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Registration of 'Vision 50' Wheat

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Abstract

'Vision 50' (Reg. No. CV-1152, PI 679953), a hard red winter (HRW) wheat (*Triticum aestivum* L.) cultivar, was derived from the cross 'Jagalene'/'Provinciale' using a modified bulk breeding method. Vision 50 was tested as VA09HRW-64 in replicated yield trials in Virginia (2011–2017) and in the USDA-ARS Uniform Bread Wheat Trials (2012–2017) and released by the Virginia Agricultural Experiment Station in 2016. Vision 50 is a widely adapted, high-yielding, awned, semidwarf (unknown *Rht* gene) HRW wheat having mid- to late-season spike emergence, strong straw strength, and resistance or moderate resistance to diseases prevalent in the mid-Atlantic region. In the Virginia Bread Wheat Elite Test from 2014 to 2017, Vision 50 produced a mean yield of 5067 kg ha^{-1} that was similar to the highest-yielding (5757 kg ha^{-1}) cultivar Shirley, a soft red winter wheat check. Vision 50 has acceptable end-use quality on the basis of comparisons with the HRW wheat check cultivar Jagger for wheat protein (11.3 vs. 12.2 g 100 g^{-1}), flour yield (72.7 vs. 66.4 g 100 g^{-1}), flour water absorption (59.5 vs. 62.3 g 100 g^{-1}), dough mixing tolerance (2.7 vs. 3.0), pup-loaf volume (815 vs. 822 cm^3), and crumb grain scores (4.2 vs. 3.8).

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Hard wheat (*Triticum aestivum* L.) producers in the US mid-Atlantic region benefit from the differentially higher prices paid for hard red winter (HRW) wheat compared with soft red winter (SRW) wheat, and millers reap the benefits of lower grain transportation costs sourcing locally grown HRW wheat (Hall et al., 2011). Following release of 'Vision 30' (PI 661153, Hall et al., 2011) in 2010 and 'Vision 45' (PI 667642, Liu et al., 2015) in 2012, HRW wheat production in the mid-Atlantic region of the United States has increased steadily. For the 2017–2018 planting season, hard wheat planted in Virginia were 2000 to 2400 ha (Clougherty, 2018).

'Vision 50' (Reg. No. CV-1152, PI 679953) is widely adapted and provides producers in the mid-Atlantic region with a HRW wheat cultivar that has good milling and baking quality for use in bread flour blends and grain yields that are competitive with those of SRW wheat cultivars. Mean yields of Vision 50 have been similar to the highest-yielding HRW wheat cultivar, Vision 45, over 6 yr (2012–2017) in the Virginia Bread Wheat Elite Test (4347 kg ha^{-1}) and in the USDA-ARS Uniform Bread Wheat Trial (UBWT) in 2015 (4464 kg ha^{-1}) and 2016 (4506 kg ha^{-1}). Vision 50 is resistant to leaf rust (caused by *Puccinia triticina* Erikss.), moderate resistant to powdery mildew [caused by *Blumeria graminis* (DC) E.O. Speer], stripe rust (caused by *Puccinia striiformis* Westend.), *Barley yellow dwarf virus*, and *Soil-borne wheat mosaic virus*.

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Abbreviations: AACC, American Association of Cereal Chemists; HRW, hard red winter; SRW, soft red winter; UBWT, Uniform Bread Wheat Trial.

Methods

Parentage, Breeding History, and Line Selection

Vision 50 was derived as an F_5 headrow from a cross of 'Jagalene' (PI 631376)/'Provinciale'. The French bread wheat cultivar Provinciale was derived from a cross between 'Barodeur'/'Genesis' and developed by the Serasem Company in Premesques, France. The cross from which Vision 50 originated was made in spring 2003, and the F_1 generation was grown in the field as a single 1.2-m headrow in 2004 to produce F_2 seed. The population was advanced from the F_2 to F_4 generation using a modified bulk breeding method. Wheat spikes (100–200 spikes produce seed around 100–150 g) were selected from the population in each segregating generation (F_2–F_3) on the basis of absence of obvious disease, early maturity, short straw, and desirable head shape and size. Selected spikes were threshed in bulk, and the seed was planted in 20.9-m^2 blocks at Blacksburg and/or Warsaw, VA, in the fall of each year. Spikes selected from the F_4 bulk were threshed individually and planted in separate 1.2-m headrows. Vision 50 was derived as a bulk of one of these $F_{4:5}$ headrows selected in 2008. The line was tested as entry 64 in nonreplicated observation yield tests at Blacksburg and Warsaw in 2009 and was designated VA09HRW-64. Subsequently it was tested in Virginia Tech bread wheat yield tests from 2010 to 2015 and in the USDA-ARS UBWT from 2012 to 2015 before its release in 2016. After its release, Vision 50 was included as a HRW wheat check in both Virginia Tech bread wheat variety trials and the UBWT.

Evaluation in Replicated Yield Trials

Vision 50, previously designated and tested as VA09HRW-64, has been evaluated in Virginia Tech yield tests since 2010 and in the UBWT since 2012. The UBWT were conducted using randomized complete block designs with two to four replications, standard variety testing protocols, and recommended management practices that vary slightly from state to state (USDA–ARS, 2019). Plant traits assessed visually (e.g., winter kill, straw strength, and disease resistance) were rated using an ordinal scale from 0 (no visible symptoms) to 9 (severe symptoms) based on intensity and severity of the affected plant area.

All replicated yield tests in Virginia were conducted according to small grain production and management protocols recommended by Brann et al. (2000) with late season nitrogen applied to tests at Warsaw, VA according to Thomason et al. (2007). Conventional till yield plots were planted at 22 seeds per 0.304 m of row with a harvest area of 4.2 m^2. At Painter, VA, plots were composed of six rows with 17.8 cm between rows; at Warsaw and Blacksburg, VA, plots consisted of seven 15.2-cm rows. Assessment of reaction to Fusarium head blight, caused by *Fusarium graminearum* (Schwabe), was conducted in replicated inoculated and mist-irrigated nurseries according to the procedures described by Chen et al. (2006).

Grain samples (1000 g) from Warsaw were supplied to the USDA Hard Winter Wheat Quality Laboratory in Manhattan, KS, for grain, flour, and milling and baking quality analysis. Single kernel wheat characteristics were determined using the single kernel characterization system (American Association of Cereal Chemists [AACC] Method 55-31; AACC, 2000). Wheat and flour protein (%N × 5.7) were determined via AACC Method 46-30 using a nitrogen determinator (Leco Corp.). Moisture and ash contents were determined by AACC Methods 08-01 and 44-15A, respectively. Wheat samples, tempered to constant moisture (16%), were milled on a Quadrumat Senior experimental mill (C.W. Brabender Co.) according to AACC Methods 26-10A and 26-50. Flour yield was determined as percentage of straight grade flour. A mixogram for each flour sample (10 g on a 14% moisture basis) was obtained using a 10-g mixograph (National Mfg. Co.) with optimum water adsorption (Finney and Shogren, 1972). Dough mixing time was visually determined from the mixogram. Mixing time to peak dough development and mixing tolerance were also determined from the mixogram (AACC Method 54-40). Corrected mixograph mixing time was adjusted based on protein content of the flour. A straight-dough, 100-g pup-loaf bake test method was used to measure bread-making properties, loaf volume, and crumb grain score (AACC Method 10-10B). Crumb grain of representative bread slices were graded from poor open grain (0) to outstanding closed grain (6).

Analysis of variance was conducted on data from individual locations and years and across locations and years in Virginia Tech tests using R 3.2.4 (R Core Team, 2016), and statistical analyses of data from the UBWT were performed using Agrobase Generation II SQL version 36.5.1 (Agronomix Software, 2004). Means and standard deviations for grain, milling, and baking data were obtained with Microsoft Excel 2010 (Microsoft, 2013). Mean comparisons of traits between genotypes were based on Fisher's unprotected LSD ($P = 0.05$) test (Saville, 1990; Piepho, 2004).

Seed Purification and Increase

During fall 2012, 348 $F_{8:9}$ headrows of Vision 50 were planted in an isolation block and evaluated for purity and trueness of type. Among the 348 breeder seed headrows, 35 rows were removed before harvest and discarded on the basis of variability and lack of trueness to cultivar type. The remaining 177 centermost rows that were similar in phenotype and visually homogenous were harvested in bulk. This initial breeder seed of Vision 50 was planted by the Virginia Crop Improvement Association in a 0.22-ha block at their Foundation Seed Farm during fall 2013 and produced 60 units (22.7 kg $unit^{-1}$) of seed in 2014. This seed was used to plant 5.2 ha in fall 2014 from which 1035 units of seed was harvested in 2015. Of this seed, 65 units were planted on 10 ha in 2015, and this increase produced about 1800 units of foundation seed for distribution to seed producers in fall 2016.

Characteristics

Botanical and Agronomic Characteristics

Vision 50 is a widely adapted, full-season, medium-height HRW wheat with high yield potential and good end-use quality. At the boot stage, plants of Vision 50 are yellow-green in color and have flag leaves that are erect, twisted, and waxy. Stems are hollow and waxy, lack anthocyanin, and have four internodes; peduncles are erect; auricles are hairless and lack anthocyanin; and terminal rachis internodes are hairless. Anthers of Vision 50 are yellow in color. Spikes of Vision 50 are awned, inclined, mid-dense, tapering in shape, and white in color at maturity. Straw is

yellow in color and lacks anthocyanin at physiological maturity. Glumes are white, lack pubescence, and are long in length and medium in width with acuminate beaks, and elevated shoulders of narrow width. The hard red kernels of Vision 50 are ovate in shape with rounded cheeks, narrow-width and deep creases, large germs, and medium noncollared brushes. The phenol test color of seed is fawn.

In the Virginia Bread Wheat Elite Test, Vision 50 had a 4 yr (2014–2017) average head emergence (days from 1 January) of 125 d, which was similar to Vision 45 and 4 d later than Vision 30 (Table 1). Average plant height of Vision 50 (84 cm) was similar to those of 'LCS Wizard' (PI 669574, Liu et al., 2016) and Vision 30 (81 cm) and 10 cm shorter than that of Vision 45. Straw strength (0 = erect to 9 = completely lodged) of Vision 50 (0.3) was similar to that (0.2) of 'Soissons' (PI 573744) and significantly ($P \geq 0.05$) stronger than that of Vision 30 (1.6) or 'Jagger' (1.8) (PI 593688, Sears et al., 1997b).

Field Performance

In the Virginia Bread Wheat Elite Test from 2014 to 2017 (Table 1), Vision 50 produced a mean grain yield of 5067 kg ha^{-1}. The mean yield of Vision 50 was similar to the HRW wheat cultivar Vision 45 (5368 kg ha^{-1}) but lower than those of the highest-yielding SRW wheat check cultivar Shirley (5757 kg ha^{-1}) (PI 656753, Griffey et al., 2010). Average test weight of Vision 50 (73.1 kg hL^{-1}) was slightly higher than that of Shirley (72.7 kg hL^{-1}) but 2.3 kg hL^{-1} lower than that of Vision 45 in Virginia.

Vision 50 also was evaluated in 177 environments over 6 yr (2012–2017) in the USDA-ARS UBWT. Only data from the 2015 and 2016 trials are presented herein (Tables 2 and 3). Mean grain yields of Vision 50 in the 2015 (4464 kg ha^{-1}) and 2016 (4506 kg ha^{-1}) UBWT did not differ significantly from those of the top-yielding cultivar Vision 45 (4815 and 4593 kg ha^{-1}, respectively). In the 2015 and 2016 UBWT, mean grain volume weights of Vision 50 (73.9 and 72.0 kg hL^{-1}) were not significantly different than those of Vision 30 (74.2 and 74.1 kg hL^{-1}). Cold hardiness of Vision 50, based on ratings of 0 = no injury to 9 = complete kill, was the same as that of 'Everest' (PI 659807, Jin et al., 2013) for late winter freeze damage in 2015 (Table 2) (6.0) and of Vision 45 for winter stress in 2016 (Table 3) (5.0).

Disease and Insect Resistance

Reaction of Vision 50 to diseases (0 = highly resistant to 9 = very susceptible) was evaluated in diverse environments in Virginia and in multiple states and locations (Tables 1–3). Vision 50 is resistant (0.9–1.0) to leaf rust and moderately resistant (0.1–2.7) to powdery mildew. Vision 50 is moderately resistant (1.6–3.0) to stripe rust on the basis of average infection type (Line and Qayoum, 1992) ratings (0–9) in field trials and a disease nursery (Tables 1–3). Seedlings of Vision 50 were moderately resistant to stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Erikss. & E. Henn.) races (QFCSC, QTHJC, MCCFC, RKQQC) evaluated in 2012 to 2015 greenhouse tests by the USDA-ARS Cereal Disease Laboratory in St. Paul, MN. Adult plants of Vision 50 were moderately resistant

Table 1. Four-year (2014–2017) mean performance of Vision 50 hard red winter wheat in the Virginia Tech Bread Wheat Elite Test in Virginia.†

Cultivar	Grain yield	Grain volume weight	Heading date	Plant height	Lodging	Disease resistance						
						Leaf rust	Powdery mildew	BYDV‡	Stripe rust	FHB§ incidence	FHB severity	FHB index¶
	kg ha^{-1}	kg hL^{-1}	d after 1 Jan.	cm	0–9#	0–9††				%		
Shirley‡‡	5757 a§§	72.7 d	122 abc	78 d	0.6 abc	0.2 a	0.2 a	1.0 ab	6.7 d	63.9 c	45.5 d	29.2 b
Tribute‡‡	5012 bc	78.0 a	121 bcd	78 d	1.4 de	1.3 bc	3.5 e	1.7 d	2.9 bc	42.9 a	27.2 a	17.3 a
Vision 45	5368 ab	75.4 bc	125 a	94 a	0.7 abc	1.0 b	0.7 b	1.4 cd	0.0 a	49.6 ab	36.6 bc	20.5 ab
Vision 30	4627 c	74.9 bc	121 bcd	81 c	1.6 e	3.7 f	0.3 ab	1.0 abc	5.0 c	57.0 bc	42.6 c	26.0 ab
Soissons	4575 c	72.2 d	124 ab	78 d	0.2 a	3.5 ef	0.6 ab	0.7 ab	0.0 a	62.0 c	30.0 ab	25.7 ab
LCS Wizard	4867 bc	76.3 b	123 abc	81 c	0.8 bc	2.1 d	1.2 c	0.6 a	2.0 ab	59.5 bc	43.2 c	29.6 b
Karl 92	4013 d	75.5 bc	120 cd	80 cd	1.4 de	3.7 f	2.0 d	1.6 d	1.9 ab	57.8 bc	35.7 abc	21.7 ab
Jagger	3806 d	75.2 bc	118 d	79 d	1.8 e	2.9 e	4.9 f	2.5 e	0.0 a	52.3 abc	32.1 ab	23.7 ab
Vision 50	5067 bc	73.1 d	125 a	84 b	0.3 ab	1.0 b	0.6 ab	1.4 cd	3.0 bc	53.3 abc	33.2 ab	25.9 ab
Mean (n = 16)	4825.2 c	74.6 c	121.8 abc	81.2 c	0.9 cd	1.7 cd	1.2 c	1.2 bcd	1.9 ab	54.7 abc	34.8 abc	23.9 ab
LSD (0.05)	511.1	1.5	3.7	3.0	0.5	0.6	0.4	0.5	2.5	12.2	9.3	10.2
CV (%)	21.1	5.9	5.9	7.4	119.0	62.3	58.1	60.3	120.1	22.2	26.5	42.3
No. of site-years	11	11	8	8	8	5	10	4	2	4	4	4

† Grain yield and grain volume weight data from Blacksburg (2014–2017), Warsaw (2014–2017), and Painter (2014–2016); head date, plant height, and lodging from Blacksburg (2014–2017) and Warsaw (2014–2017); leaf rust from Blacksburg (2014, 2016, 2017) and Warsaw (2014–2016); powdery mildew data from Blacksburg (2014–2016), Warsaw (2015, 2016), and Painter (2014, 2015); *Barley yellow dwarf virus* (BYDV) data from Blacksburg (2015), Warsaw (2016, 2017), and Painter (2014); stripe rust data from Blacksburg (2014) and Warsaw (2016); Fusarium head blight (FHB) data from Scab Nursery in Blacksburg (2014–2016) and Mt. Holly (2017).

‡ BYDV = *Barley yellow dwarf virus*.

§ FHB = Fusarium head blight.

¶ FHB index = % incidence × % severity ÷ 100.

0 = erect; 9 = completely lodged.

†† 0 = highly resistant; 9 = highly susceptible.

‡‡ Soft red winter wheat check cultivar.

§§ Means in a column followed by the same letter are not significantly different at the 0.05 probability level based on Fisher's unprotected LSD pairwise comparison.

Table 2. Mean performance of Vision 50 hard red winter wheat in the 2014–2015 USDA-ARS Uniform Bread Wheat Trial.

Cultivar	Grain yield	Volume weight	Head date	Plant height	Lodging	Growth habit	Late frozen damage	Disease resistance								
								Bacterial leaf streak	Fusarium head blight	Leaf rust	Powdery mildew	Stripe rust tests	Strip rust nursery	*Stag. nod.*† leaf blotch	*Stag. nod.*† glume blotch	BYDV‡
	kg ha^{-1}	kg hL^{-1}	d after 1 Jan.	cm	0–9§	0–9¶	0–9#	1–9††	0–9‡‡							
Appalachian White	4053 bcd§§	72.9 bcd	126 a	88 b	2.5 bcd	5.7 def	4.0 ab	3.0 ab	5.5 bc	4.0 c	0.7 ab	1.3 ab	2.0	3.7 ab	1	1.3 a
Everest	3890 bcd	75.8 ab	119 d	81 cd	3.3 de	4.5 bcd	6.0 cd	5.0 c	4.5 ab	1.5 ab	0.8 ab	4.9 def	9.0	6.0 ab	6.5	1.0 a
NuEast	3482 d	76.2 a	123 b	89 b	2.5 bcd	4.0 abc	7.0 d	4.5 bc	6.0 cd	2.5 abc	2.0 bc	5.4 ef	9.0	6.0 ab	6	1.8 a
Shirley¶¶	3896 bcd	70.2 d	123 b	77 d	1.2 a	6.8 f	3.0 a	7.5 e	7.0 de	1.0 a	0 a	6.5 f	9.0	3.5 a	3	1.0 a
TAM 303	3605 d	72.1 cd	121 c	87 b	4.3 e	4.8 cde	5.0 bc	5.5 cd	7.0 de	3.5 c	3.7 d	4.5 def	4.0	7.0 b	6	1.3 a
USG 3120¶¶	4435 abc	74.0 abc	119 d	87 b	1.3 ab	2.8 a	7.0 d	1.5 a	7.5 e	1.5 ab	0.8 ab	3.6 bcd	8.0	5.0 ab	–	1.0 a
Vision 30	3722 d	74.2 abc	122 bc	84 bc	3.0 cd	3.5 ab	6.0 cd	6.0 cde	5.0 bc	8.0 d	0 a	6.5 f	9.0	4.7 ab	3	1.3 a
Vision 45	4815 a	74.2 abc	126 a	96 a	1.0 a	6.0 ef	4.0 ab	5.0 c	5.5 bc	3.0 bc	1.2 abc	0.9 a	3.0	4.7 ab	1	1.0 a
Vision 50	4464 ab	73.9 abc	122 a	86 bc	1.6 abcd	4.5 bcd	6.0 cd	7.0 de	3.5 a	1.0 a	2.7 cd	1.6 abc	2.0	5.7 ab	6.5	1.7 a
Mean (n = 35)	3858 cd	73.6 abc	123 a	85 bc	1.9 abc	4.8 cde	5.1 bc	4.5 bc	6.2 cd	3.7 c	1.3 abc	3.2 bcd	6.3	5.0 ab	–	1.2 a
LSD (0.05)	590.6	3.1	1.7	5.1	1.4	1.2	1.19	1.91	1.12	1.82	1.5	2	-	3.4	–	1.3
CV (%)	9.4	2.5	1.7	5.6	85.0	25.0	14.0	20.2	9	21.8	121.9	47.2	-	23.6	–	27.0
No. of locations	16	11	8	10	8	3	1	1	1	1	2	4	1	3	1	2

† *Stag. nod.* = *Stagonospora nodorum*.

‡ BYDV = *Barley yellow dwarf virus*.

§ 0 = erect; 9 = completely lodged.

¶ Growth habit (midwinter rating): 0 = very upright; 9 = very prostrate.

late frozen damage (late-winter rating leaf damage): 0 = no injury to 9 = complete kill.

†† 1 = highly resistant; 9 = highly susceptible.

‡‡ 0 = highly resistant; 9 = highly susceptible.

§§ Means in a column followed by the same letter are not significantly different at the 0.05 probability level based on Fisher's unprotected LSD pairwise comparison.

¶¶ Soft red winter wheat check.

to stem rust, with disease severity (0–100%) ratings from trace to 50% in field tests conducted using a composite of races including QFCSC, QTHJC, RCRSC, RKQQC, and TPMKC at St. Paul from 2012 to 2017. Adult plants of Vision 50 were susceptible (50% severity) to race TTKSK (Ug99) in a field trial of entries in the 2016 UBWT evaluated in Kenya (Table 3). Molecular marker analyses indicates that Vision 50 has the *Sr24/Lr24* gene complex. Vision 50 is also moderately resistant (0.4–1.7) to *Barley yellow dwarf virus* (Tables 1– 3) and *Soil-borne wheat mosaic virus* (0–5.0, data not presented). Vision 50 was susceptible (7.0) to bacterial leaf streak, caused by *Xanthomonas translucens* pv. *Undulosa*, at one test site in the 2015 UBWT (Table 2). Vision 50 has expressed moderate resistance to moderate susceptibility to glume blotch (3.0–6.5) and leaf blotch (3.5–5.7) both caused by *Stagonospora nodorum* (Tables 2 and 3). Under natural field infection by *Fusarium graminearum*, reaction of Vision 50 varied from moderately resistant (3.5) (Table 2) to susceptible (8.0) in the 2015 and 2014 UBWT (data not show). In Virginia's inoculated and mist-irrigated scab nursery (Table 1), Vision 50 had a 4-yr mean Fusarium head blight index (incidence × severity/100) value (0–100) of 25.9, which was slightly higher than that of the moderately resistant check 'Tribute' (17.3) (PI 654422, Griffey et al., 2005) and slightly lower than that of the susceptible check cultivar Shirley (29.2). Vision 50 was susceptible to five biotypes (B, C, D, O, and L) of Hessian fly [*Mayetiola destructor* (Say)] in seedling tests conducted by USDA-ARS Crop Production and Pest Control Research Unit, West Lafayette, IN. In three North Carolina field trials of entries in the 2014 UBWT, Vision 50 also was moderately susceptible to Hessian fly (mean rating of 5.3, where 0 = no plant damage to 9 = yellow and/or dead lower leaves, fewer tillers, and stunting) under natural infestation (data not presented). Reaction of Vision 50 to speckled leaf blotch (caused by *Septoria tritici* Roberge in Desmaz.), *Wheat spindle streak mosaic virus*, and *Wheat streak mosaic virus* is not known.

End-Use Quality

Grain characteristics and milling and baking quality of Vision 50 in Virginia Tech tests have been evaluated by the USDA-ARS Hard Wheat Quality Laboratory in Manhattan, KS, since 2010; and 3 yr of data from 2014 to 2016 are presented in Table 4. Data from the single kernel characterization system indicate that kernels of Vision 50 are hard in

Table 3. Mean performance of Vision 50 hard red winter wheat in the 2015–2016 USDA-ARS Uniform Bread Wheat Trial.

Cultivar	Yield	Volume weight	Head date	Plant height	Lodging	Winter stress	Disease resistance									Hessian fly resist biotype
							Powdery mildew	Leaf rust	Stripe rust	BYDV†	Root rot	*Stag. nod.*‡ leaf blotch	*Stag. nod.*‡ glume blotch	Stem rust St. Paul, MN	Stem rust Njoro, Kenya	
	kg ha^{-1}	kg hL^{-1}	d after 1 Jan.	cm	0–9§	0–9¶	——— 0–9# ———					— 1–9†† —		— rating‡‡ —		BCOL
Appalachian White	3894 c§§	74.7 abc	117.3 a	88 bc	3.4 cd	4.0 bc	0.7 ab	1.0 a	1.7 ab	1.2	5.5 c	3.5	2.0	40S	TMSS	none
Everest	4432 ab	76.0 ab	104.5 e	78 fg	2.3 bc	3.0 ab	2.1 abc	0.3 a	3.5 ab	0.7	2.5 a	7.5	7.5	50MSS	50MSS	none
NuEast	3813 c	76.3 a	113.3 c	90 ab	2.6 bc	2.0 a	4.0 c	0.5 a	3.5 ab	0.6	7.5 d	5.0	5.0	40MSMR	60SMS	BCOL
Shirley¶¶	4405 ab	71.6 e	114.8 bc	75 g	2.0 ab	2.0 a	0.0 a	0.4 a	4.9 b	0.3	3.0 ab	4.5	3.5	0	15MR	none
TAM 303	3813 c	72.9 cde	109.7 d	86 cd	4.0 d	3.0 ab	3.7 c	1.0 a	3.4 ab	1.4	7.5 d	6.0	6.5	20MSMR	40MRMS	none
USG 3120¶¶	4560 a	75.1 ab	101.1 f	86 cd	1.7 ab	6.0 d	2.7 bc	1.0 a	3.0 ab	0.7	3.5 abc	7.5	3.5	20S	20MR	none
Vision 30	3793 c	74.1 bcd	109.4 d	80 ef	2.6 bc	4.0 bc	0.8 ab	3.5 b	4.0 ab	0.7	5.5 c	6.5	3.0	0	40MSS	B
Vision 45	4593 a	74.6 abc	117.0 ab	92 a	2.4 bc	5.0 cd	0.1 a	1.5 b	0.6 a	0.6	5.5 c	5.0	3.0	20S	50S	none
Vision 50	4506 ab	72.0 de	116.5 ab	83 de	0.7 a	5.0 cd	0.1 a	0.9 b	2.3 ab	0.4	5.0 bc	3.5	3.0	10S	50S	none
Mean (N = 39)	4096 bc	74.3 abc	110.4 d	83 de	2.2 bc	3.8 bc	1.8 abc	1.4 b	2.2 ab	0.9	5.3 c	5.4	4.4	–	–	–
LSD (0.05)	422.7	2.1	2.4	3.6	1.4	1.3	2.36	1.60	3.63	–	2.2	–	–	–	–	–
CV (%)	14.7	4.0	2.4	5.4	66.4	20.3	77.8	85.7	72.7	33.3	24.6	23.7	39.9	–	–	–
No. of locations	11	11	7	9	6	1	3	5	4	3	1	1	1	1	1	1

† BYDV = *Barley yellow dwarf virus*.

‡ *Stag. nod*. = *Stagonospora nodorum*.

§ 0 = erect; 9 = completely lodged.

¶ Winter stress (midwinter rating leaf damage): 0 = no injury; 9 = complete kill.

0 = highly resistant; 9 = highly susceptible.

†† 1 = highly resistant; 9 = highly susceptible.

‡‡ Stem rust field reaction; St. Paul, MN, used a composite races of QFCSC, QTHJC, RCRSC, RKQQC, and TPMKC; Kenya race was TTKSK (Ug99). Ratings included severity as percentage area affected from 0 to 100, and infection response types of resistant (R), moderately resistant (MR), moderately susceptible (MS), and susceptible (S); T = trace.

§§ Means in a column followed by the same letter are not significantly different at 0.05 probability level based on Fisher's unprotected LSD pairwise comparison.

¶¶ Soft red winter wheat check cultivar.

texture, with an average index value of 48.3 (0 = very soft; 100 = very hard), which was most similar to that of Soissons (48.8). Flour yields of Vision 50 ranged from 71.8 to 74.2 g 100 g^{-1} with an average of 72.7 g 100 g^{-1}, which was most similar to that of Soissons (72.6 g 100 g^{-1}), a high flour yield check. Grain and flour protein contents of Vision 50 (11.3 and 9.8 g 100 g^{-1}) were most similar to those of Soissons and LCS Wizard (11.4 and 10.0 g 100 g^{-1}). Vision 50 has acceptable mixograph water absorption (59.5 g 100 g^{-1}), and is similar to Vision 45 (59.2 g 100 g^{-1}), LCS Wizard (59.6 g 100 g^{-1}), and Soissons (59.3 g 100 g^{-1}) but is slightly lower than Jagger (62.3 g 100 g^{-1}). Dough mixing time (3.06 min) of Vision 50 was most similar to Vision 45 (3.30 min). Mean dough mixing tolerance of Vision 50 (2.7) was the same as 'Karl 92' (PI 56425, Sears et al., 1997a). Average 100-g pup loaf volume of Vision 50 (815 cm^3) was similar to Jagger (822 cm^3). Average crumb grain score (0 = open to 6 = dense) of Vision 50 (4.2) was slightly higher than the other hard wheat checks except for Soissons (4.3).

Availability

The Virginia Crop Improvement Association provided foundation seed of Vision 50 to seed producers during fall 2016. Vision 50 will be marketed by the Mennel Milling Company based in Fostoria, OH, and seed will be produced and distributed by Virginia Identity Preserved Grains, LLC, West Point, VA. An application for Plant Variety Protection of Vision 50 is currently under review by the USDA Agricultural Marketing Service Science & Technology Plant Variety Protection Office. A seed sample of Vision 50 has been deposited with the USDA-ARS National Center for Genetic Resources Preservation, where it will be available for distribution after expiration of its US Plant Variety Protection. Small amounts of seed for research purposes may be obtained from the corresponding author for at least five years after the date of this publication.

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Table 4. Milling and baking quality of Vision 50 hard red wheat in 2014–2016 Virginia Tech tests conducted by the USDA-ARS Hard Winter Wheat Quality Laboratory, Manhattan, KS.

Cultivar	SKCS† kernel hardness				Wheat protein at 14% moisture				Flour yield				Flour ash at 14% moisture				Flour protein at 14% moisture			
	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
	0–100‡				g 100 g^{-1}															
Vision 30	54.0	50.0	70.5	58.2	11.8	12.6	12.2	12.2	67.4	69.1	65.3	67.3	0.38	0.37	0.45	0.40	10.2	11.6	11.2	11.0
Vision 45	56.6	43.3	63.8	54.6	10.8	12.6	10.9	11.4	69.4	71.5	69.5	70.1	0.42	0.36	0.45	0.41	9.4	11.2	10.1	10.2
LCS Wizard	67.0	55.9	77.2	66.7	11.0	11.7	11.5	11.4	66.9	70.3	66.7	68.0	0.42	0.39	0.49	0.43	9.2	10.2	10.6	10.0
Jagger	60.9	59.7	73.5	64.7	11.3	12.4	13.0	12.2	66.6	67.0	65.6	66.4	0.41	0.43	0.50	0.45	9.8	11.2	11.4	10.8
Karl 92	51.6	50.0	62.7	54.8	12.0	14.2	13.2	13.1	66.3	66.0	64.4	65.6	0.38	0.41	0.48	0.43	10.1	12.9	12.0	11.7
Soissons	52.5	38.7	55.3	48.8	10.5	12.2	11.3	11.4	71.4	75.2	71.1	72.6	0.41	0.43	0.46	0.43	9.0	10.8	10.1	10.0
Vision 50	53.0	41.1	50.9	48.3	10.6	11.9	11.4	11.3	71.8	72.1	74.2	72.7	0.38	0.39	0.42	0.39	9.0	10.3	10.2	9.8
Mean§	56.0	48	70.9	58.3	11.0	12.4	11.5	11.7	66.8	68.5	67.3	67.5	0.4	0.40	0.48	0.43	9.4	11.0	10.4	10.2
SD§ (0.05)	15.9	17	9.0	–	0.7	0.8	0.6	–	2.8	2.7	2.4	–	0.0	0.03	0.04	–	0.6	0.9	0.6	–

Cultivar	Flour water absorption				Dough mixing tolerance				Adjusted dough mixing time				Crumb score				Loaf volume			
	2014	2015	2016	Mean	2014	2016	2015	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean	2014	2015	2016	Mean
	g 100 g^{-1}				0–6¶				min				0–6#				cm^3			
Vision 30	60.3	61.2	63.4	61.6	3	3	4	3.3	4.34	5.02	3.15	4.17	3.0	3.5	4.0	3.5	795	945	810	850
Vision 45	59.3	58.4	59.8	59.2	2	2	2	2.0	2.91	4.31	2.68	3.30	3.5	4.0	4.0	3.8	775	885	835	832
LCS Wizard	58.2	59.8	60.7	59.6	2	1	2	1.7	2.68	2.76	2.08	2.51	3.5	3.0	1.0	2.5	780	815	835	810
Jagger	60.4	62.1	64.5	62.3	2	3	4	3.0	3.11	4.85	3.46	3.81	4.0	4.0	3.5	3.8	770	850	845	822
Karl 92	61.4	64.2	63.5	63.0	4	0	4	2.7	4.44	6.75	4.25	5.15	4.5	4.0	3.5	4.0	805	920	855	860
Soissons	58.2	59.2	60.5	59.3	4	3	4	3.7	4.01	6.46	3.87	4.78	4.5	4.0	4.5	4.3	745	900	855	833
Vision 50	59.6	58.6	60.3	59.5	3	2	3	2.7	2.89	3.56	2.73	3.06	4.5	4.0	4.0	4.2	760	850	835	815
Mean§	58.6	60.1	61.5	60.1	2.5	2.3	3	2.5	3.1	4.71	3.0	3.59	3.0	3.3	3.2	3.2	741	852	791	795
SD§ (0.05)	2.1	2.4	1.6	–	1.2	1.3	1	–	1.1	1.94	0.9	–	1.2	1.0	1.2	–	52.4	63.6	70.8	–

† Single kernel characterization system (SKCS), AACC Method 55-31.01 (http://methods.aaccnet.org/methods/55–31.pdf).

‡ 0 = very soft; 100 = very hard.

§ Mean value of all entries evaluated in trial in 2014 (*N* = 34), 2015 (*N* = 32), and 2016 (*N* = 29).

¶ 0 = weak dough with poor mixing tolerance; 6 = strong dough with good mixing tolerance.

0 = poor open grain; 6 = outstanding closed grain.

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