

WASHINGTON AGRICULTURAL RESEARCH CENTER
WASHINGTON STATE UNIVERSITY
PULLMAN, WASHINGTON

Announces the Release of

'FARNUM'

Hard Red Winter Wheat

Introduction

'Farnum' (Reg. No. CV _____, PI 638535) is a hard red winter wheat (*Triticum aestivum* L.) was developed by the Agricultural Research Center of Washington State University in cooperation with the Agricultural Experiment Stations (AESs) of the University of Idaho and Oregon State University, and the United States Department of Agriculture-Agricultural Research Service (USDA-ARS). Farnum was named after the Farnum road area of the Horse Heaven Hills in Benton County, Washington. Farnum was released as a replacement for the hard red winter wheat varieties 'Finley' (PI 586757; Donaldson et al., 2000) and 'Hatton' (Cltr 17772) and as a complement to 'Bauermeister' (PI 634717; Jones et al., 2007) in the non-irrigated semi-arid (<380 mm of average annual precipitation) crop-fallow regions in Washington State based on its; (a) high grain yield potential; (b) high grain protein content (GPC); (c) high-temperature, adult-plant (HTAP) resistance to local races of stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici*); and (d) superior bread baking quality. Farnum was tested under the experimental designations of 73050(7+8)-6, KK50-2 and WA007975, which were assigned through progressive generations of advancement. Farnum is best adapted to the semi-arid, crop-fallow production regions of Benton and Franklin counties in eastern Washington where rapid seedling emergence under deep furrow planting conditions are required.

Methods

Farnum is a BC₃F_{2,3} head row selection derived from the backcross, WA007869 (PI 606766)*4/Glupro, using DNA marker assisted backcross breeding (MABB). WA007869, is a high yielding advanced hard red winter wheat that was proposed for pre-release in 1998 by Dr. Stephen Jones with the parentage of 'Buchanan'/4/'Kavkaz'/3/'PI 17346'/Itana'/'Wanser'. Due to the low grain protein content and marginal bread baking quality of the flour, WA007869 was not approved for release. Dr. Kim Kidwell initiated a collaborative effort with Dr. Jones to introgress the high GPC gene from Glupro (North Dakota State University, 1995), which received the gene from *Triticum turgidum* ssp. *dicoccoides* (DIC) accession FA15-3 (Avivi, 1978), into WA007869. A genomic region of DIC carrying the high GPC gene was initially mapped as a QTL on chromosome 6BS and subsequently the QTL was dissected into a single locus *Gpc-B1* (Joppa et al., 1997; Olmos et al., 2003; Distelfeld et al., 2004). The DIC allele of the *Gpc-B1* locus was reported to increase the GPC by 1.4% in both tetraploid and hexaploid wheat (Joppa et al., 1997; Mesfin et al., 2000).

Six F₁ seeds (WA007869/Glupro) were planted in the WSU Wheat Plant Growth Facility in 1999 and backcrossed to WA007869 to generate 172 BC₁F₁ seeds. At each backcross (BC_nF₁) generation, derivatives of WA007869 with DIC allele at *Gpc-B1* locus were identified by assaying for the presence of the simple sequence repeat (SSR) markers (*Xgwm644*, *Xgwm193*, *Xgwm508*), which are associated with the DIC allele (Khan et al., 2000; Distelfeld et al., 2004). *Xgwm644* and *Xgwm193* are 5.1 cM proximal and *Xgwm508* is 4.8 cM distal to the *Gpc-B1* locus. The third and final backcross was completed in October 2001. Selected BC₃F₁ lines representing 106 families were advanced to BC₃F₃ using single seed descent in the WSU Wheat Plant Growth Facility. Two thousand sixty-eight BC₃F_{2,3} head rows from the 106 families were planted in a field nursery in Pullman, WA, in October 2002. Individual rows were evaluated for general adaptation, plant height, stripe rust resistance, lodging, seed shattering, and grain appearance. Seed from 30 to 50 plants within each of the 140 selected head rows were bulk harvested to obtain BC₃F_{2,4} seed for early generation quality assessment. A 15 g subsample of each selected head row was UDY milled using a 0.5 mm screen. Flour produced was evaluated for protein content and hardness using a Bran+Luebbe InfraAlyzer 450. Selections with appropriate protein and hardness were

then evaluated for gluten strength using the sodium duodecyl-sulfate-sedimentation method (AACC, 2000). Based on these early generation end use quality assessments, 39 lines were planted in a replicated field nursery in Central Ferry, Washington in October 2003. One line, designated as WA007975, was identified to have superior agronomic performance, high grain protein content and excellent milling and baking quality was entered into the WSU Extension Uniform Hard Winter Cereal Variety Testing Trial in the fall of 2004. The co-dominant sequence tag site (STS) marker *Xucw89*, which is completely linked to the DIC allele of *Gpc-B1* locus, was used as diagnostic marker to confirm the presence of the allele in WA007975 (Distelfeld et al., 2006). WA007975 was evaluated in replicated field trials at twenty-six sites in the WSU Extension Uniform Hard Winter Cereal Variety Testing Trials in 2005, 2006 and 2007.

In 2006, Breeder seed of WA007975 (Farnum) was produced as a reselection based on phenotypic uniformity and resistance to stripe rust of 1800 BC₃F_{2,6} head rows grown under irrigation in Othello, WA. Selected head rows were bulk harvested, resulting in the production of 1000 kg of Breeder seed (Washington State Crop Improvement Association). Additionally, 2000 heads were snapped from the breeder seed block and were planted in the fall of 2007 to continue the purification process, with the goal of removing any remaining undesirable plants. In 2008, bulk harvested seed from selected BC₃F_{2,7} will be used to generate a new Farnum breeder seed lot for advancement.

Characteristics

Farnum is a tall, hard red winter wheat cultivar with late-season maturity that is phenotypically similar to WA007869. Farnum has a lax, tapering erect curvature inflorescence with tan awns and glumes that are long in length, wide in width with medium, oblique shoulders, and medium, acuminate beaks which lack pubescence. Farnum has elliptical kernels that are red, hard and mottled. Seed of Farnum has a mid-size germ with a shallow crease, rounded cheeks and medium, non-collared brush. Farnum has a coleoptile that lacks anthocyanin pigmentation, is prostrate in juvenile plant growth habit, and the flag leaf is green in color, erect, not twisted, and non-waxy at Feekes growth stage 10.0 (Large, 1954). The stem of Farnum has four nodes, lacks anthocyanin pigmentation, a waxy bloom is not present, the last internode of the rachis is semi-solid, the auricle is pigmented, pubescence is absent, and the peduncle is erect with a length of 43 cm.

Disease Resistance

Farnum was tested by the USDA-ARS, Wheat Genetics, Quality, Physiology, and Disease Research Unit, Pullman, WA on the Spillman, Plant Path, and Whitlow farms near Pullman, WA, Lind, WA, Walla Walla, WA, and Mt. Vernon, WA from 2005-2007 under natural infection of stripe rust (data from 2007 field trial is presented in Table 1). In the field at flowering to soft dough stages, Farnum had infection types (IT) 2-5 and severity (0-40%), which were lower than those of 'PS 279' (susceptible check) and Finley. When Farnum was tested at the seedling stage in the greenhouse under low temperature cycles (diurnal temperatures gradually changing from 4 to 20°C) (Chen and Line, 1992), reactions to currently and previously predominant races of wheat stripe rust (PST-17, PST-37, PST-43, PST-45, and PST-100) were assessed (Table 2). Farnum was susceptible to all races indicating that it does not have all-stage (seedling) resistance to these races. However, when tested with races PST-45, PST-100, and PST-116 at the adult plant stage in the greenhouse under high-temperatures (diurnal temperature cycle gradually changing from 10 to 35°C) (Chen and Line, 1995), Farnum was highly resistant (IT 2) (Table 2). The contrasting reactions of the seedling vs. the adult-plant tests with PST-45, PST-100, and PST-116 indicate that Farnum has a moderate level of non-race-specific, high-temperature, adult-plant resistance (HTAP), which has proven to be durable in other winter wheat cultivars, including the hard red winter wheat variety Bauermeister. The HTAP resistance in Farnum is lower than that in Bauermeister, however, different genes control the resistance mechanisms. Based on data collected in the 2006-2007 crop year by the WSU Extension Uniform Hard Red Winter Cereal Variety Testing Trials, the speckled snow mold resistance of Farnum was comparable to Eltan and Bauermeister and superior to that of Finley (data not shown).

Agronomic Performance

Farnum was evaluated in replicated field trials at 26 sites in the WSU Extension Uniform Hard

Red Winter Cereal Variety Testing Trials from 2005 to 2007. Due to a planting error, data for Finley in 2005 were not available. To ensure statistical confidence, the 2005 data were removed from the data set presented here. In 2006 and 2007 the grain yield averages of Farnum, Finley and Bauermeister were 3561 kg ha⁻¹, 3494 kg ha⁻¹ and 3494 kg ha⁻¹, respectively, in semi-arid locations with <380 mm of average annual precipitation (the target production zone). Grain yield of these three cultivars were not significantly different from one another ($P < 0.1$). Average grain volume weights of Farnum (768 kg m⁻³) were significantly lower than that of Bauermeister (777 kg m⁻³) and Finley (803 kg m⁻³) ($P < 0.1$). Thousand-kernel weight averages of Farnum, Finley, and Bauermeister were 37.5 g, 44.6 g, and 45.5 g, respectively.

Means of other agronomic traits obtained from the WSU Extension Uniform Hard Red Winter Cereal Variety Testing Trials from 2006 and 2007 are shown for the target production zone in Table 3. Farnum headed significantly later than Finley ($P < 0.1$), and was comparable to Bauermeister. Farnum was 2.1 cm shorter than Finley and 6.9 cm taller than Bauermeister ($P < 0.1$). The coleoptile length of Farnum was nearly equal to the club wheat variety 'Moro' (Citr 13740; Rohde et al., 1966) and longer than that of Finley and Bauermeister. Coleoptile length is associated with the ability of a seedling to emerge when deep furrow planted and Moro is the emergence standard for the semi-arid region. The lodging percentage of Farnum was higher than that of Finley and Bauermeister in the target production zone. Cold hardiness is an important trait for growers in the semi-arid regions where protective snow cover may be absent during cold periods. Cold hardiness tests were conducted on entries from the 2005-2006 WSU Extension Uniform Hard Red Winter Cereal Variety Testing Trials by Dr. Kim Campbell in the WSU Wheat Plant Growth Facility. Cold hardiness ratings indicate that Farnum is similar to most hard red winter wheat cultivars currently in production in the Pacific Northwest.

End-Use Quality

The USDA-ARS Western Wheat Quality Laboratory in Pullman, WA evaluated the end-use quality of Farnum using grain produced in 23 breeding and commercial variety testing trials in Washington from 2003 through 2007. A sub-set of this data from five locations is presented in Table 4. Finley and Bauermeister were used as checks in these evaluations. Farnum has excellent milling and baking quality compared to other hard red winter wheat varieties currently in production. Single kernel hardness values of Farnum, Finley, and Bauermeister meet the hard red winter wheat (HRWW) quality target range of 60-80. Whole grain protein content for Farnum (129 g kg⁻¹), Finley (125 g kg⁻¹) and Bauermeister (124 g kg⁻¹) were not significantly different from one another ($P < 0.01$). The most notable difference among these three varieties was the change in protein content (Δ protein) between whole grain and flour samples. The Δ protein in Farnum was significantly ($P < 0.01$) lower than that of Finley but it was identical to that of Bauermeister. Flour yield of Farnum (704 g kg⁻¹) was significantly ($P < 0.01$) lower than that of Finley (720 g kg⁻¹) but it was not significantly different from that of Bauermeister. Farnum had an average milling score of 85.7, which was significantly ($P < 0.01$) lower than Finley but similar to that of Bauermeister. Flour ash content for Farnum (3.9 g kg⁻¹) was similar to Finley (3.7 g kg⁻¹) and Bauermeister (4.1 g kg⁻¹). Mixograph water absorption of Farnum (643 g kg⁻¹) was not significantly ($P < 0.01$) different than that of Finley (639 g kg⁻¹) or Bauermeister (634 g kg⁻¹). Bake mixing time of Farnum was similar to Finley and Bauermeister. Average 100 g pup loaf volume for Farnum (956 cm³) was similar to Finley (950 cm³), but it was significantly ($P < 0.01$) larger than that of Bauermeister (896 cm³). All above tests utilized approved AACC methods (AACC, 2000).

In 2007, Farnum was evaluated by the Pacific Northwest Wheat Quality Council. This evaluation concluded that Farnum had similar end-use quality attributes when compared to Finley in nearly every assessment category. Loss of protein content (Δ protein) from grain to flour was significantly lower in Farnum than that of Finley, which mirrored the data from the USDA-ARS Western Wheat Quality Laboratory; however, the dough handling properties and baking quality of both varieties were comparable.

Availability

Foundation seed of Farnum will be maintained by the Washington State Crop Improvement Association under supervision of the Department of Crop and Soil Sciences, Washington State University, Pullman, WA, and the Washington State University Agricultural Research Center. A seed sample has been deposited in the USDA-ARS National Plant Germplasm System (NPGS) and small quantities of seed

may be directly obtained for research purposes by contacting the NPGS. U.S. Plant Variety Protection (PVP) status for this cultivar is pending.

References

- American Association of Cereal Chemists. 2000. Approved methods of the AACC. 10th ed. AACC, St. Paul, MN.
- Avivi, L. 1978. High protein content in wild tetraploid *Triticum dicoccoides* Korn. In: Ramanujam S. Ed. Proceedings of the 5th International Wheat Genetics Symposium. New Delhi, India: Indian Society of Genetics and Plant Breeding (ISGPB), 372-380.
- Chen, X.M. and R.F. Line. 1992. Identification of stripe rust resistance genes in wheat cultivars used to differentiate North American races of *Puccinia striiformis*. *Phytopathology* 82:1428-1434.
- Chen, X.M. and R.F. Line. 1995. Gene action in wheat cultivars for durable high-temperature adult-plant resistance and interactions with race-specific, seedling resistance to stripe rust caused by *Puccinia striiformis*. *Phytopathology* 85:567-572.
- Distelfeld, A., C. Uauy, S. Olmos, A.R. Schlatter, J. Dubcovsky, and T. Fahima. 2004. Microcolinearity between a 2-cM region encompassing the grain protein content locus *Gpc-6B1* on wheat chromosome 6B and a 350-kb region on rice chromosome 2. *Functional & Integrative Genomics* 4:59-66.
- Distelfeld, A., C. Uauy, T. Fahima, and J. Dubcovsky. 2006. Physical map of the wheat high-grain protein content gene *Gpc-B1* and development of a high-throughput molecular marker. *New Phytologist* 169:753-763.
- Donaldson, E., B. Sauer, S.R. Lyon, C.F. Morris, and R.F. Line. 2000. Registration of 'Finley' Wheat. *Crop Sci.*40:1197.
- Joppa L.R., C. Du, G.E. Hart, and G.A. Hareland. 1997. Mapping gene(s) for grain protein in tetraploid wheat (*Triticum turgidum* L.) using a population of recombinant inbred chromosome lines. *Crop Sci.* 37:1586-1589.
- Jones, S.S., S.R. Lyon, K.A. Balow, M.A. Gollnick, J.W. Burns, W.F. Schillinger, and P.E. Reisenauer. 2007. Registration of 'Bauermeister' Wheat. *Crop Sci.* 47:430-431.
- Khan, I.A., J.D. Procnier, D.G. Humphreys, G. Tranquilli, A.R. Schlatter, S. Marcucci-Poltri, R. Froberg, and J. Dubcovsky. 2000. Development of PCR-based markers for a high grain protein content gene from *Triticum turgidum* ssp. *dicoccoides* transferred to bread wheat. *Crop Sci.* 40:518-524.
- Large, E.C. 1954. Growth stages in cereals. *Plant Pathol.* 3:128-129.
- Mesfin A., R. C. Froberg, K. Khan, and T. C. Olson 2000. Increased grain protein content and its association with agronomic and end-use quality in two hard red spring wheat populations derived from *Triticum turgidum* L. var. *dicoccoides*. *Euphytica* 116:237-242.
- Olmos S., A. Distelfeld, O. Chicaiza, A.R. Schlatter, T. Fahima, V. Echenique, and J. Dubcovsky. 2003. Precise mapping of a locus affecting grain protein content in durum wheat. *Theor. Appl. Genet.* 107:1243-1251.
- Rhode C.R. 1966. Registration of Moro wheat. *Crop Sci.* 6:502.

Table 1. Stripe rust infection type (IT[†]) and severity (%) on Farnum, Finley, Bauermeister and susceptible check PS 279 tested in 2007 field trials under natural infection of *Puccinia striiformis* f. sp. *tritici*.

Cultivar	‡Spillman		‡Plant Path		‡Whitlow		‡Mt. Vernon		‡Walla Walla		‡Lind [§]	
	IT	%	IT	%	IT	%	IT	%	IT	%	IT	%
Farnum	3-5	40	5	20	2	20	2	2	2-3	20	0	0
Finley	8	80	8	30	5	40	5	40	8	30	0	0
Bauermeister	2	10	2	1	2	10	2	10	2	5	0	0
PS 279	8	100	8	90	8	60	8	100	8	70	8	20

[†] Infection Type (IT) was recorded based on the 0-9 scale with IT 8 and 9 combined as 8 (the most susceptible reaction) in field. Generally, IT 0-3 are considered resistant, 4-6 intermediate, and 7-9 susceptible. Two IT separated by a "-" indicate heterogeneous reactions with most plants having the first IT and few plants with the second IT.

[‡] Spillman, Plant Path and Whitlow are three different field nurseries in Pullman; Mt. Vernon is in western Washington; Walla Walla is in southeast Washington; Lind is in the semi-arid (<380 mm of average annual precipitation) crop-fallow regions in central Washington State.

[§] Stripe rust population was too low to have adequate data at Lind, but entries with IT ≥ 3 and any level of severity should be considered susceptible.

Table 2. Infection type (IT) of Farnum and susceptible check PS 279 tested under low temperatures (diurnal cycle 4-20°C) and adult plants tested under high temperatures (diurnal cycle of 10-35°C) with selected races of *Puccinia striiformis* f. sp. *tritici*. High IT in the seedling stage, but a low IT in the adult stage indicates presence of high temperature adult plant (HTAP) resistance.

Cultivar	Race	Seedling	Adult Plant
		IT	IT
Farnum	17	8	-
PS 279 (susceptible)	17	8	-
Farnum	37	8	-
PS 279 (susceptible)	37	8	-
Farnum	43	8	-
PS 279 (susceptible)	43	8	-
Farnum	45	8	2
PS 279 (susceptible)	45	8	8
Farnum	100	8	2
PS 279 (susceptible)	100	8	8
Farnum	116	-	2
PS 279 (susceptible)	116	-	8

Table 3. Means of heading date, plant height, coleoptile length, lodging and cold hardiness obtained from the 2006-2007 WSU Extension Uniform Hard Red Winter Cereal Variety Testing Trials in areas receiving <380 mm average annual precipitation.

Cultivar	Heading Date (days from Jan 1 [†])	Plant Height (cm)	Coleoptile Length (% Moro [‡])	Lodging (%)	Cold (Hardiness [§])
Farnum	146.7	83.3	97	4	28
Finley	142	85.4	83	0	39
Bauermeister	145.9	76.4	74	1	33

[†] Day of year (DOY).

[‡] Moro coleoptile length 101.3 mm from greenhouse tests May 2007.


[§] Mean Relative Area under the Death Progress Curve from 2005-2006 cold hardiness tests, lower value is better.

Table 4. Milling and baking data for grain samples of Farnum, Bauermeister and Finley obtained from breeding trials at five locations from 2003 to 2007. Data were generated at the USDA-ARS Western Wheat Quality Laboratory at Pullman, WA.

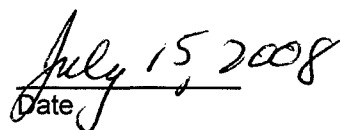
Trait (units)	Farnum	Finley	Bauermeister	Hard Red Winter Wheat Quality Targets [†]
Single Kernel Hardness	75	68.4	71.7	60-80
Whole Grain Protein (g kg ⁻¹)	129	125	124	≥ 120
Flour Protein (g kg ⁻¹)	122	113	117	≥ 110
Δ Protein (g kg ⁻¹)	7	12	7	≤ 10
Flour Yield (g kg ⁻¹)	704	720	705	≥ 680
Milling Score	85.7	88.2	84.4	≥ 85
Flour Ash (g kg ⁻¹)	3.9	3.7	4.1	≤ 3.7
Mixing Absorption (g kg ⁻¹)	643	639	634	≥ 602
Bake Mix Time (min)	3.0	3.0	2.9	3.0-5.0
Loaf Volume (cm ³)	956	950	896	≥ 870
Crumb Score (Score) [‡]	4.2	4.6	5.7	≤ 5

[†]Adopted by the Quality Targets Steering Committee of the Pacific Northwest Wheat Quality Council in 2007, Salt Lake City.

[‡]Subjective, 1-good, 9-poor.



 Ralph P. Cavalieri
 Director, Agricultural Research Center
 Washington State University


 Date

Mr. Ronald Whittum
WA State Crop Improvement Asso.
Foundation Seed Service
WSU – Seedhouse
Pullman, WA 99164-6420

September 28, 2009

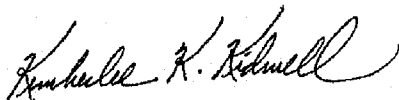
Dear Ron,

The purpose of this letter is to provide you with a supplemental description for the hard red winter wheat variety 'Farnum'. The variety description for Farnum should include a tolerance for white seed. Based on its pedigree, the level of white seed in Farnum is a varietal characteristic that has a genetic base.

Farnum breeder seed was first produced in 2007. Initial seed purity tests (WSDA) of this breeder seed lot indicated that Farnum contained 4 white seed per pound. In 2008, both breeder and foundation seed was produced from the 2007 breeder seed lot and results indicated 3 and 7 white seed per pound, respectively (WSDA test). An additional seed purity tests (WSDA) on foundation seed produced in 2009 indicate 9 white seed per pound. The second (2008) breeder seed production continued to exhibit white wheat, though at a slightly lower level than previously observed.

Farnum contains white seed that should be considered a variant within the variety. A white seed variant may occur in Farnum at a frequency of up to .15% (15 per 10,000 seed) in all classes of certified seed. Other variation from the original description of this variety should not be considered true-to-type.

Sincerely,



Dr. Kimberlee K. Kidwell
Associate Dean, Academic Programs
Interim Spring Wheat Breeder

cc. R Cavaliere