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CULTIVAR

Registration of 'Langin' Hard Red Winter Wheat

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Abstract

'Langin' (Reg. No. CV-1141, PI 678945) hard red winter wheat (*Triticum aestivum* L.) was developed by the Colorado Agricultural Experiment Station and released in August 2016 through a marketing agreement with the Colorado Wheat Research Foundation. In addition to researchers at Colorado State University, USDA–ARS researchers at Manhattan, KS, St. Paul, MN, and Pullman, WA, contributed to its development. Langin was developed with the objective of making available a hard red winter wheat cultivar with improved grain yield, end-use quality, and stripe rust resistance compared with 'Byrd' hard red winter wheat. Langin is a doubled haploid cultivar developed using the wheat × maize (*Zea mays* L.) wide hybridization method from the cross CO050270/Byrd made in 2009 at Fort Collins, CO. Following doubled haploid generation in 2010, Langin was selected at Fort Collins in July 2011, assigned experimental line number CO11D446, and evaluated in yield trials in Colorado and other states in the US hard winter wheat region from 2012 to 2016. The name Langin was chosen in honor of former Colorado State University Extension and Agricultural Experiment Station agronomist Edward J. Langin (1924–2006).

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Hard winter wheat (*Triticum aestivum* L.) is a central component of dryland (rainfed) and irrigated cropping systems on the eastern plains of Colorado. For the 10-yr period 2006 to 2015, annual Colorado winter wheat production averaged 2.05 million metric tons with an average annual farm gate value of $444.8 million (USDA–NASS, 2017). Successful wheat production and grain marketing in eastern Colorado is fostered by adoption of wheat cultivars that have good drought stress tolerance, a high level of winter-hardiness, high grain yield potential, adequate host-plant resistance to prevalent disease and insect pests, and end-use quality characteristics typical of the hard red winter (HRW) wheat market class.

Since the emergence of stripe rust (caused by *Puccinia striiformis* Westend. f. sp. *tritici* Erikss.) as a serious disease in the US Great Plains in 2000 (Chen et al., 2002), and following several subsequent epidemics throughout the region (Wan and Chen, 2014), producers in Colorado have increasingly focused on stripe rust resistance in their cultivar selection decisions. For several years following emergence of stripe rust in 2000, breeders in this region focused heavily on resistance conferred by the *Yr17* gene found in 'Jagger' (Sears et al., 1997), which was defeated with the first race shift in the region observed in 2010 (Wan and Chen, 2014). Resistance present in 'TAM 111' (PI 631352; Lazar et al., 2004), 'Everest' (PI 659807), and other cultivars subsequently was defeated with a second race shift observed in 2012 (Basnet et al., 2014; Wan et al., 2016). Because of these race shifts and the difficulties these pose for both

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Abbreviations: BLUE, best linear unbiased estimator; CSU, Colorado State University; HMWG, high molecular weight glutenin; HRW, hard red winter; SKCS, single kernel characterization system; SRPN, Southern Regional Performance Nursery.

breeders and producers, germplasm and cultivars with effective and durable resistance are needed.

'Langin' (Reg. No. CV-1141, PI 678945) hard red winter wheat was developed by the Colorado Agricultural Experiment Station and released in August 2016 through a marketing agreement with the Colorado Wheat Research Foundation. Langin was released as a replacement for 'Byrd' (PI 664257; Haley et al., 2012a), a HRW wheat cultivar that was released in 2011 and by 2015 and 2016 had become the most widely grown winter wheat cultivar in Colorado (USDA-NASS, 2016). The name *Langin* was chosen in honor of former Colorado State University (CSU) Extension and Agricultural Experiment Station Agronomist Edward J. Langin (1924–2006).

Methods

Langin was developed using the wheat × maize (*Zea mays* L.) hybridization method (Laurie and Bennett, 1988; Santra et al., 2017) from the cross CO050270/Byrd made in 2009 at Fort Collins, CO. Byrd is a HRW wheat cultivar released by CSU in 2011 and CO050270 is a CSU experimental line with the pedigree 'Hatcher' (PI 638512; Haley et al., 2005)/NW97S295 ('Arlin' [PI 564246]/'Pronghorn' [PI 593047]). Doubled haploids were produced in 2010 from the F_1 generation, and seed of the doubled haploid plant was planted in a double "headrow" (two rows, 1 m long, 23 cm row spacing) in February 2011 at Fort Collins. Based on visual observations of overall agronomic appearance, Langin was selected in July 2011 and assigned experimental number CO11D446.

CO11D446 was subsequently evaluated in an unreplicated observation nursery at Fort Collins in 2012, the CSU Elite Trial from 2013 to 2016, dryland (rainfed) and irrigated CSU variety trials from 2014 to 2016, the Cooperative USDA–ARS Regional Germplasm Observation Nursery from 2014 to 2016, and the Cooperative USDA–ARS Southern Regional Performance Nursery (SRPN) in 2014 and 2015. The CSU Elite Trials were arranged in resolvable, latinized row-column designs (John and Williams, 1995) with two replications in 2013 and 2014 and partial replication (Williams et al., 2011) in 2015 and 2016. The CSU variety trials were arranged in resolvable, latinized row-column designs with three replications. All trial randomizations and statistical analyses were done within the R programming language (R Core Team, 2015); codes are freely available by email request to the corresponding author. Trial randomizations were prepared using version 0.2-31 of the R package *DiGGer* (Coombes, 2009).

Seed purification of Langin was done by headrow purification. In July 2013, 258 single spike selections were selected from a seed increase plot growing at Fort Collins. Seed from each spike was planted in 2.4-m-long rows in Yuma, AZ, in November 2013. Of the 258 progeny rows, 246 were hand-harvested in June 2014 on the basis of visual observations of plant height uniformity. Seed of the progeny rows was visually examined to confirm red kernel color and then bulked to form the pre-breeder seed. For each subsequent seed increase cycle, purification was accomplished using visual identification and manual removal of tall and red-glumed off-types. A subsample of the pre-breeder seed was used to plant a 0.4-ha breeder seed increase at Fort Collins in September 2014. The breeder seed production was harvested in July 2015. Breeder seed was used to plant a 4-ha foundation seed increase in Yuma in November 2015. The foundation seed production field was harvested in June 2016.

Agronomic, disease resistance, and end-use quality data were analyzed using the Student's paired *t* test (t.test function) in base R. Yield and grain volume weight (test weight) data from the CSU Elite Trial and CSU variety trials were analyzed with the asreml package in R (Butler, 2009) using a two-stage procedure (Piepho et al., 2008). In the first stage, individual trials (environments) were analyzed with a series of spatial models that included genotype as a fixed effect, row and column coordinates as random effects, and several different residual error models specified in the *rcov* argument within the asreml call (as described in Butler, 2009). The restricted maximum likelihood (REML) loglikelihood value was used to select the best model for each environment. Best linear unbiased estimates (BLUEs) from the first stage of the analysis were then subject to a combined analysis over environments using a heterogeneous compound symmetry model (Malosetti et al., 2013) with environments and genotypes as fixed effects and the diagonal elements (covariances) of the genotype × environment matrix specified in the *rcov* argument within the asreml call. As discussed by Malosetti et al. (2013), the heterogeneous compound symmetry model efficiently accommodates heterogeneous correlations between environments as often occur when individual environment means within a multienvironment trial vary greatly due to differing environmental stress conditions. In the second stage of the analysis, only genotypes common to all environments were included. The Fisher's least significant difference (LSD) of the across-environment BLUEs was estimated using the predictparallel function in the asremlPlus package in R (Brien, 2016). The 0.05 α probability level was used for all mean comparisons.

Characteristics

General Description

Langin is an awned, white-glumed, hard red winter wheat. Langin has early maturity (time to heading), similar to 'Ripper' (PI 644222; Haley et al., 2007; n = 30 comparisons), 1.9 d earlier (n = 49) than Byrd, and 5.5 d earlier than 'Denali' (PI 664256; Haley et al., 2012b; n = 51). Langin is medium-short at maturity, 2.5 cm shorter than (n = 97) Hatcher and 5.8 cm shorter than (n = 106) Byrd. The coleoptile length (evaluated according to Hakizimana et al., 2000) of Langin (71.5 mm; n = 11) is medium, similar to Hatcher and 7.4 mm shorter than (n = 11) Byrd. Straw strength of Langin is fair (5.5 score, n = 39; 1 to 9 scale, where 1 = erect and 9 = flat), similar to that of Hatcher (5.5) and Byrd (5.0) and less than that of Denali (3.7). Preharvest sprouting tolerance of Langin, assessed through determination of a germination index (Mares et al., 2005) from field-grown samples, is good (germination index = 0.18; n = 18), similar to that of Byrd (0.21) and Hatcher (0.13). Observations of winter survival ability in eastern Colorado and the 2014 and 2015 SRPN (eight environments; USDA-ARS, 2015) suggest that the winterhardiness of Langin is at least adequate for successful production in the west-central Great Plains region of the United States.

Disease and Insect Resistance

Langin has been characterized for disease and insect resistance in Colorado and through cooperative evaluations of the USDA–ARS Coordinated Regional Testing Program (USDA–ARS, 2015). In artificially inoculated field tests at Rossville, KS, in 2013 and 2015, Langin showed a resistant reaction to stripe rust, with an average infection type of 2.0 and an average severity of 1.3% (n = 3 observations). In these same nurseries, the susceptible repeated check line KS89180B-2 showed a highly susceptible reaction, with an average infection type of 7.7 and an average severity of 94.6%. Observations under natural stripe rust infection in the SRPN grown in Washington in 2014 and 2015 showed that Langin is moderately susceptible to prevalent races in that region, with an average infection type of 6.3 and an average severity of 38% (n = 4 observations). In these same nurseries, the susceptible check 'TAM 107' (PI 495594; Porter et al., 1987) showed an average infection type of 8.0 and an average severity of 69%. Under natural stripe rust infection in Colorado in 2015 and 2016, Langin showed a moderately resistant reaction (2.6 score, where 1 = resistant and 9 = susceptible; n = 43), more resistant than Hatcher (4.0), Byrd (6.4), and Denali (7.3). Although the exact origin of the stripe rust resistance in Langin is unknown, it is likely that the partial resistance observed in Hatcher is involved given that the moderate level of stripe rust resistance in Byrd (Haley et al., 2012a) and the high level of resistance in Denali (Haley et al., 2012b) was defeated with the race shift that occurred in the region in 2012 (Basnet et al. (2014).

In greenhouse seedling evaluations at St. Paul, MN, Langin was susceptible to US stem rust (caused by *Puccinia graminis* Pers.:Pers f. sp. *tritici* Eriks. & E. Henn.) races QFCSC, QTHJC, MCCFC, RCRSC, RKQQC, TPMKC, TTTTF, GFMNC, and QCCSM and susceptible to African race TTKSK. Field adult-plant evaluations at St. Paul in 2014 and 2015 confirmed that Langin is susceptible to the North American stem rust races. Adult plant-evaluation at Njoro, Kenya, in 2014 indicated that Langin is susceptible to Ug99 related races. Greenhouse seedling evaluations with leaf rust (caused by *Puccinia triticina* Eriks.) have shown that Langin is susceptible to most common leaf rust races in the United States (TNBGJ, MCTNB, MFPSB, KFBJG, MBDSD, TFBJQ, MJBJG, MHDSB, TCRKG, PBLRG). In 2014, under natural field infection with unknown leaf rust races at Castroville, TX, Langin showed a susceptible adult-plant reaction.

Other evaluations in Colorado or through the USDA–ARS Coordinated Regional Testing Program (USDA–ARS, 2015) have shown that Langin is resistant to *Soil-borne wheat mosaic virus*, susceptible to a collection of endemic biotypes of the Hessian fly [*Mayetiola destructor* (Say)] (Chen et al., 2009), susceptible to greenbug Biotype E [*Schizaphis graminum* (Rondani)], and susceptible to Russian wheat aphid (*Diuraphis noxia* Kurdjumov) Biotypes 1 and 2. Langin is moderately susceptible to *Wheat streak mosaic virus* but has shown resistance to a Texas collection of the wheat curl mite (*Aceria tosichella* Keifer; Dhakal et al., 2017). Langin lacks DNA markers *Wsm1* (Qi et al., 2007) and *Wsm2* (Lu et al., 2012) associated with *Wheat streak mosaic virus* resistance.

Field Performance

Langin was tested at 35 rainfed environments of the CSU Elite Trial in Colorado from 2013 to 2016 and 26 rainfed environments of the Colorado Uniform Variety Performance Trial from 2014 to 2016. In the first stage of the analyses for grain yield, a two-dimensional spatial model (AR1×AR1; Gilmour et al., 1997) was the best model for >79% of the environments (trials). In the combined analysis (second stage) across all rainfed environments (n = 61 environments), the grain yield of Langin was less than the hard white winter wheat cultivar Antero (PI 667743; Haley et al., 2014), similar to the HRW wheat cultivar Avery (PI 676977; Haley et al., 2018), and higher than each of the other cultivars in the trials (Table 1). In the single-year

Table 1. Grain yield and grain volume weight of hard white winter (HWW) and hard red winter (HRW) wheat cultivars in the Colorado State University (CSU) Elite Trial from 2013 to 2016, the Colorado Uniform Variety Performance Trial (UVPT) from 2014 to 2016, and the Colorado Irrigated Variety Performance Trial (IVPT) from 2014 to 2016.

Entry	Type	Grain yield†									Grain volume weight
		2013 Elite	2014 Elite	2015 Elite	2016 Elite	2014 UVPT	2015 UVPT	2016 UVPT	Combined Elite and UVPT	Irrigated Elite and IVPT‡	
		kg ha^{-1}									kg m^{-3}
Antero	HWW	2318	4540	4823	5510	4046	5156	5718	4521	5975	756
Langin	HRW	2278	4364	4937	5802	3779	4863	5558	4407	6044	750
Avery	HRW	2314	4573	4485	5356	4194	4180	5551	4467	5886	753
Hatcher	HRW	2221	4297	3838	5508	3845	4038	5500	4283	5434	751
Sunshine	HWW	2201	4105	4172	5201	3737	4280	5476	4199	5567	748
Denali	HRW	2354	4489	4417	5317	3874	4350	5428	4352	6162	767
Byrd	HRW	2203	4416	4555	5400	3955	4086	5373	4337	5781	758
Brawl CL Plus§	HRW	2361	4091	3725	4985	3819	3665	5164	4128	5590	759
Snowmass§	HWW	1991	4039	4320	4964	3705	3988	5139	4048	–	755
Environments		7	10	8	10	9	9	8	61	11	49
Mean¶		2249	4324	4364	5338	3884	4290	5434	4305	5805	755
LSD (0.05)		179	255	455	372	222	454	328	105	492	3

† Individual year and combined data from the CSU Elite Trial and the UVPT are from rainfed environments only.

‡ Irrigated environments included one for each year of the CSU Elite Trial (2013 to 2016), two for the IVPT in 2014 and 2015, and three for the IVPT in 2016.

§ Brawl CL Plus: Haley et al. (2012c); Snowmass: Haley et al. (2011).

¶ Trial mean includes only those entries in the table.

analyses, Langin showed higher grain yield in 2015 and 2016, when stripe rust was more of a yield-limiting factor in the trials, but lower grain yield in 2013 and 2014, when stripe rust was not a significant yield-limiting factor (Table 1). Grain volume weight of Langin across the rainfed environments (Table 1; n = 49) was below average, lower than all of the other cultivars tested except Hatcher, Avery, and Sunshine (PI 674741; Haley et al., 2017).

Across 11 irrigated environments, Langin was the second highest ranked entry for grain yield, better than the HRW wheat cultivar Hatcher but not significantly better than any of the other HRW wheat cultivars tested (Table 1). The irrigated trials included in these analyses comprised varied geography and production management conditions, which contributed to a larger degree of variation among environments and thus a relatively higher LSD value for mean comparisons. Despite its high yield potential, Langin will not be recommended for irrigated production except where producers are accustomed to including a timely growth regulator (e.g., trinexapac-ethyl) application in their management plans.

Langin was tested in the SRPN in 2014 and 2015 (USDA-ARS, 2015). Averaged across the hard winter wheat region, Langin was the second highest yielding entry in 2014 (27 locations, 3984 kg ha^{-1}, 40 total entries) and the ninth highest yielding entry in 2015 (19 locations, 3659 kg ha^{-1}, 42 total entries).

End-Use Quality

Milling and bread-baking characteristics of Langin and the HRW wheat check cultivars Byrd and Denali were determined using approved methods of the American Association of Cereal Chemists (AACC, 2000) in the CSU Wheat Quality Laboratory. Multiple samples from the 2013, 2014, and 2015 growing seasons were used for comparison.

Byrd is known for having relatively strong dough mixing properties, as is common with genotypes that carry the *Glu-D1d* [5+10 high molecular weight glutenin (HMWG) subunits] allele at the *Glu-D1* locus. Despite its relatively low water absorption, higher values for pup loaf baking volume are typical for Byrd. Conversely, Denali is known for having weaker dough mixing properties, as is common with genotypes that carry the *Glu-D1a* (2+12 HMWG subunits) allele at the *Glu-D1* locus, and generally inferior pup loaf baking characteristics (i.e., shorter mixing time, lower mixing tolerance, and lower loaf volume). From evaluations of the 2015 SRPN (USDA-ARS, 2015) and the 2014 Wheat Quality Council testing program (Wheat Quality Council, 2015), Langin carries the *Glu-D1d* allele at the *Glu-D1* locus, the *Glu-A1b* allele (2* HMWG subunit) at the *Glu-A1* locus, and the *Glu-B1b* allele (7+8 HMWG subunits) at the *Glu-B1* locus. Neither Langin nor the two check cultivars carry the T1BL-1RS or T1AL-1RS wheat–rye (*Secale cereale* L.) chromosomal translocations.

Overall, Langin showed intermediate values for milling-related characteristics relative to Byrd and Denali (Table 2). Compared with Byrd, Langin had similar kernel weight, kernel diameter, kernel hardness, and grain ash concentration (120 g kg^{-1} moisture basis) and lower total and break flour extraction (with a modified Brabender Quadrumat Senior, C.W. Brabender). These comparisons suggest a similar potential for milling performance of Langin relative to Byrd. Compared with Denali, which is known for better milling performance compared with Byrd, Langin had lower kernel weight, kernel diameter, grain ash concentration, and grain volume weight but higher total flour extraction.

Values for baking-related characteristics of Langin were generally superior compared with both Byrd and Denali (Table 2). Compared with the better quality check Byrd, Langin showed longer Mixograph (National Manufacturing) mixing time and better mixing tolerance and longer bake mixing time in straight-dough pup-loaf baking tests. Compared with Byrd, Langin showed similar bake water absorption and crumb grain scores and slightly lower pup loaf bake volume.

Table 2. Milling, dough-mixing, and bread-baking characteristics of wheat cultivar Langin and check entries across multiple environments from the 2013, 2014, and 2015 growing seasons in Colorado.

Trait and unit of measurement	Environments	Langin	Byrd	Denali
SKCS kernel weight (mg)†	23	28.7	27.8ns‡	30.4*
SKCS kernel diameter (mm)	23	2.52	2.53ns	2.60*
SKCS kernel hardness (score)	23	59.3	60.5ns	58.6ns
Grain volume weight (kg m^{-3})	24	739	740ns	761*
Grain ash concentration (g kg^{-1})§	31	14.3	14.7ns	14.9*
Break flour extraction (g kg^{-1})	24	486	516*	494*
Total Flour extraction (g kg^{-1})	24	723	736*	714*
Grain protein concentration (g kg^{-1})§	41	120	123*	12 ns
Mixograph mixing time (min)	26	6.1	5.3*	3.2*
Mixograph tolerance (0–6)¶	26	4.9	4.6*	2.5*
Bake mix time (min)	24	6.0	5.2*	3.1*
Bake water absorption (g kg^{-1})	24	627	631ns	610*
Loaf volume (L)	24	1.03	1.06*	0.82*
Crumb grain (0–6)¶	24	3.7	3.8 ns	2.5*

* Significance of the difference between Langin and the check cultivar based on a Student's paired t test procedure at the 0.05 probability level.

† Single kernel characterization system (SKCS).

‡ ns = not significant.

§ Grain ash and protein concentration reported on a 120 g kg^{-1} moisture basis.

¶ Scale for mixograph tolerance and crumb grain scores: 6 = outstanding, 0 = unacceptable.

Availability

The Colorado Agricultural Experiment Station will maintain breeder seed of Langin. Multiplication and distribution rights of other classes of Certified seed have been transferred from the Colorado Agricultural Experiment Station to the Colorado Wheat Research Foundation, 4026 South Timberline Road, Suite 100, Fort Collins, CO, 80525. Langin has been submitted for US Plant Variety Protection under Public Law 91-577 with the Certification Only option (PVP no. 201700298). Recognized seed classes will include the Foundation, Registered, and Certified. Small quantities of seed for research purposes may be obtained from the corresponding author for at least 5 years from the date of publication. Seed of Langin has been deposited with the USDA–ARS National Plant Germplasm System, where it will be available for distribution on expiration of Plant Variety Protection, 20 years after publication.

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