	145	133	126	111	127	138	126
Purl	125	130	131	145	133	132	94	130	139	124
lsd	16	11	17	15	6	13	15	11	21	7

	12-16 in.						<12 in.					
Name	Almira	Anatone	Creston	Lamont	Reardan	Ave.	Bickleton	Connell	Harrington	Horse Heaven	Lind	Ave
ARS Crescent	77	75	73	95	127	89	27	69	67	40	70	56
ARS12015-68CBW	64	75	75	85	111	82	24	61	57	36	60	48
Bruehl	73	66	81	88	101	82	25	64	54	39	58	47
Castella	74	59	88	95	119	87	25	56	51	38	60	46
OR5170022	64	70	79	84	97	79	19	60	41	29	60	42
Pritchett	81	73	72	95	117	88	29	62	54	39	59	49
WA8317	69	69	84	85	106	83	26	61	60	38	58	49
Otto	66	72	81	94	108	84	27	57	49	39	57	46
Devote	66	70	88	89	108	85	25	64	60	45	61	51
M-press	79	71	95	91	122	92	29	68	57	38	56	50
Norwest Duet	82	78	78	95	122	91	32	67	68	37	59	53
Purl	74	83	82	88	114	88	27	65	51	40	60	48
lsd	10	11	13	8	14	4	3	14	15	8	12	4

* The low score at Mayview for Castella is likely due to deer and elk feeding.

** Shaded entries are in the same highest lsd group.

Table 2. Summaries from 2021 WSU Cereal Variety Testing Program
By Rainfall Zone, Club Wheats are in Italics

	> 20 in.					16-20 in.				
Name	*Colton*	*Fairfield*	*Farmington*	*Pullman*	*Average*	*Dayton*	*Mayview*	*St. John*	*Walla Walla*	*Average*
ARS Crescent	59	37	74	58	57	36	55	90	77	74
ARS14DH1122-26	59	34	78	61	58	34	50	82	74	69
ARSX09500-17CBW	59	38	83	68	62	42	57	98	85	80
Cameo (ARS09X492-6CBW)	63	41	89	73	66	41	58	95	78	77
Castella	64	35	82	69	63	51	--	100	76	--
Pritchett	65	35	79	76	64	47	61	96	77	78
LCS Hulk	66	38	75	72	63	53	58	93	78	76
M-Press	67	35	76	71	62	51	59	93	80	77
Norwest Duet	70	43	84	68	66	42	58	98	83	80
Piranha CL+	70	40	104	83	74	54	58	101	83	82
Purl	68	32	78	69	62	46	58	98	81	79
LSD	5	4	6	7	3	10	10	12	10	5
Ave	67	37	84	74	65	48	58	93	81	77

	12-16 in.						<12 in.						
	Almira	*Anatone*	*Creston*	*Lamont*	*Reardan*	*Average*	*Bickelton*	*Connell*	*Harrington*	*Horse Heaven*	*Lind*	*Ritzville*	*Average*
ARS Crescent	40	41	56	95	61	59	15	40	53	22	39	40	35
ARSX12015-68CBW	40	31	54	95	56	55	13	32	43	18	34	34	29
ARSX12097-8D	39	31	51	92	54	53	14	43	54	21	37	44	35
Castella	36	--	62	70	59	--	15	38	57	24	42	42	36
OR5170022	21	27	38	85	41	42	8	37	41	14	29	38	28
Pritchett	39	39	61	108	58	61	18	43	52	23	48	49	39
WA8317	35	26	37	93	50	48	13	36	39	17	35	37	30
Devote	45	35	62	97	60	60	17	44	48	25	50	49	39
M-Press	44	38	68	103	64	63	18	42	56	23	43	49	38
Norwest Duet	40	37	60	103	60	60	16	47	51	21	47	43	38
Otto	33	30	54	83	62	52	14	44	44	22	44	47	36
Piranha CL+	37	44	65	107	69	65	19	48	52	24	45	49	40
LSD	7	7	7	14	8	4	2	7	5	3	6	7	2
Ave	39	37	58	98	60	58	17	43	50	23	41	45	36

* The missing data for Castella at Mayview and in average are due to Elk and Deer feeding.

** Shaded entries are in the same highest LSD group for the trial

Table 3. Locations used in USDA-ARS club wheat breeding program for evaluation of breeding lines.

Location	Cooperators	Rationale for location
Harrington, WA	WSU Winter Wheat, WSU Variety Testing, Wagner	Emergence, low rainfall wheat-fallow, traditional club wheat production region.
Kahlotus, WA	WSU Winter Wheat, Moore	Emergence, low rainfall, wheat-fallow production region.
Lind, WA	WSU Dryland Experiment Station	Emergence, low rainfall, wheat-fallow production region.
Ritzville WA	WSU Winter Wheat, Schoesler	Emergence, low rainfall, wheat-fallow production region, traditional club wheat production region
St Andrews, WA	WSU Variety Testing	Winter Survival, low rainfall, wheat-fallow production region.
Farmington, WA	WSU Winter Wheat, Pfaff	Annual production region, stripe rust, cold spring, productive but low pH soil.
Genesee, ID	Kambitsch Farm Univ. of Idaho	Highly productive, heavy soils, annual production region
Pendleton, OR	CBARC, Oregon State Univ.	Early maturity, terminal heat stress, mild winter, intermediate rainfall.
Pullman, WA	Spillman Farm	Annual production region, stripe rust, stem rust, Cephalosporium stripe and eyespot diseases.
Walla Walla, WA	WSU Winter Wheat, Moore	Early maturity, weed pressure, intermediate rainfall, stripe rust.
Central Ferry, WA	USDA Plant Introduction Unit	Stripe rust resistance, eyespot resistance, seed increase location
Rockford, WA	WSU Winter Wheat,	Aluminum toxicity, low pH
Mansfield, WA	WSU Winter Wheat,	Snowmold resistance, winter survival
Waterville, WA	WSU Winter Wheat,	Snowmold resistance, winter survival

WGC Project Number:	3019-3156			
WGC Project Title:	Club wheat breeding			
Project PI(s):	Kim Garland Campbell, Arron Carter, Michael Pumphrey			
Project Initiation Date	07/01/2019			
Project Year:	3			
Objective	Deliverable	Progress	Timeline	Communication
Develop agronomically competitive club wheat cultivars targeted to the diversity of rainfall and production zones on the PNW.	Club cultivar releases	Release of Pritchett, Castella, and Cameo.	Cultivar releases targeted one per rainfall zone every three years	Presentations at annual field days, plot tours, and you-tube videos. Wheat life articles and peer reviewed publications. Garland-Campbell, Kimberly. Garland Campbell, Kimberly. "The origins of club wheat" *Wheatlife* 64.10(2021): 41-43.
Develop club breeding lies and cultivars for the <15-inch rainfall zone with improved resistance to snow mold and fusarium crown rot, improved emergence, and winter survival.	Club cultivar releases are entered into Western Regional and State Extension Trials	Pritchett and Castella are targeted to the <15-inch rainfall region. Four-6 lines entered regional trials each year.	Yearly entry of breeding lines into regional trials	Garland Campbell, Kimberly, et al. "Registration of 'Castella' soft white winter club wheat." *Journal of Plant Registrations* 15.3 (2021): 504-514. Garland-Campbell, Kim, et al. "Registration of 'Pritchett' soft white winter club wheat." *Journal of Plant Registrations* 11.2 (2017): 152-158.
Develop club breeding lies and cultivars for the >15-inch rainfall zone with improved resistance to eyespot, cephalosporium stripe, aluminum, and cereal cyst nematodes.	Club cultivar releases are entered into Western Regional and State Extension Trials	Cameo is targeted to the > 15-inch rainfall region. Four-6 lines entered regional trials each year.	Yearly entry of breeding lines into regional trials	Garland-Campbell, Kim, et al. "Registration of 'Cameo' soft white winter club wheat." *Journal of Plant Registrations* in review, submitted Dec. 2021. Wen, Nuan, et al. "Distribution of cereal cyst nematodes (Heterodera avenae and H. filipjevi) in Eastern Washington State." *Plant disease* 103.9 (2019): 2171-2178.
Develop club wheat breeding	Club cultivar	The breeding line ARSX09500-	Yearly entry of breeding	

lines with early spring green up, targeted to SE Washington.	releases are entered into Western Regional and State Extension Trials	17CBW has this trait and has performed well in testing in SE WA.	lines into regional trials	
Objective 2. Release germplasm and cultivars with the excellent end use quality characteristic of club wheat and with resistance to preharvest sprouting and late maturity alpha amylase (LMA)	Club wheat breeding lines will maintain stable falling numbers.	Castella and Cameo have more stable falling numbers (above 300) than Pritchett and Bruehl.	New breeding lines assessed yearly in Washington Cereal Variety Trials.	Sjoberg, Stephanie M., et al. "Unraveling complex traits in wheat: Approaches for analyzing genotype× environment interactions in a multi-environment study of falling numbers." *Crop Science* 60.6 (2020): 3013-3026. Sjoberg, Stephanie M., et al. "Application of the factor analytic model to assess wheat falling number performance and stability in multienvironment trials." *Crop Science* 61.1 (2021): 372-382.