

Registration of 'Xerpha' Wheat

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Abstract

Many of the current soft white winter (SWW) wheat (*Triticum aestivum* L.) cultivars produced in Washington are adapted to specific environments. The objective of this research was to develop a high yielding, disease resistant SWW cultivar with competitive yield potential for all Washington winter wheat production environments. 'Xerpha' (Reg. No. CV-1045, PI 645605) SWW wheat was developed by the Agricultural Research Center of Washington State University (WSU) and released in 2008. It was selected from an 'Eltan'/'Estica' cross made in 1999 and advanced to the F₅ in the greenhouse by a modified single seed descent breeding strategy. Successive progeny were advanced under field conditions by a modified pedigree-bulk breeding method under the experimental designations SSD01061 and eventually WA007973. Xerpha was the highest, or among the highest, yielding SWW cultivars in every precipitation zone in the WSU Extension Uniform Cereal Variety Testing Program (EUCVTP) trials in 2006, 2007, and 2008. It was released as a replacement for 'Madsen' and Eltan on the basis of its superior grain yield in Washington's low (<400 mm average annual precipitation (AAP)), intermediate (400–500 mm AAP), and high (> 500 mm AAP) precipitation zones; excellent grain volume weight; strong cold tolerance, and high-temperature, adult-plant (HTAP) resistance to stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici*).

MADSEN (PI 511673; Allan et al., 1989) and Eltan (PI 536994; Peterson et al., 1991) have been the top two SWW cultivars produced in Washington for nearly two decades (USDA-NASS, 2008). Madsen has strong resistance to eyespot foot rot [caused by *Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams = *Pseudocercospora herpotrichoides* (Fron) Deighton, W-type] and *O. acufiformis* (Boerema, R. Pieters & Hamers) Crous & W. Gams (= *Pseudocercospora herpotrichoides* var.

acufiformis Nirenberg, R-type) but lacks the yield potential of recently released SWW cultivars, especially in low (<400 mm AAP) precipitation areas. Eltan is produced primarily in the low to intermediate (400–500 mm AAP) precipitation zones because of its susceptibility to diseases common to the high precipitation (>500 mm AAP) areas. The purpose of this research was to develop a high yielding disease resistant SWW cultivar with competitive yield potential for all Washington winter wheat production environments.

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Xerpha (Reg. No. CV-1045, PI 645605) SWW wheat was developed by the Agricultural Research Center of Washington State University (WSU) and released in 2008. Derived from an Eltan/Estica (PI 585231) cross, Xerpha is unique in that it has very broad adaptation within Washington. It was released as a replacement for Madsen and Eltan on the basis of its superior grain yield in Washington's low, intermediate, and high precipitation zones; excellent grain volume weight, strong cold tolerance, and high-temperature, adult-plant adult-plant (HTAP) resistance to stripe rust. Xerpha is named in honor of Xerpha Mae Gaines (1891–1970), WSU alumna, botanist, taxonomist, and weed scientist, in recognition of her vast and lasting contributions to agriculture and science at WSU and the Pacific Northwest.

Abbreviations: AAP, average annual precipitation; AUDPC, area under death progress curve; EUCVTP, Extension Uniform Cereal Variety Testing Program; HTAP, high-temperature, adult-plant; IT, infection type; SWW, soft white winter; WPGC, Wheat Plant Growth Center; WSCIA, Washington State Crop Improvement Association; WSU, Washington State University.

Methods

Early Generation Population Development

Xerpha was tested under the experimental designations SSD01061 and WA007973, which were assigned through progressive generations of advancement. Xerpha was selected as an F_{6.7} line from the cross Eltan/Estica made in 1999 in the WSU Wheat Plant Growth Center (WPGC) by

Published in the Journal of Plant Registrations 4:137–140 (2010).

doi: 10.3198/jpr2009.06.0306crc

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Steven R. Lyon. The SWW wheat cultivar Eltan is adapted to Washington's low to intermediate precipitation zones and Estica is a hard red winter cultivar from the Netherlands (developed by Cebeco Zaden B.V.) with high grain yield potential, especially areas with >500 mm AAP.

Seeds (F_1) of the population from which Xerpha was selected were planted in the WPGC into a divided tray with 48-cell inserts (McConkey & Co., Sumner, WA) in Sunshine Professional Growth Media #1 (Sun Gro Horticulture Canada Ltd., Seba Beach, AB, Canada) with liquid fertilizer (20N-10P-20S). Seedlings were grown to the 2-leaf stage in a growth chamber (Conviron GR48, Winnipeg, MB, Canada) with a 16-h photoperiod at 22°C and then transferred to a Conviron G48 chamber set at 4°C with a 12-h photoperiod for 8 wk of vernalization. Seedlings were removed from vernalization and transplanted into 10-cm pots, 1 seedling per pot, in the greenhouse with a 16-h photoperiod at 21 to 24°C and a night temperature of 15 to 18°C. A single seed determined to be soft and white through visual examination was advanced from each plant in the F_2 through F_5 generations. One hundred forty-four F_2 seeds were advanced in the WPGC to the F_5 by the modified single seed descent procedure described above. A modified pedigree-bulk breeding method was used to advance succeeding generations.

Line Selection and Evaluation

The F_6 seed from each of 144 plants was individually bulked and planted as unreplicated field plots at the WSU Spillman Agronomy Farm near Pullman, WA, in 2001 with a double-disc planter. The plots were 3.3 m long with 7 rows, spaced 15 cm apart. Of the 144 F_6 lines planted, SSD01061 was among a group of 50 F_7 lines that were selected in 2002 on the basis of visual observations of agronomic appearance and resistance to natural stripe rust, eyespot foot rot, and *Cephalosporium* stripe (caused by *Cephalosporium gramineum* Nis. & Ika.) infections. An 85-g subsample of the bulked seed harvested from the selected lines was used to plant similarly sized unreplicated F_7 yield trial plots in 2002 at Spillman Agronomy Farm. During 2003 and 2004, the F_8 and F_9 generations were field tested in replicated preliminary yield trials in low and high precipitation areas. The low AAP trial was at the WSU Lind Dryland Research Station, Lind, WA, and planted with a deep-furrow, split-packer, 4-row planter with 40-cm row spacing, 3.3 m long. The high AAP trial was at the Spillman Agronomy Farm and planted with a double-disc planter with similar plot size as the F_7 . Selection was based on general adaptation, plant height, maturity, disease resistance, grain yield, test weight, and milling and baking quality from the two precipitation zones. One line (SSD01061) emerged from the field nurseries as superior in grain yield and test weight. It was designated as WA007973 and from 2005 to 2008 (F_{10} – F_{13}) was evaluated in replicated field trials from 36 breeding advanced yield trial location-years and 74 location-years in the WSU EUCVTP trials.

Seed Purification and Increase

Seed purification of Xerpha began in 2004 and was repeated in 2005 by visual identification and manual removal of variants (primarily tall and awnless off-types)

from bulk seed increases grown under irrigation at Central Ferry, WA. In fall 2006, 3000 $F_{6,11}$ spikes of WA007973 grown near Pullman were threshed individually and planted as 4-m long head-rows spaced 30 cm apart and grown under furrow-irrigation at Othello, WA, by the Washington State Crop Improvement Association (WSCIA) for Breeder seed production. The head-rows were visually inspected and selected for phenotypic uniformity, maturity, and resistance to stripe rust. Nonconforming rows (<1%) were removed before the 2007 harvest and the bulked head-rows resulted in the production of 2700 kg of Breeder seed. The Breeder seed was planted on about 25 ha under center pivot irrigation near Quincy, WA, and produced nearly 182,000 kg of Foundation seed in 2008.

Statistical Analysis

Statistical analyses were done with SAS Version 9.1 (SAS Institute, Cary, NC). Analysis of variance for agronomic and disease resistance data were performed across locations within years, and a combined analysis was performed across location-years with entries common to all trials. Since Washington has three major wheat-producing regions based on AAP, the 2005 to 2008 data for grain yield, grain volume weight, and grain protein content from the WSU EUCVTP trials were subjected to combined analysis of variance across locations-years within AAP regions as well as over all locations. Head-to-head comparisons were made to the common check cultivars Madsen and Eltan from 2005 to 2008 WSU EUCVTP trials by the Student's paired *t*-test procedure ($\alpha = 0.05$) of Agrobase Generation 2, version 18.3.1 (Agronomix Software, Inc., Winnipeg, Canada). End-use quality data were analyzed by the Student's paired *t*-test procedure (Cochran and Cox, 1957).

Characteristics

Agronomic and Botanical Description

Xerpha is a midheight SWW wheat with moderately late maturity. Its average heading date (Day of Year 156) ($n = 74$) is the same as Madsen and 2 d earlier ($P < 0.01$) than Eltan (158). It has middense, oblong, erect, awned spikes with white glumes that are medium long, wide width, with wide, oblique shoulders, and medium, acuminate beaks that lack pubescence. The kernels of Xerpha are ovate, white, and soft with a midsize germ and midsize crease, rounded cheeks, and a short, non-collared brush. Xerpha has an erect juvenile plant growth habit with blue-green plant color at Feekes growth stage 10.0 (Large, 1954) and a coleoptile that lacks anthocyanin pigmentation. Flag leaves of Xerpha are recurved, twisted, and show a waxy bloom at the boot stage. The stem of Xerpha has five nodes, lacks anthocyanin pigmentation, and has an erect peduncle with an average length of 22 cm. The last internode of the rachis is hollow, the auricle is not pigmented, and pubescence is absent. The average plant height of Xerpha is 91 cm ($n = 74$), which is similar to Eltan (92) and taller ($P < 0.01$) than Madsen (89). The average coleoptile length (Murphy et al., 2008) of Xerpha is 64.4 mm ($n = 30$), similar to Eltan (62.4) and Madsen (70.6). In 2006 and 2007, Xerpha and Madsen did not lodge when grown under a center pivot irrigation system at Moses

Lake, WA, as compared with Eltan, which lodged 80% in 2006 and 25% in 2007. Cold hardiness tests were conducted in the growth chambers of the WSU WPGC according to Reddy et al. (2006). The relative area under the death progress curve (AUDPC) was determined on the basis of the number of plants that die at each of five test temperatures from -10 to -20°C. The AUDPC values were calculated on a relative basis where 0 = 100% survival and 100 = 100% mortality. Xerpha's mean AUDPC rating was 29 ($n=100$), as compared with Eltan, 34.6, and Madsen, 45.7.

On the basis of evaluations of Breeder and Foundation seed lots, Xerpha may contain naturally occurring variants of up to (i) 10 red seeds in 454 g of seed, (ii) height variants (50–200 mm taller) at a frequency of approximately 1 in 10,000, and (iii) awnless spikes at a frequency of approximately 1 in 80,000.

Disease Reactions

Xerpha was tested for reaction to stripe rust in field plots from 2003 to 2007 at Pullman and Mt Vernon and exhibited resistance similar to Eltan. Susceptible infection type [(IT) = 8; 0–9 scale] reactions early, and resistant ITs (2–3) late in the growing season at Mt Vernon indicate that Xerpha has HTAP resistance. This was verified by greenhouse evaluations conducted in 2005 and 2006 when Xerpha was susceptible to all tested races in the seedling stage (Chen and Line, 1992) but had resistant reactions (IT 2–5) at adult-plant stages (Chen and Line, 1995). The tested races included previously predominant races (PST-17, PST-37, PST-43, and PST-45) and current predominant races (PST-100 and PST-116). The contrasting reactions of seedlings compared with adult plants confirmed that Xerpha has non-race specific HTAP resistance to stripe rust, which has proven to be durable in many wheat cultivars grown in the Pacific Northwest (Chen, 2005).

Xerpha showed moderate resistance to dwarf bunt (caused by *Tilletia controversa* Kühn) (visual disease assessment) similar to Madsen when under high disease pressure with a pathogenic race composite having virulence to the bunt resistance genes *Bt1*, *Bt2*, *Bt3*, *Bt4*, *Bt6*, *Bt7*, *Bt9*, *Bt10*, *Bt14*, and *Bt15* in 2006 and 2007 inoculated field trials near Logan, UT.

Visual disease assessments (8.0 score, 1 = susceptible and 8 = resistant) for *Cephalosporium* stripe from two inoculated field trials conducted in 2006 and 2007 at the Palouse Conservation Field Station near Pullman indicate Xerpha is tolerant to *Cephalosporium* stripe similar to Eltan, the most tolerant commercial winter wheat variety produced in Washington (Stiles and Murray, 1996).

Xerpha exhibits tolerance to eyespot foot rot. In 2006 and 2007, eyespot foot rot inoculated field trials at the Plant Pathology Farm near Pullman showed Xerpha had a mean disease index level (Murray et al., 1994) of 78.3 similar to the susceptible check Eltan (75.6) but significantly greater ($P < 0.001$) than the resistant check Madsen (26.3). However, in the same trials Xerpha's mean grain yield was 10,273 kg ha⁻¹, similar to Madsen (9,917) and significantly greater ($P < 0.001$) than Eltan (9,030).

Xerpha was tested under natural field infections of speckled snow mold (caused by *Typhula idahoensis* Rems and *T. ishikariensis* Imai.) in 2007 in Douglas County, Washing-

ton. Visual disease assessments (8.0 score, 1 = susceptible and 8 = resistant) show Xerpha (4.4) was similar to Madsen (3.2) but less ($P < 0.01$) than Eltan (6.4), while in the same trials, the mean grain yield of Xerpha (4401 kg ha⁻¹) was similar to Eltan (4334) and significantly greater ($P < 0.01$) than Madsen (3171).

Grain Yield Performance

Xerpha was evaluated for grain yield in replicated field trials under fallow, nonirrigated, and irrigated conditions. Xerpha was tested at 74 locations by the WSU EUCVTP during 2005 (18 locations), 2006 (18), 2007 (19), and 2008 (19) in Washington. The 4-yr average grain yield of Xerpha ($n=74$) was 7191 kg ha⁻¹, significantly greater ($P < 0.01$) than Madsen (6486) and Eltan (6382). Grain volume weight of Xerpha ($n=74$) averaged 761 g L⁻¹, similar to Eltan (762) and Madsen (762), and the whole grain protein content of Xerpha ($n=74$) was 109 g kg⁻¹ similar to Eltan (110) and significantly less ($P < 0.01$) than Madsen (116). When separated by AAP regions (Table 1), Xerpha had significantly greater grain yield ($P < 0.01$) and similar grain volume weight in every region as compared with Madsen and Eltan. Its grain protein content was significantly less ($P < 0.01$) than Madsen in every region, similar to Eltan in the mid and high AAP regions, and significantly less ($P < 0.05$) in the low AAP region.

End-Use Quality

Grain, milling, and end-use quality evaluations of Xerpha (Table 2) were conducted by the USDA-ARS Western Wheat Quality Lab (WWQL) at Pullman by approved methods of the American Association of Cereal Chemists (AACC, 2000) from grain produced in breeding and commercial variety testing trials in Washington from 2002 through 2006. Results from the quality assessments were averaged over trials in which Xerpha, Eltan, and Madsen were grown. Xerpha has significantly heavier seeds than both Madsen and Eltan, whereas grain hardness of Xerpha is similar to Madsen and significantly greater than Eltan. Both the grain and flour protein content and the flour ash content of Xerpha are similar to Eltan but significantly less than Madsen. The flour yield of Xerpha is significantly greater than Eltan but significantly less than Madsen. Xerpha's mixograph water absorption was equal to Madsen and Eltan. The average sugar snap cookie diameter and sponge cake volume for Xerpha was significantly less than Eltan and equal to Madsen. The WWQL concluded that Xerpha has acceptable grain, milling, and end-use qualities (USDA-ARS Western Wheat Quality Laboratory, 2009).

Availability

U.S. Plant Variety Protection for Xerpha has been issued (PVP Certificate # 200900289). A seed sample has been deposited in the USDA-ARS National Small Grains Collection, Aberdeen, ID, where it will become available for distribution after expiration of PVP. Seed of Xerpha will be maintained by the WSCIA under supervision of the Dep. of Crop and Soil Sciences and the Washington State Agricultural Research Center. Small quantities of seed for research purposes may be obtained from the corresponding author

Table 1. Summary of grain yield, grain volume weight, and grain protein content by precipitation zone for Xerpha soft white winter wheat as compared individually with soft white winter wheat cultivars Eltan and Madsen, evaluated in the Washington State University Extension Uniform Cereal Variety Testing Program from 2005 to 2008 in Washington.

Cultivar	<400 mm AAP [†]			400–500 mm AAP			>500 mm AAP		
	Grain yield	Grain volume weight	Grain protein	Grain yield	Grain volume weight	Grain protein	Grain yield	Grain volume weight	Grain protein
	kg ha ⁻¹	g L ⁻¹	g kg ⁻¹	kg ha ⁻¹	g L ⁻¹	g kg ⁻¹	kg ha ⁻¹	g L ⁻¹	g kg ⁻¹
Xerpha	5575	759	106	7980	765	113	9388	759	112
Eltan	5051**	762	109*	6984***	767	111	8235***	757	112
Madsen	4942**	762	113**	7312**	768	117***	8522***	755	119***
n [‡]	36	36	36	18	18	18	20	20	20

*Significant at the 0.05 probability level.

**Significant at the 0.01 probability level.

*** Significant at the 0.001 probability level.

[†]AAP, average annual precipitation.

[‡]n, number of observations.

Table 2. Quality summary of 6 yr of paired comparisons of Xerpha with Madsen and Eltan soft white winter wheats grown in Washington, 2001 to 2006.

Cultivar	Kernel weight	Grain hardness index	Grain protein content	Flour milling yield	Flour ash content	Flour protein content	Mixograph water absorption	Cookie diameter	Sponge cake volume
	mg	score g kg ⁻¹			g kg ⁻¹			cm	mL
Xerpha	38.2	43.2	107	687	3.8	90	559	9.3	1207
Eltan	35.2	30.9	105	681	3.7	92	556	9.4	1287
LSD _{0.05}	1.0	1.5	3	4	0.10	3	9	0.1	30
P-value [†]	<0.01	<0.01	0.27	<0.01	0.09	0.12	0.6	0.01	<0.01
n [‡]	30	30	33	31	30	30	16	30	9
Xerpha	38.0	42.4	104	686	3.8	87	557	9.3	1229
Madsen	35.2	42.5	108	694	3.9	95	552	9.3	1208
LSD _{0.05}	0.7	1.5	3	4	0.10	3	10	0.1	25
P-value [†]	<0.01	0.79	0.01	<0.01	0.01	<0.01	0.3	0.5	0.09
n [‡]	30	30	33	31	30	30	18	30	10

[†]P-values represent the significance of the comparison between Xerpha and the respective check cultivar based on Student's paired t-test procedures (SAS version 9.1, SAS Institute, Cary, NC).

[‡]n, number of observations.

for at least 5 yr from the date of this publication according to the provisions of the Wheat Worker's Code of Ethics (Annual Wheat Newsletter, 1995).

Acknowledgments

The authors greatly appreciate the following personnel who assisted with field testing, quality assessment, and disease screening during the development of this variety: B. Baik (WSU), T. Harris, (WSU), J. Burns (WSU), B. Goates (USDA-ARS), and C. Morris (USDA-ARS). Xerpha was developed with financial support from the Washington State Grain Alliance and the Washington State Agricultural Research Center.

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