Proposal for Release of Hard Red Winter Wheat Candidate Cultivar OK09915C

Prepared by the

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Selection for herbicide tolerance

Confirmation of herbicide tolerance

Acknowledgments

The OSU Wheat Improvement Team gratefully acknowledges the generous and continual support of the

Oklahoma Agricultural Experiment Station
Oklahoma Cooperative Extension Service
OSU's Technology Development Center
BASF Agrochemical Products
Oklahoma Wheat Commission
and the
Oklahoma Wheat Research Foundation

The development and release of this cultivar embraces OSU's land-grant commitment to public service, technology transfer, and economic development.

Experimental Designation

OK09915C

A Hard Red Winter (HRW) bread wheat (*Triticum aestivum* L.) type, which meets or exceeds the Recommended Quality Targets approved by the Hard Winter Wheat Quality Targets Committee, Feb. 2006.

Proposed Names

‘[redacted]’

See Exhibit 1 for clearance granted by the USDA, Marketing and Regulatory Programs, Seed Regulatory & Testing Branch

Motivation, Origination, and Breeding Procedure

OK09915C marks the beginning of a new era in OSU wheat improvement research as the first two-gene Clearfield® cultivar to be released by the Oklahoma Agricultural Experiment Station (OAES). The Clearfield® wheat management system capitalizes on artificially induced mutation events to simulate and target genetic variation that already occurs naturally in many plants. Clearfield® cultivars heretofore released by the OAES, including Okfield and Centerfield, feature a single gene that confers resistance to the herbicide imazamox, one of several herbicides in the imidazolinone family that provides broad-spectrum weed control by inhibiting the enzyme acetohydroxyacid synthase (AHAS).

Protein synthesis in plants depends on the biosynthesis of amino acids, the building blocks of all proteins. The AHAS enzyme is key to the synthesis of a certain set of amino acids containing side chains of carbon atoms (hence called branched-chain amino acids). Imidazolinone herbicides bind to the catalytic component of AHAS (the catalytic component actually contains two large subunits) in such a way to prevent proper functioning of the enzyme. Mutations either exist naturally or may be induced which may lower the sensitivity of AHAS to imidazolinone herbicides, owing to a single amino acid substitution in a crucial area of the AHAS protein where the herbicide would typically interact or bind (Tan et al., 2005, *Pest Manag. Sci.*, 61:246-257).

Because the genome of hard winter wheat is effectively triplicated, the possibility exists to incorporate, or stack, multiple genes for imazamox resistance. With proper application protocols, a single gene is sufficient to allow imazamox control of weeds such as cheat and jointed goatgrass. The addition of a second gene, combined with the use of a methylated seed oil adjuvant that accentuates the performance of imazamox, may provide more effective control against Italian ryegrass and feral rye. The resistance gene present in Okfield and Centerfield is called *AHASL1D* (formerly called *Imi1*) and is located on the long arm of chromosome 6D. With the generosity and assistance of BASF Agrochemical Products (hereafter, BASF), we have introgressed an additional gene called *AHASL1B* (formerly called *Imi2*), located on the long arm of homoeologous chromosome 6B, with the intent to stack it with *AHASL1D* in the same genotype or cultivar. OK09915C is the first commercial-ready product of this gene introgression research. It is important to note here that all OAES wheat varieties other than

Okfield, Centerfield, and OK09915C carry wild-type AHASL allele(s) which do *not* encode imazamox-tolerant AHASL protein(s). OK09915C originated as a hybridization event performed in 2004 within the OSU Wheat Breeding project directed by Dr. Brett Carver.

Parentage

OK09915C was derived from a three-way cross, in which the first (single) cross occurred in March 2004, and the second cross occurred in March 2005. A crossing strategy was chosen to minimize the possibility of segregation for the wild-type allele at *AHASL1D* while selecting for the mutant allele at *AHASL1B* (Exhibit 2).

A winter wheat crossing block was established in Fall 2003 for the intent to intermate i) elite OSU experimental lines confirmed in the field to be imazamox tolerant (IT) and, based upon parentage, carriers of *AHASL1D*, with ii) a donor germplasm line named N91D2308-13 provided by BASF as a carrier of *AHASL1B* in a 'Mason' soft red winter wheat background. The relevant single cross in the pedigree of OK09915C was inventoried as 04x888 with the parentage, listing the female first, N91D2308-13/OK03908C (Exhibit 3).

In Fall 2004, a follow-up crossing block was established to perform three-way crosses by intermating the single crosses produced in Spring 2004 with two of the four *AHASL1D* carriers used previously (hence, some of the three-way crosses were effectively backcrosses). The three-way cross to which OK09915C traced was inventoried as 05x380 with the pedigree, listing the female first, N91D2308-13/OK03908C//OK03928C. Choice of *AHASL1D* carriers used in the single and three-way crosses was based on adaptation to Oklahoma and acceptable disease resistance, expressed as canopy green-leaf retention, from replicated yield trials conducted in 2003 and 2004. The subsequent F_1 plant generation was grown in the greenhouse in Stillwater, OK in 2005-2006, and the F_2 seed were produced from a bulk harvest of about 15 F_1 plants.

Expanding back on the pedigree of OK09915C, OK03908C has the pedigree TXGH12588-120*4/FS4//'Jagger'. TXGH12588-120 was an experimental sister selection of the hard red winter wheat cultivar 'TAM 110' developed by the Texas A&M University-Amarillo breeding program, FS4 was an M_2-derived selection from the French wheat cultivar 'Fidel' using induced mutagenesis (*AHAS1D* donor provided originally by American Cyanamid), and Jagger was developed by Kansas State University as a hard red winter wheat cultivar. OK03928C has the pedigree TXGH2588-26*4/FS4//'2174'/3/'Intrada', in which TXGH12588-26 was a different experimental sister selection of the hard red winter wheat cultivar TAM 110 developed by the Texas A&M University-Amarillo breeding program, FS4 is as described before, and 2174 and Intrada are hard red winter and hard white varieties, respectively, developed at Oklahoma State University.

Breeding history

Line development, selection, and testing. In 2006-2007, the F_2 generation was advanced and evaluated along with 32 other F_2 Clearfield® populations at the Expanded Wheat Pasture Unit (EWPU) near Marshall, OK (Exhibit 3). A dual-purpose management system was imposed to reduce the seed production of individual plants with poor fitness under early planting conditions and for grazing recovery (within-population selection). Actual stocking rate and grazing duration were invoked consistent with farmer practice. The application of 160 g a.i./ha imazamox plus 0.25% v/v nonionic surfactant, which is three times the commercial rate or 12 oz/ac of Beyond, following grazing but preceding stem elongation enabled selection for plants containing both *AHASL* mutations (heterozygous or homozygous condition). A subset of the same F_2 populations was grown at Lahoma, OK under a grain-only management system, where opportunistic readings were collected for leaf rust reaction, stay-green (green leaf retention), straw strength, physiological maturity, and plant height. Combined with those readings, grain yield was measured to eliminate highly inferior populations (among-population selection). Breeder seed for population advancement was strictly harvested en masse from the dual-purpose site. For a select few of the 33 F_2 populations evaluated in 2006-2007, six were chosen for head selection and advancement as F_2-derived progenies. OK09915C traces to one of those six populations identified as 072039011. About 100 heads were selected from plants with appropriate earlier maturity and shorter stature. The $F_{2:3}$ headrow progenies were evaluated the following year at Stillwater, OK.

Of the 96 headrows evaluated in spring 2008, five (5%) were harvested from population 081160002 for further visual inspection of the grain. Across the entire collection of 445 headrow populations in 2008, 8% of the headrows were harvested, on average, from a specific population. The lower proportion of selected progenies in population 081160002 (5%) reflected a higher proportion of late progenies. Criteria used in 2008 to finalize selections among headrows were reaction to imazamox among the Clearfield® materials only (3x commercial rate), stay-green, reaction to stem rust (given an unusual stem rust incidence in 2008), plant height (no taller than 'Endurance'), straw strength, maturity (no later than Endurance), shattering response, spike density and size, uniformity of phenotype at harvest maturity, kernel size and kernel size consistency, kernel color (lack of yellow berry phenotype), and kernel morphology indicative of acceptable test weight.

Four of the five $F_{2:3}$ progenies were bulked and advanced as $F_{2:4}$ progenies for evaluation in non-replicated nurseries at Stillwater and Lahoma in 2008-2009. Only the nursery at Stillwater was harvested. In all, each nursery contained 126 experimental lines that were putative double-mutants for *AHASL1D* and *AHASL1B*. Specific criteria used in selection in 2009 included whole-canopy and flag-leaf stay-green, disease resistance (primarily leaf rust and BYD), physiological maturity, plant height, visual uniformity, grain yield, test weight, and multiple quality traits associated with hard wheat milling and baking quality. The nursery at Stillwater was treated with a 2x application of imazamox. OK09915C traced to selection 091179015, and this particular line produced the highest test weight (60.3 lb/bu) with the largest kernel size (33.4 mg; 2.75 mm kernel diameter) among 36 selections harvested. Selection 091179015 yielded 36 bu/ac at Stillwater, compared to a nursery mean yield of 34 bu/ac. In summary, selection 091179015 was named OK09915C and advanced because it demonstrated exceptional milling quality and dough strength, relatively good herbicide tolerance, leaf rust resistance, acceptable agronomic fitness, and acceptable within-line homogeneity. OK09915C also produced a uniform chaff color that was dark bronze and equivalent to AP502CL.

OK09915C was first entered into replicated yield trials during harvest year 2010. Through 2013, OK09915C appeared with *n* experimental lines or varieties in the following nurseries in Oklahoma and surrounding states, some of which were dedicated entirely to testing Clearfield® materials:

2010	Clearfield® Replicated Yield Trials 1, RYT1	$n = 30$
2011	Clearfield® Oklahoma Elite Trial 1, OET1	$n = 10$
2011	Clearfield® RYT1 (as a check only)	$n = 20$
2012	Oklahoma Elite Trial 3, OET3	$n = 35$
2012	Oklahoma Small Grains Variety Performance Tests, OSGVPT	*n* = variable no. of entries
2012	Uniform Variety Trial, UVT (Texas AgriLife)	$n = 33$
2012	Clearfield® Qualification Trial (QT)	$n = 6$
2013	OET3	$n = 30$
2013	QT	$n = 6$
2013	Southern Regional Performance Nursery, SRPN	$n = 43$
2013	OSGVPT	*n* = variable no. of entries

Breeder-seed advancement. OK09915C traces to a single $F_{2:3}$ headrow advanced through subsequent inbreeding generations by bulk harvest of breeder-seed plots. Thus it was produced through continuous bulk-selfing without reselection, and is an F_2-derived line in the F_8 generation ($F_{2:8}$) as of the 2013 harvest. Production of breeder seed occurred in separate nurseries but parallel to the testing nurseries listed above, yet at equivalent generations of inbreeding. The breeder-seed nurseries were designed to allow phenotyping for visually discerning traits, assessment of uniformity, and for hand-harvest, which minimizes seed contamination from neighboring plots. These nurseries were established at field laboratories operated by the OAES at Stillwater, OK and/or Goodwell, OK.

Immediately following a breeder-seed increase of 400 lb during the 2011 harvest, the decision was made to place OK09915C under foundation seed increase near Stillwater, OK under the direction of Oklahoma Foundation Seed Stocks (OFSS). About 525 cleaned bushels of foundation seed were produced in 2012 for use in registered seed production in the 2012-2013 crop season, with the anticipated production of >15,000 bushels registered seed.

OK09915C was observed to be uniform and stable since 2011. Minor plant height variation within the cultivar is commensurate with derivation of the pureline from an F_2 single plant, and thus height differences among plants may vary up to ±5 in. from the average height, depending on the level of height expression in a given environment. Variants observed in breeder-seed and foundation-seed plantings in 2013 were limited to i) taller plants exceeding the range of natural variation at an anticipated frequency of less than 1 in 200, or ii) plants with white glume color at a frequency of less than 1 in 250.

Description and Performance

Candidate assessment for cultivar release relied on multiple sources of data from harvest years 2010 to 2012. Three principal sources were used to assess agronomic and end-use quality performance: i) OSU breeding nurseries across Oklahoma (primarily replicated yield nurseries), ii) the Oklahoma Small Grains Variety Performance Tests, conducted throughout Oklahoma by the Oklahoma Cooperative Extension Service, and iii) the BASF Qualification Trials conducted throughout the Great Plains as a pre-release requirement of BASF.

For the purpose of establishing distinctness in the application for U.S. Plant Variety Protection, OK09915C is expected to phenotypically resemble Jagger or TAM 110 as a result of its grandparent-offspring relationship with those cultivars and on the basis of similarity in chaff color, or AP502CL on a comparable basis for chaff color. Distinctiveness can be made with regard to the presence of, or level of, imazamox tolerance, and to other pest resistance or maturity traits depending on the specific cultivar comparison.

The nursery mean reported in each table of this proposal usually reflects, unless otherwise stated, the mean performance of *all* checks and breeder lines selected and advanced for further testing from a particular nursery; hence the nursery mean provided may not equal the mean of the entries shown in a given table. The "top LSD group" was determined from the entry in a given nursery with the highest value (or lowest, if more desirable) among all entries, and not necessarily the entry shown in a given table with the highest (or lowest) value. "Average" levels of performance indicate a certain candidate performed similar to the mean of the nursery in which it was tested. For some of the trait comparisons, values highlighted in red indicate significant inferiority of the specified check cultivar relative to OK09915C; those in blue indicate superiority of the check.

Grain yield performance and areas of adaptation

Overview of testing environments. Environmental conditions varied among years within the primary evaluation period, 2010-2012, including a season-long, severe drought period in harvest year 2011, late-season heat and drought stress in 2012, and two independent stripe rust outbreaks in 2010 and 2012, each featuring predominant race shifts in the pathogen population. The 2010 infection compromised the resistance previously provided by gene *Yr17* present in Jagger and many of its derivatives, and the 2012 infection compromised the resistance (genes unknown) harbored in contemporary cultivars 'Armour' and 'Garrison'. Stripe rust was not present at all in 2011 due to the very dry conditions. The hotter and drier climates of 2011 and 2012 caused accelerated maturity, especially in 2012, such that later maturing cultivars may have experienced some yield disadvantage relative to the very early cultivars.

Grain yield comparisons in breeding nurseries and the OSGVPT. As an indication of high yielding ability and yield consistency, OK09915C placed in the top-yielding group in two of the past three years of breeder trials (Table 1). Weighted across years 2010 to 2012 according to the number of test sites, OK09915C exceeded the nursery mean by 6%, whereas Centerfield equaled the nursery mean and Duster exceeded it by 11%. Successive years of breeder trial testing featured high turnover of experimental lines with a potential incremental increase in yielding ability, and hence, the bar for comparison should have been raised each successive year. The candidate showed only a slight setback in 2012, not because the competition was necessarily greater from other experimental lines, but because the environmental conditions did not typically favor a cultivar with the later maturity pattern. OK09915C performed exceptionally and consistently well at Lahoma and Cherokee in all years (data not shown). Relative performance at Goodwell under irrigation was too inconsistent to draw definitive conclusions.

Competitiveness of OK09915C with contemporary cultivars can be deduced by two independent sets of 2012 wheat variety performance data collected in Oklahoma by Texas AgriLife and OSU, allowing a genetically broader comparison than from the breeder trials, albeit in only one year. The candidate yielded at the same level as recent releases from OAES and AgriPro, such as Billings, Ruby Lee, Iba, Jackpot, and Greer (Table 2). It yielded better than Garrison and Armour, most likely a result of their acute sensitivity to the prevailing race(s) of stripe rust present in 2012, and it well surpassed the yield of Jagger even though Jagger was not unusually sensitive to stripe rust in 2012. The only cultivar to significantly exceed OK09915C across the six 2012 environments in the OSGVPT was Gallagher, likely owing to its ideal maturity pattern and better stripe rust resistance. OK09915C is expected to perform in the top yielding group in most cases, if 2012 yield trends carry much predictive value. The primary yield-conducive factors in2012 were accelerated reproductive development, stripe rust resistance, and heat stress tolerance. Yield responses for OK09915C are not yet fully documented in dual-purpose (though preliminary observations indicate good grazing tolerance) or intensive-management systems.

Grain yield following herbicide application. Based on standardized, multi-state trials conducted according to BASF protocol, OK09915C exhibited the full level of herbicide tolerance expected of a two-gene cultivar. In direct comparisons to the standard two-gene cultivar, AP503CL, only at Hays, KS did OK09915C not exceed AP503CL in grain yield under an augmented treatment of imazamox and a methylated seed oil (MSO) adjuvant. Even in the absence of the herbicide, OK09915C out-yielded AP503CL at Perkins, OK and Lincoln, NE. The high degree of herbicide tolerance of the candidate was expressed in its yield ratio of 1.07 (2x+MSO treatment/control) averaged across four environments. The corresponding ratio for AP503CL was 0.96.

Test weight performance

In breeder trials since 2010, OK09915C held a 2 lb test weight advantage over Centerfield, Duster, and Endurance (Table 4). Centerfield and Duster each had test weights above or equivalent to the nursery mean, making the advantage of OK09915C extraordinary. Its 3-year mean of nearly 61 lb/bu is the highest multi-year average posted by an OSU candidate at time of release and underscores the effort expended to improving test weight in OSU Clearfield® materials. Corroboration of breeder trial data can be taken from the 2012 OSGVPT, where OK09915C demonstrated top-tier test weight among contemporary cultivars (Table 5). No cultivar significantly exceeded OK09915C in a single environment. These 2012 data place

OK09915C in the same statistical test weight class as Doans, considered one of the highest test weight cultivars currently grown in the southern Plains.

Disease and insect reactions

Foliar disease resistance of OK09915C is acceptable for most common diseases, as outlined in detail in Exhibit 4 and further summarized in Table 5 with the addition of relevant checks. OK09915C provides full protection against wheat soilborne mosaic (WSBM) but is less consistent in protection to wheat spindle streak mosaic (WSSM), a pattern similar to Centerfield. It also provides an effective level of protection against barley yellow dwarf (BYD) similar to Duster. Reaction to leaf rust is intermediate to moderately resistant, whereas reaction to current races of stripe rust (2010 to 2012) is considered intermediate, though reaction in any environment may fluctuate for better or worse. One conspicuous weakness in the disease armor of OK09915C is its susceptible reaction to powdery mildew. OK09915C also tends to show moderately susceptible to susceptible reactions to tan spot and septoria leaf blotch according to limited greenhouse testing of seedlings, but additional data should be collected in the field before drawing firm conclusions.

Gene *Lr34* is present in some plants of OK09915C, as confirmed by a resistant haplotype for three polymorphic marker sites in *Lr34* (data provided by L. Yan). The frequency of the gene is not yet known but is probably less than 50%. The *Lr34* gene offers significant value to wheat producers in Oklahoma, because it confers partial resistance to other common diseases such as stripe rust, powdery mildew, stem rust, and BYD. The favorable reaction of OK09915C to BYD may be attributable to the presence of *Lr34* or other unknown genes which suppress transmission of BYD by aphids.

OK09915C is susceptible to the prevailing greenbug biotype E and to Russian wheat aphid. Its reaction to bird-cherry oat aphid is unknown. OK09915C exhibited a heterogeneous reaction (35% resistant plants) in a greenhouse seedling test to a Hessian fly population derived from field collections in Scott County, Kansas. This population contained primarily biotype GP, with a small portion virulent to cultivars containing various resistance genes.

Other agronomic characteristics

Stay-green. A comprehensive indicator used in OSU breeding nurseries to monitor generalized protection against foliar pathogens is green-leaf duration, or stay-green rating. Cultivar candidacy is reserved for those lines which typically produce ratings <3 on a 0-to-5 canopy scale or ratings later in kernel filling that are <7 on a 1-to-9 flag-leaf scale. OK09915C produced relatively good stay-green ratings compared with Centerfield, Duster, or Endurance (Table 6), and it possesses good overall leaf hygiene that is commensurate with disease reactions noted above.

Acid-soil tolerance. Strictly on the basis of visual ratings in an acidic field environment (Enid, OK; pH<4.5), OK09915C exhibited acid-soil tolerance slightly better than Centerfield and slightly inferior to Duster (Table 7). Actual yield comparisons, which have not been determined prior to the 2012-2013 crop season, could modulate those rankings or even render the visual differences insignificant. With the available phenotypic data, OK09915C would be classified as tolerant. Genotypic data reveals the same allele as Atlas 66 at two critical molecular marker loci, *Xwmc331* and *Xgdm125*, linked to the Al-induced malate transporter gene *ALMT1* on chromosome 4DL. This locus significantly contributes to Al tolerance in Atlas 66 and apparently in OK09915C (G. Bai, USDA-ARS, Manhattan, KS).

Maturity. Visual ratings of winter dormancy release from 2010 to 2012 placed OK09915C in a late maturity group (Table 8). Thus it is expected to reach the first-hollow-stem (FHS) stage in the company of Endurance and Centerfield, as was the case in 2012, though more field data are needed to predict FHS arrival with greater precision. Genotypic data further corroborate this prediction. OK09915C contains alleles at the *VRN-A1* and *PPD-D1* loci which confer later stem elongation and later heading (Table 8). Both loci are major determinants in triggering FHS arrival and heading in winter wheat. This combination of alleles is infrequent among hard winter wheat genotypes. Typically, the later allele for *VRN-A1* is found with the earlier allele at *PPD-D1*, as in Endurance and Duster. OK09915C is not expected to be any earlier to heading than Endurance, and relative to the early cultivar Billings, it may reach the FHS stage two weeks later and reach heading about one week later (Table 8).

Differences in maturity between OK09915C and other contemporaries were much more compressed at physiological maturity, so the later winter dormancy release and heading may play to its advantage in the event of late winter freezes. The favorable grain yield patterns from 2011 and 2012 imply OK09915C is still able to yield well when forced to mature more rapidly than other varieties like Billings. Nevertheless, this is a late-maturity cultivar that may not realize its full yield potential in environments more conducive to earliness.

Other agronomic traits. OK09915C is considered to be a tall semidwarf with the *Rht1* semidwarf gene, i.e., it has the genotype *Rht-B1b* (semidwarf allele) and *Rht2-D1a* (wild-type allele) but does not contain the *Xgwm261* marker allele indicative of *Rht8* (G. Bai, USDA-ARS, Manhattan, KS). OK09915C is expected to have the same plant stature as Endurance or extend about two inches taller than Duster (Table 9). OK09915C produced favorable ratings for lodging and shattering resistance, though with one exception in 2010 at Goodwell, a moderate amount of shattering was recorded as a ‘2’ on a 0-to-4 scale (Table 9). Hence OK09915C may have the propensity to shatter in highly conducive environments.

Milling quality

Test weight provides a comprehensive and market-compatible assessment of milling quality. Further assessment may be derived from measurements of kernel texture, weight, and size. Kernels with softer texture may crush more easily, require less milling energy, and produce a finer flour, whereas kernels with harder texture may produce a coarser flour with higher milling energy requirement and higher levels of starch damage, which can associate with higher water absorption, typically a desirable characteristic for bread baking.

Kernel hardness and experimental milling yield of OK09915C were well within the acceptable range for hard winter wheat (Table 10). Kernel weight and diameter of OK09915C exceeded expected standards, averaging 31.8 mg and 2.72 mm, respectively since 2010.

OK09915C has the potential to produce larger kernels than Centerfield, and its kernel weight exceeded that of Duster by 20% in 2012. In summary, OK09915C ensures a level of milling quality equal to or exceeding that of current non-Clearfield cultivars.

Baking quality

Protein content and quality. From 2010 to 2012, OK09915C averaged 13.2% wheat protein across 19 environments in Oklahoma and 11.8% flour protein in 13 environments (Table 11). Relative to the nursery mean, its wheat protein was slightly above-average, and hence OK09915C is considered to be in the top 50% of advanced OSU wheat breeding materials. Limiting comparisons to common environments where other cultivars were included, OK09915C was only 0.1 percentage units short of Centerfield, a high-protein cultivar, and it exceeded Duster by 0.6 percentage units, a cultivar considered intermediate for wheat protein. OK09915C also has high-quality protein as determined by the adjusted sedimentation volume of a flour-water suspension. Sedimentation tests provide a direct indicator of protein swelling capacity and an indirect indicator of loaf volume. The mean sedimentation volume for OK09915C across years (6.8 mL) falls within the upper range of values normally observed among OSU breeding lines. In individual-year comparisons, OK09915C exceeded Centerfield, Duster, and Endurance.

Dough quality. Information on mixograph properties provides a cursory view of dough strength, a key component of baking quality. With several measurements over years and locations, the mixograph can be highly effective in predicting baking quality from straight-dough formulations. Specifically, the mixograph measures the resistance, or tolerance, to mixing of a flour-water dough sample.

From a time-course drawing, the mixograph curve, or mixogram, rises to a peak as the gluten-starch complex develops with mixing and then falls as it degrades with further mixing. The rate at which the curve rises and falls provides a measure of mixing tolerance, often quantified as *mixograph stability*, for which higher values (greater rate of rise and fall) indicate lower stability, and therefore lower tolerance and dough strength. The narrowing of the curve after the peak also indicates degree of mixing tolerance, and is typically measured about two minutes beyond the time at which a dough reaches peak development (two minutes past peak). Aside from environmental deviations, a very short mixing time (< 3 minutes) coupled with low curve width (< 10 mm) and high mixograph stability value (>10) is indicative of poor mixing tolerance and dough strength. Due to an inverse in scale, mixograph stability is negatively associated with farinograph stability, estimated by the time in minutes for which the farinograph curve remains above a standardized base level. Higher, but not excessive, values of stability (10 to 18 minutes) are desirable, because they indicate greater mixing tolerance and the capacity to withstand longer fermentation times during commercial processing. Farinograph stability is not reported here, though limited data from the 2011 crop samples indicated very good farinograph attributes with moderate development time (5.5 min) and high stability (>20 min). For comparison, flour samples of Billings collected from the same environments produced a development time of 5.2 min and a stability value of 14.6 min

(Richard Chen, USDA-ARS, Manhattan, KS).

OK09915C performed within the norm for all mixograph properties, indicating desirable dough strength. Across 14 environments from 2010 to 2012, mixograph tolerance rating averaged 4.0 on a scale of 0 to 6 (Table 12). Mixograph mixing time averaged 4.0 minutes, whereas mixogram curve width and stability averaged 18.4 cm and 6.6 (scaleless). Mixograph attributes for OK09915C were better than the nursery mean, and hence OK09915C is considered to be in the top 50% of advanced OSU wheat breeding materials for mixing tolerance. This level of mixing tolerance appeared to exceed Centerfield, with a slightly shorter mixograph mixing time of 3.6 min, a lower mixogram curve width of 13.5 mm and a higher stability value (lower tolerance) of 9.6. Only Duster might be considered to have more favorable mixograph attributes, albeit at a lower protein level.

Based on 10% one-dimensional SDS-PAGE, OK09915C contains common high molecular weight glutenin subunits (GSs) at the *Glu-B1* (7*+8) and *Glu-D1* loci (5+10). The GS encoded at the *Glu-A1* locus is not yet resolved. For the low molecular weight GSs, OK09915C contains alleles *Glu-A3a*, *Glu-B3g*, and *Glu-D3a* (data provided by P. Rayas-Duarte). OK09915C and Centerfield contain the same alleles at *Glu-B1*, *Glu-D1*, and *Glu-D3*, but they differ at *Glu-A3* (allele *b* for Centerfield) and *Glu-B3* (*a* allele).

Experimental baking. Two years of experimental baking using the straight-dough method did not reveal any serious weaknesses for OK09915C (Table 13). It produced acceptable, but not stellar loaf volumes, and visual characteristics, such as crumb grain and texture, were also acceptable and consistent with other common cultivars, with the possible exception of Billings being superior (Table 13). However, OK09915C fared better than Billings in an independent bake evaluation conducted by the Hard Winter Wheat Quality Laboratory (USDA-ARS, Manhattan, KS) on flour samples composited from several environments in 2011. Respective loaf volumes for OK09915C and Billings were 900 and 750 cc, and respective loaf volume regressions (higher is more desirable) were 67.4 and 52.8. Crumb scores on a scale of 0 to 6, favored Billings (3.0) over OK09915C (1.5), indicating minor deficiencies for OK09915C in the internal structure, color, or texture of bread loaves produced from this sample (data not shown).

Quality profile

OK09915C has superior test weight potential with large kernel size (32 mg per kernel, 2.7 mm kernel diam); average straight-grade flour yield with acceptable flour refinement (from preliminary data, 0.43% flour ash) and above-average kernel hardness (<75) based on either ground particle size or resistance to crushing. With appropriate fertilization practices, OK09915C will exceed 12% in wheat protein with normal wheat-to-flour protein loss, and good to excellent water absorption based on mixograph, bake, or farinograph data. Dough strength is above-average, manifested in appealing mixograms of 4.0 minutes mix time, 18 mm curve width at 2 min past the peak, mixogram stability value of 7, and 4.0 mixing tolerance on a 0-to-6 scale, preliminary farinograms of 5 min peak time and 20 min stability, and preliminary alveograms of 0.73 P/L ratio and 396 W value. Straight-dough bake mixing time is intermediate, or about 5 minutes. Pup loaf volume should exceed 850 cc. Crumb grain and color are acceptable but additional testing is needed to corroborate below-average crumb grain scores. OK09915C has the HMW glutenin subunits unknown, 7*+8, 5+10 (*Glu-A1*, *-B1*, and *–D1*, respectively). OK09915C is a non-carrier of any wheat-1RS rye translocation. Other translocations are unknown or not tested.

Summary Justification

The development of OK09915C signifies the first wave of two-gene Clearfield® advanced materials to cycle through the OSU wheat improvement program. The agronomic performance of OK09915C in a Clearfield® management system surpasses expectations of a two-gene mutant in a hard red winter wheat background. Agronomic performance in a conventional management system, in the absence of imazamox application, also exceeds expectations of a hard red winter wheat candidate cultivar. OK09915C should appeal to southern Plains wheat producers who have enjoyed success with Centerfield, the last single-mutant Clearfield® cultivar released by the OAES. A Clearfield® cultivar with increased imazamox tolerance and well adapted to Oklahoma will fill a significant genetic void in areas challenged by weed pressures from Italian ryegrass and feral rye. This expectation is founded on the demand for foundation seed of OK09915C in summer 2012. OK09915C signifies no drop-off in milling and baking quality that processors have come to expect from cultivars lacking imazamox tolerance. In fact OK09915C provides an unusual and favorable combination of yield potential, test weight, and dough strength.

Probable Area of Adaptation and Limitations

OK09915C is adapted to all of Oklahoma, though the area of greatest competitiveness appears to be in the northern half of the state. This region could shift further south in years more accommodating of later heading and physiological maturity. It has the potential to spread into areas well north of Oklahoma. SRPN testing did not commence until the 2012-2013 crop season, but limited testing via the BASF Qualification Trials in 2012 supports this claim. More independent variety trial testing is needed to confirm that OK09915C will have a similar, if not broader, adaptation range as Centerfield, particularly outside of Oklahoma. Evidence is insufficient to exclude OK09915C from acid-soil or grazing environments, although these are not likely to be a precondition to using a Clearfield® management option.

Varietal Replacement:

Cultivar	Anticipated superior attribute of OK09915C justifying replacement
Centerfield	Yield ability and responsiveness in Oklahoma Tolerance to imazamox, especially when combined with an MSO adjuvant Test weight and associated milling attributes Mixing tolerance and associated dough strength

AP503CL	Yield ability and responsiveness in Oklahoma Acid soil tolerance Barley yellow dwarf tolerance Partial resistance to leaf rust and stripe rust

Seed Production Plan and Status

Breeder seed will be maintained by the OSU wheat breeding project and by OFSS, whereas Foundation seed will be maintained by OFSS. More than 15,000 bushels Registered seed and 1200 bushels Foundation seed are expected to be available in Summer 2013.

Certification Classes

Certification classes of seed production recognized for each line should be Foundation, Registered, and Certified.

Proposed Method of Release

OK09915C will be placed under U.S. Plant Variety Protection, with the Title V option, and should be released through Oklahoma State University's wheat cultivar licensing program, consistent with terms of the commercial license agreement established with BASF Agrochemical Products, which allows commercial deployment of the BASF Trait (*AHASL1B* + *AHASL1D*). Application for plant variety protection will be filed within one year of date of first commercial sale of seed.

Collaborators

Evaluation of OK09915C was accomplished courtesy of certain participating members of OSU's Wheat Improvement Team, as well as certain breeders throughout the Great Plains associated with the Hard Winter Wheat Performance Nursery Program. They represent state Agricultural Experiment Stations, the USDA-ARS, and private companies. Special assistance was provided by Guhua Bai, Paul St. Amand, Richard Chen, Ming Chen, and Brad Seabourn with USDA-ARS, Manhattan, KS. Others assisting locally or cooperating in the research leading to the development of OK09915C were Nathan Stepp, Melanie Bayles, Jeff Wright, Connie Shelton, Richard Austin, Brian Olson, Tilin Fang, Romulo Lollato, Tina Johnson, Ray Sidwell, Lawrence Bohl, Erich Wehrenberg, Bobby Weidenmaier, Mike Hogg, Kevin Johnson, Roger Osburn, and Roger Gribble.

revised 3/1/13

Table 1. Grain yield comparisons in replicated breeding nurseries varying from *n* =3 to 8 environments per year. Means highlighted in yellow were within one LSD value of the highest yielding entry in a given nursery, which may or may not be reported here.

Entry	2010 RYT1 *n* =3	2011 RYT1 (ck) *n* =3	2011 OET1 *n* =3	2012 OET3 *n* =8	2010-2012 Absolute	2010-2012 Relative
	- - - - - - - - - -	- - - - - - - - - -	- - - - - bu/ac - - - - -	- - - - - - - - - -	- - - - - - - - - -	
OK09915C	**52**	**40**	**39**	**49**	**45**	**1.06**
Centerfield	48	40	31	--	--	1.00
Duster	57	45	--	50	--	1.11
Endurance	--	--	--	44	--	0.90
Nursery mean	46	37	35	49	42	1.00
LSD (0.05)	*12*	*6*	*6*	*5*		
Lahoma	X	X	X	X		
Granite/Sweetwater	X	X	X	X		
Goodwell-irrigated	X	X	X	X		
Marshall-DP				X		
Cherokee-DP				X		
Kingfisher				X		
Tipton (low N)				X		
Enid (low pH)				X		

Table 1
Grain yield by year
Breeding trials

Table 2. **Grain yield** comparisons from two sets of wheat variety trials conducted in Oklahoma in 2012: Texas AgriLife Uniform Variety Trials (UVT), and the Oklahoma Small Grains Variety Performance Tests (OSGVPT). Individual site data are shown for six of 10 total sites. Where highlighted, a given entry was significantly worse than (red) or better than (blue) OK09915C. OSGVPT data provided by J.T. Edwards, Oklahoma State University.

	Multi-site means		Representative sites from both sets of trials					
Entry	**UVT** *n* **=4**	**OSGVPT** *n* **=6**	**Granite**	**Union City-DP**	**Alva**	**Goodwell-irrigated**	**Kingfisher**	**Lahoma with fungicide**
				- - - - bu/ac - - - -				
OK09915C	**57**	**52**	**65**	**44**	**50**	**62**	**56**	**62**
Endurance	48	49	53	38	48	52	55	56
Duster	49	49	56	34	51	56	58	59
Billings	59	55	64	44	51	78	64	63
Garrison	45	42	52	35	49	51	49	65
Ruby Lee	51	53	55	54	57	58	64	65
Gallagher	60	58	69	45	56	63	66	63
Iba	55	53	55	35	51	66	58	63
Doans	56	49	59	50	46	57	56	48
Greer	52	49	60	36	41	52	60	61
Jackpot	58	53	63	46	46	65	62	64
Jagger	48	48	55	35	44	46	61	58
Fuller	56	52	59	52	46	67	62	55
Armour	44	39	53	40	48	55	53	53
Mean (all entries tested)	**52**	**49**	52	42	49	57	57	58
LSD (0.05)	***6***	***4***	*7*	*6*	*5*	*14*	*6*	*5*
			Southwest		Northwest		Central	

Table 2
Grain yield, 2012 WVTs

Table 3. **Grain yield** comparisons from four sets of BASF Qualification Trials conducted across three states in 2012. Where highlighted, a given entry was significantly worse than (red) or better than (blue) OK09915C within a given herbicide treatment. Oklahoma data provided by J.T. Edwards, Oklahoma State University.

	Stillwater, OK		Perkins, OK		Hays, KS		Lincoln, NE	
Entry	**Control**	**2x + MSO**	**Control**	**2x + MSO**	**Control**	**2x + MSO**	**Control**	**2x + MSO**
	- bu/ac -							
OK09915C	**48**	**52**	**34**	**40**	**76**	**80**	**64**	**63**
AP503CL	44	40	27	28	81	80	54	49
Mean (all entries tested)	44	43	31	29	69	73	50	37
LSD (0.05)	*7*		*6*		*6*		*7*	

Table 3
Grain yield, 2012 BASF QT

Table 4. **Test weight** comparisons from 3 years of statewide breeder trials conducted in 2 to 5 environments per year. Where highlighted for a single year, a given entry was significantly worse than (red) or better than (blue) OK09915C.

Entry	2010 Mean (*n* =2)	2010 Min	2010 Max	2011 - RYT1 Mean (*n* =2)	2011 - RYT1 Min	2011 - RYT1 Max	2011 - OET1 Mean (*n* =4)	2011 - OET1 Min	2011 - OET1 Max	2012 Mean (*n* =5)	2012 Min	2012 Max	3-yr mean	Deviation from check [a] Centerfield	Deviation from check [a] Duster	Deviation from check [a] Endurance
	-lb/bu-															
OK09915C	**59.0**	57	61	**62.4**	62	63	**61.7**	60	63	**60.3**	58	62	**60.9**	**1.7**	**1.7**	**2.3**
Centerfield	57.0	55	59	61.0	61	61	60.0	59	62	--			59.5			
Duster	57.8	56	60	61.3	60	62	--			58.2	57	60	58.8			
Endurance	--			--			--			58.0	56	61	58.0			
Nurery mean	56.4	54	58	59.7	59	61	59.7	57	61	58.5	57	61	58.7	-0.6	-0.5	0.5
LSD (0.05)	*1.1*			*1.6*			*0.9*			*3.0*						
No. of sites<58 lb/bu	1			0			1			2			∑=4			
No. of sites<56 lb/bu	1			0			0			0			∑=1			

[a] Positive deviations indicate the corresponding entry may be superior to the indicated check; negative deviations may indicate inferiority to the indicated check.

Table 4
Test weight
Breeding trials

Table 5. Test weight comparisons from six environments of the 2012 Oklahoma Small Grains Variety Performance Tests. Where highlighted, a given entry was significantly worse than (red) or better than (blue) OK09915C. Data provided by J.T. Edwards, Oklahoma State University.

Entry	Mean	Marshall	Kingfisher	Union City-DP	Lahoma	Lahoma with fungicide	Alva
	---------- lb/bu ----------						
OK09915C	**59.8**	**58.4**	**61.7**	**58.4**	**61.6**	**61.4**	**57.5**
Endurance	56.8	55.0	60.3	54.5	57.4	59.0	54.4
Duster	57.2	55.5	59.9	53.6	56.9	60.3	56.8
Billings	59.1	58.3	61.4	56.3	59.3	61.1	58.2
Ruby Lee	57.5	53.6	61.4	55.2	56.4	61.7	56.9
Gallagher	58.3	56.8	61.4	56.0	59.4	60.8	55.2
Iba	58.8	57.6	60.5	56.8	60.3	61.8	56.0
Doans	60.0	59.4	62.2	57.2	61.7	61.9	57.7
Greer	55.3	51.3	57.6	52.4	57.7	59.4	53.3
Jagger	56.5	53.0	59.4	53.8	57.1	58.8	57.1
Fuller	57.7	54.4	60.5	55.9	58.4	59.7	57.3
Mean (all entries tested)	57.9	54.5	60.2	55.6	58.0	60.1	56.5
LSD (0.05)	*1.1*	*1.5*	*1.0*	*2.6*	*1.4*	*1.0*	*2.3*

Table 5

Test weight, 2012 WVTs

Table 6. Consensus **foliar disease** and **Hessian fly** reactions from field and greenhouse environments, 2010-2012. More detailed data is reported in Exhibit 3.

		Leaf rust[a]				Stripe rust				Viruses			Powdery mildew					Green-leaf duration[c]	
Year	Entry	Seedling	Oklahoma	Oklahoma	*Lr34* haplotype	Oklahoma	Oklahoma	Kansas[b]	Markers 2N, 5A	SBWMV	WSSMV	BYDV	Seedling	Adult	Pm3a	Tan spot *seedling*	Septoria *seedling*	Early	Late
			(0-4)	(0-9)		(0-4)	(0-9)	% Sev. (IT)						(0-4)				(0-5)	(1-9)
2012	**OK09915C**	**MS**		**0.0**	**SRR/HRR**	**0.8**	**3.0**	**5% (4)**	**–, –**	**R**	**IC**	**I**	**MS**	**S**	**+**	**S**	**MS**	2.0	**4.3**
	Centerfield																		
	Duster	R		0.0	RHH	1.2	0	10%	–, –	R	R	I	S	I	–	S	MS	2.7	7.6
	Endurance	MR		1.5	SSS	0.9	3.0	25%	H, –	R	R	MS	S	MS	–	S	S	2.3	5.9
2011	**OK09915C**	**S**	**na**	**2**	**SR-**	**na**	**na**	**20%(5)**	**–, ?**	**R/MR**	**MS**	**na**	**na**	**na**	**+**	**na**	**na**	2.1	**6.0**
	Centerfield	S		4				10% (3)		R	MS							1.8	5.6
	Duster	R		1	RHH			20% (3)	–, ?	R	R				–			2.1	5.3
	Endurance				RHS			30% (6)	–, ?						?			1.9	5.8
2010	**OK09915C**	**na**	**1.7**	**na**	**na**	**na**		**na**	**na**	**na**	**na**		**na**	**na**		**na**	**na**	**1**	**4.5**
	Centerfield		1.0		RR-													0	5.5
	Duster		0.0		RHH													0	5.5
	Endurance				RHS														

In-state readings collected by B. Carver and R. Hunger; reactions to stripe rust in KS provided by Robert Bowden, USDA-ARS, Manhattan, KS. APR = adult-plant resistance

[a] Leaf rust reaction recorded on 0 (immune) to 4 (very susceptible) or 9 (very susceptible) scales at multiple locations.

[b] x% (y) indicates % severity of given infection type on scale of 1 (resistant type) to 9 (highly susceptible type).

[c] Green-leaf duration values derived as the mean of multiple ratings taken in various Oklahoma environments during mid to late grain-fill.

Table 7. **Acid-soil tolerance** field ratings (0-5 scale) collected from breeding nurseries conducted at Enid, OK, 2010-2012, pH<4.5.

Entry	Year	Juvenile	Early adult	Adult	**Consensus rating**
OK09915C	2010	1	2	3	
	2011-RYT1	1	1	1	
	2011-OET1	0	1	0	
	2012 (low N)[a]	3.7	2.7	--	
	Mean	**1.4**	**1.7**	**1.3**	**T**
Centerfield	2010	1	1	1	
	2011-RYT1	3	2	2	
	2011-OET1	3	3	3	
	2012 (low N)	--	--	--	
	Mean	**2.3**	**2.0**	**2.0**	**MT**
Duster	2010	0	1	0	
	2011-RYT1	0	1	1	
	2011-OET1	--	--	--	
	2012 (low N)	2.7	1.0	--	
	Mean	**0.9**	**1.0**	**0.5**	**VT**
Iba	2010	--	--	--	
	2011-RYT1	--	--	--	
	2011-OET1	--	--	--	
	2012 (low N)	3.7	3.7	--	
	Mean				**MS**

n =1 to 3 observations per entry-year

Table 8. Relative ratings for **winter dormancy release**, actual measurements of **first hollow stem** (FHS) stage collected at Stillwater (by Jeff Edwards), heading dates recorded at three Oklahoma locations, relative ratings for **physiological maturity**, and genotypes for three developmental loci (identified by Liuling Yan, Oklahoma State University).

	Dormancy release rating[a]			First hollow stem Stillwater		Heading date			Physiol. Maturity[b] (2012)	Allele identity[c]
Entry	2010	2011	2012	2012	2013	Stillwater (2011, 2012)	Lahoma (2012)	Goodwell (2012)		*VRN-A1/PPD-D1/VRN-D3*
	- - - - - - - (1 - 5) - - - - - - -			day of year		days after March 31			(0-5)	
OK09915C	**5.0**	**4.2**	**3.8**	**62**		**13.0**	**11.5**	**27.5**	**4**	**BAA**
OK09935C	3.0	3.6	2.5	--		--	6.0	23.0	3	BAH
Centerfield	4.0	3.3	3.5	64		--	--	--	--	BBB
Duster	2.0	2.9	3.5	58		11.0	7.5	26.0	3	BBB
Endurance	4.3	3.9	4.1	62		10.0	8.0	27.5	4	BBB
Billings	2.5	2.5	1.9	46		7.0	3.5	21.0	3	BBB
Nursery mean	2.9	3.1	2.8	52		10.0	7.2	25.2	2.8	--

[a] Visual scale of increasing values represents gradually later dormancy release relative to the nursery evaluated, ranging from 1 (very early) to 5 (very late). Measured at Goodwell (irrigated and dryland) in 2010; Stillwater, Granite, Lahoma, and Goodwell-irrigated in 2011; and at Stillwater, Granite, Lahoma, Enid, and Goodwell-irrigated in 2012.

[b] Visual scale of increasing values represents gradually later physiological maturity, based on presence of green peduncles and heads, ranging in values from 0 (extremely early) to 5 (very late). Measured at Stillwater.

[c] Genotype designations correspond to the same allele found in Jagger (A) or 2174 (B). Jagger alleles at *VRN-A1* and *VRN-D3* accelerate development, whereas the Jagger allele at *PPD-D1* delays it. Alleles for 2174 have opposite effect for each gene. Genotype BAB is expected to show the latest maturity at FHS stage, heading, and physiological maturity.

Table 9. Mature-plant traits measured in breeding nurseries and the 2012 Oklahoma Small Grains Variety Performance Tests (variety trial data provided by Jeff Edwards).

	2012 Plant height		2012 Lodging ratings			Shattering ratings			
Entry	OET3 Lahoma	OSGVPT 6 sites [a]	Granite	Goodwell-irrigated	Goodwell-irrigated	2010 Goodwell-irrigated	2011 Lahoma	2012 Lahoma	2012 Granite
	- - - - - in - - - - -		- - - - - (0-5) - - - - -		% lodged	- - - - - - - - - - - (0-4) - - - - - - - - - - -			
OK09915C	**36**	**32**	**0.0**	**2.0**	**18**	2	0.8	0.5	0.5
Centerfield	--	--	--	--	--	0	0.0	--	--
Duster	33	31	3.5	3.5	45	0	0.0	0.0	0.0
Endurance	37	32	0.0	2.0	5	--	--	2.0	1.5
Ruby Lee	37	34	1.5	3.0	33	--	--	1.5	1.0
Billings	37	30	3.0	3.0	65	--	--	1.0	0.0
Armour	35	29	0.5	0.5	0	--	--	1.0	0.0
Trial mean	**35**	**31**	0.5	2.0	18	0.3	0.3	1.0	0.6
LSD (0.05)	*2*	--	*1.0*	*1.3*	*23*	--	*0.2*	*0.8*	*0.8*

LSD reported for only those trials with replicated data.

[a] Data collected from single replicates of variety trials at Alva, Buffalo, Gage, Kingfisher, Lahoma, and Marshall.

Table 10. **Milling characteristics**, based on single-kernel characterization system (SKCS) and near-infrared (NIR) analysis, taken from the 2010-2012 breeding trials in 2 to 5 environments per year. Data provided by C.E. Shelton, OSU Wheat Quality Laboratory.

	Hardness index										SKCS														
	NIR					SKCS					Kernel weight					Kernel diameter					Flour yield				
Entry	10	11-1[a]	11-2[a]	12	Mean	10	11-1	11-2	12	Mean	10	11-1	11-2	12	Mean	10	11-1	11-2	12	Mean	10	11-1	11-2	12	Mean
											-mg-					-mm-					-%-				
OK09915C	**83**	**87**	**79**	**76**	**81**	**68**	**84**	**79**	**69**	**75**	**33.4**	**30.2**	**30.6**	**32.9**	**31.8**	**2.84**	**2.64**	**2.65**	**2.76**	**2.72**	**60.0**	**59.0**	**58.8**	**64.3**	**60.5**
Centerfield	81	86	84	--		74	88	80	--		30.1	29.2	29.0	--		2.74	2.70	2.64	--		56.0	59.1	60.2	--	
Duster	82	84	--	72		70	86	--	73		28.9	26.5	--	26.7		2.67	2.51	--	2.53		60.7	58.8	--	64.2	
Endurance				63					65					29.3					2.58					65.2	
Billings				69					64					34.7					2.75					65.7	
Trial mean	**76**	**76**	**78**	**65**	**74**	**65**	**78**	**79**	**63**	**71**	**30.7**	**29.3**	**28.5**	**30.5**	**29.8**	**2.72**	**2.60**	**2.59**	**2.63**	**2.64**	**58.8**	**58.7**	**59.3**	**64.9**	**60.4**
LSD (0.05)	*6*	*7*	*5*		--	*4*	*5*	*3*		--	*2.4*	*3.4*	*1.7*		--	*0.08*	*0.09*	*0.07*		--	*1.8*	*2.0*	*1.6*		--
Target range	>60					>60					>30.0					>2.50					>60.0				

Number of environments per year was 2 (2010 RYT1), 2 (2011-1, RYT1), 4 (2011-2, OET1), and 5 (2012 OET3).

Where highlighted (only for kernel size and flour yield), a given entry was significantly worse than (red) or better than (blue) OK09915C.

Table 11. **Protein** content from near-infrared analysis and protein quality based on sedimentation volume adusted for flour protein, taken from the 2010-2012 breeding trials in 2 to 5 environments and from 6 environments of the 2012 Oklahoma Small Grains Variety Performance Tests (OSGVPT) . Data provided by C.E. Shelton, OSU Wheat Quality Laboratory, and by J.T. Edwards.

	Wheat protein (12% mb)						Flour protein (14% mb)					Adjusted sedimentation volume				
Entry	2010	2011 -1[a]	2011 -2[a]	2012 OET3	2012 OSGVPT	Mean	10	11-1[a]	11-2[a]	12 OET3	Mean	10	11-1[a]	11-2[a]	12 OET3	Mean
					%									mL		
OK09915C	14.6	**13.6**	**13.4**	**12.3**	**12.3**	**13.2**	12.6	**11.9**	**11.7**	**10.8**	**11.8**	**6.6**	**--**	**7.4**	**6.4**	**6.8**
Centerfield	14.3	14.0	13.7	--	--		12.2	12.4	12.2	--		5.9	--	6.3	--	
Duster	13.9	12.8	--	11.9	12.0		12.0	11.1	--	10.5		6.0	--	--	5.9	
Endurance	--	--	--	11.9	12.0		--	--	--	10.5		--	--	--	4.8	
Billings	--	--	--	12.0	12.1		--	--	--	10.5		--	--	--	6.3	
OK Bullet	--	--	--	--	12.7		--	--	--	--		--	--	--	--	
Trial mean	**14.3**	**13.5**	**13.4**	**11.8**	**12.1**	**13.0**	**12.3**	**12.0**	**11.7**	**10.4**	**11.6**	**5.9**		**6.3**	**6.1**	**6.1**
LSD (0.05)	*0.6*	*1.2*	*0.3*		*0.4*		*0.7*	*1.2*	*0.5*			*0.3*		*0.4*		
Target	≥11.5%						≥10.0%					higher values				

Number of environments per year was 2 (2010 RYT1), 2 (2011-1, RYT1), 4 (2011-2, OET1), 5 (2012, OET3), and 6 (2012 OSGVPT).
Where highlighted, a given entry was significantly worse than (red) or better than (blue) OK09915C.

Table 11
Protein content
Sedimentation volume

Table 12. Gluten strength based on **mixograph characteristics** measured on samples taken from the 2010-2012 breeding trials in 1 to 5 environments. Data provided by C.E. Shelton, OSU Wheat Quality Laboratory.

	Mixing time						Mixing tolerance rating						Mixogram curve width						Mixogram stability					
Entry	10	11-1[a]	11-2[a]	12 OET3	12 Lahoma	Mean	10	11-1[a]	11-2[a]	12 OET3	12 Lahoma	Mean	10	11-1[a]	11-2[a]	12 OET3	12 Lahoma	Mean	10	11-1[a]	11-2[a]	12 OET3	12 Lahoma	Mean
	---------- min ----------						---------- 0-6 ----------						---------- mm ----------											
OK09915C	**4.2**	**3.9**	**4.3**	**4.6**	**2.8**	**4.0**	**4.0**	**3.0**	**3.5**	**4.6**	**5**	**4.0**	**21.0**	**21.1**	**17.8**	**15.8**	**16.1**	**18.4**	**8.9**	**9.7**	**8.9**	**3.7**	**1.6**	**6.6**
Centerfield	4.4	3.6	3.9	--	2.5	**3.6**	2.5	2.5	2.3	--	3	**2.6**	15.5	12.3	11.7	--	14.3	**13.5**	8.7	11.4	12.8	--	5.3	**9.6**
Duster	5.2	4.9	--	5.0	3.3	**4.6**	4.5	4.5	--	4.4	5	**4.6**	19.2	27.8	--	15.5	14.5	**19.3**	4.2	4.1	--	3.7	1.9	**3.5**
Endurance	--	--	--	4.3	3.1	**3.7**	--	--	--	2.8	4	**3.4**	--	--	--	13.7	10.6	**12.2**	--	--	--	7.0	4.4	**5.7**
Billings	--	--	--	4.7	3.7	**4.2**	--	--	--	4.2	4	**4.1**	--	--	--	15.6	15.4	**15.5**	--	--	--	4.9	4.7	**4.8**
Trial mean	**4.3**	**3.6**	**4.2**	**4.5**	**3.3**	**4.0**	**3.3**	**2.6**	**3.1**	**3.7**	**3.7**	**3.3**	**20.6**	**16.5**	**14.3**	**15.3**	**14.3**	**16.2**	**7.3**	**10.8**	**8.5**	**5.0**	**6.0**	**7.5**
LSD (0.05)	*1.2*	*1.2*	*0.7*		--	*1.0*	*1.4*	*1.4*	*1.0*		--	*1.3*	*6.8*	*14.7*	*3.6*		--	*8.4*	*6.1*	*7.7*	*4.4*		--	*6.1*
Target range	3 - 5 min						≥ 2.5						≥ 12 mm						< 10					

Number of environments per data set was 2 (2010 RYT1), 2 (2011-1, RYT1), 4 (2011-2, OET1), 5 (2012, OET3), and 1 (2012 WQC plots at Lahoma).

Where highlighted, a given entry was significantly worse than (red) or better than (blue) Duster. Statistical comparisons were not highlighted for mixing time, as an intermediate value of about 3.5 to 5.0 minutes is preferred.

Table 13. Baking characteristics of grain samples composited (Comp) from four environments each in 2011 and 2012, or from a single site (Lahoma, OK) in 2012. Data provided by C.E. Shelton, OSU Wheat Quality Laboratory.

	Bake absorption				Loaf volume				Visual - total[c]			
Entry	11[a] Comp	12[a] Comp	2012 Lahoma[b]	Mean	11[a] Comp	12[a] Comp	2012 Lahoma[b]	Mean [c]	11[a] Comp	12[a] Comp	2012 Lahoma[b]	Mean
	- - - - - - - - % - - - - - - - -				- - - - - - - - - cc - - - - - - - - -				- - - - - - - - (0 - 11) - - - - - - - -			
OK09915C	**65.0**	**63.0**	**62.0**	**63.3**	**913**	**735**	**850**	**833**	**9.0**	**6.5**	**8.0**	**7.8**
Centerfield	65.0	--	62.0	**63.5**	925	--	850	**888**	9.0	--	8.0	**8.5**
Duster	--	63.5	63.0		--	805	878		--	6.5	8.0	
Endurance	--	63.5	63.0		--	700	800		--	5.5	8.0	
Billings	--	63.5	64.0		--	800	950		--	8.0	9.5	
Trial mean	**64.6**	**63.2**	**63.4**	**63.7**	**912**	**810**	**869**	**864**	**8.5**	**7.2**	**8.0**	**7.9**
Target range	>63.0				>800 across years in this sample				>7.0			

[a] Composite grain samples collected from 4 Oklahoma environments in each year

[b] Single samples collected from the Wheat Quality Council growout at Lahoma in 2012.

Proposal for Release of Plant Materials
Hard Red Winter Wheat Cultivar

OK09915C

Exhibit 1
Variety Name Clearance
USDA, Seed Regulatory and Testing Branch

Exhibit 2
Breeding Scheme

Exhibit 3
Breeding History

Exhibit 4
Disease Reaction Summary
Dr. Bob Hunger, OSU

Exhibit 1

USDA

United States Department of Agriculture

Agricultural Marketing Service

Livestock, Poultry, and Seed Program

Seed Regulatory and Testing Division
801 Summit Crossing Place, Suite C
Gastonia, North Carolina 28054
704-810-7264, FAX 704-852-4189
www.ams.usda.gov/seed

February 1, 2013

Mr. Brett Carver
Oklahoma State University
368 AG Hall, Dept. of Plant and Soil Sciences
Stillwater, Oklahoma 74078

Dear Mr. Carver:

In response to your inquiry concerning variety names, we have checked our variety name database and have found the following:

Name Cleared: '[redacted]' for common wheat has been cleared.

We are no longer doing Trademark searches on proposed variety names. The Trademark database can be accessed via the Internet at the following web site: "www.uspto.gov". Because there is no variety registration system, we cannot assure you that these names are free of conflicts. Moreover, our clearance confers no legal precedence.

We are happy to help you in this matter. **Please inform us about your new variety releases, including the kind, release date, and experimental designation(s) of the new varieties. Also, please indicate which names you decline to use so that they may be returned to the pool of available names.**

Thank you.

Sincerely,

Kevin Robinson
Seed Marketing Specialist

Exhibit 2

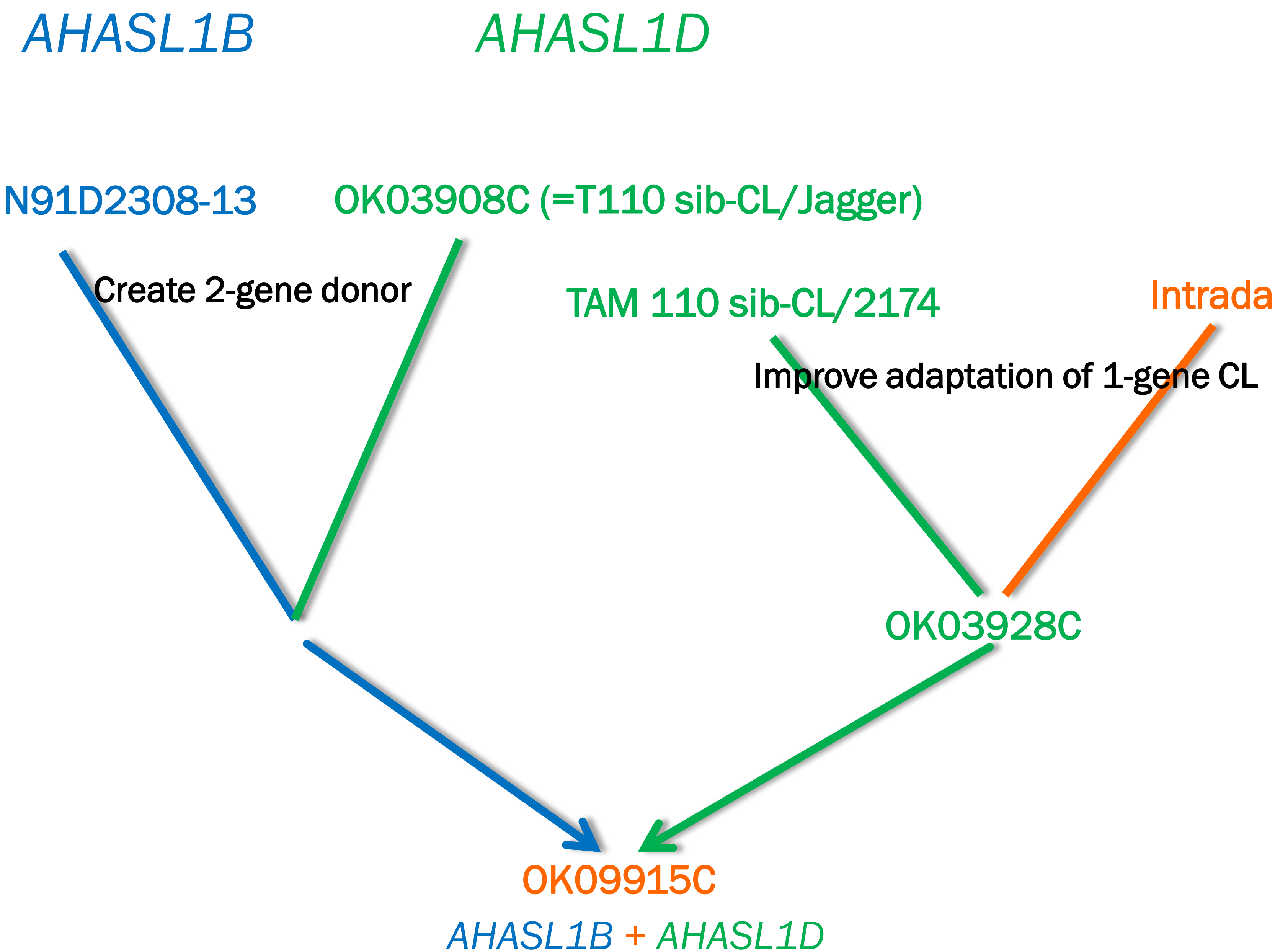
AHASL1B
AHASL1D
N91D2308-13
OK03908C (=T110 sib-CL/Jagger)
Create 2-gene donor
TAM 110 sib-CL/2174
Intrada
Improve adaptation of 1-gene CL
OK03928C
OK09915C
AHASL1B + AHASL1D

Exhibit 3

Selection path for OK09915C from 2004 to 2013. Population or entry number appears in italics.

Year	Nursery, NID	Location	Entry no. or other
2013	OET3, 93	Statewide	*26*
	OET1, 90	Statewide	*4*
	RYT2, 84	Statewide	*3*
	SRPN	Statewide	*9*
	BSI, 96	Goodwell (GD)	*20 (1 trip)*
	Wheat Var. Trials	Statewide	18 sites+
	QT	ST,PK	
	OFSS		re-increase
2012	OET3, 93	Statewide	*26*
	Wheat Var. Trials	Statewide	*8 sites*
	UVT, 98	LA, GR, EN, GD	*33*
	QT	ST, PK	
	RGON		*86*
	BSI, 96	Goodwell	*29 (1 trip)*
	<7 bu to OFSS		
2011	OET1, 90	LA,GR,GD	*2*
	RYT1, 88 (as ck)	LA,GR,GD	*3*
	BSI, 96	Goodwell	*32 (3 trips)*
2010	RYT1, 86	LA, GD, SW	*7*
2009	DPON-Supp, 79	ST, LA	*15*
2008	Head Rows	Stillwater	*08116002*
2007	Bulks, F2	Marshall	*072039011*
2006	F1 bulk	Greenhouse	*06G1347*
2005	F1 hybrid (topcross)	Greenhouse	*05x380*
2004	F1 hybrid (single cross)	Greenhouse	*04x888*

Exhibit 4

Division of Agricultural Sciences and Natural Resources

OKLAHOMA STATE UNIVERSITY AGRICULTURE

Department of Entomology and Plant Pathology
127 Noble Research Center
Stillwater, Oklahoma 74078-3033
Phone: 405-744-5643
Fax: 405-744-6039
www.entoplp.okstate.edu

22-Feb-2013

Dr. Brett Carver
Department of Plant & Soil Sciences
Oklahoma State University
Stillwater, OK 74078

Dear Dr. Carver:

Below are summary statements describing the reaction of **OK09915C** to the wheat soilborne mosaic (WSBM)/wheat spindle streak mosaic (WSSM) complex, the rusts (leaf, stripe and stem), powdery mildew, tan spot, septoria glume blotch, barley yellow dwarf and other diseases as available. The observations used to determine these reactions are presented on the attached pages. Testing of this line is also being done this season, which may further delineate disease reactions.

OK09915C

WSBM/WSSM complex: Results from field trials indicate that OK09915C is resistant to WSBM but susceptible to WSSM. This is indicated by values from the enzyme-linked immunosorbent assay (ELISA) indicating presence of coat protein of *Wheat spindle streak mosaic virus* and absence of coat protein of *Soil-borne wheat mosaic virus*. In Oklahoma, WSBM is the most detrimental of these two virus diseases.

Leaf rust: OK09915C shows seedling susceptibility to leaf rust caused by *Puccinia triticina*. Adult plants in the field show leaf rust pustules but at greatly reduced incidence compared to susceptible varieties. Hence I would call OK09915C as intermediate to moderately resistant to leaf rust. DNA marker testing indicates the presence of Lr34, which may be providing this protection. If Lr34 is alone, this could explain the high rating in south Texas where the highly favorable environment and heavy inoculum pressure could overwhelm Lr34 if it is by itself.

Stripe rust: Field ratings indicate an intermediate level of resistance to stripe rust. DNA marker testing indicates the presence of Yr2A, which could be responsible for this resistance. As with leaf rust, the level of stripe rust resistance may be overwhelmed in a combination of heavy inoculum and continuous favorable environment.

Stem rust: Based on seeding tests conducted in Minnesota, OK09915C is susceptible to races of *P. graminis* f. sp. *tritici* present in the U.S. However, field ratings in Minnesota and Kenya indicate moderate susceptibility to stem rust.

Powdery mildew: Seedling assays conducted in the greenhouse indicate susceptibility to powdery mildew. Field observations indicate OK09915C is moderately susceptible to susceptible to powdery mildew.

Barley yellow dwarf: Ratings in two trials in one year indicate that OK09915C has a level of resistance to BYDV comparable to Duster, which is considered moderately resistant to BYD.

Tan spot & septoria: Based on limited (one year) of greenhouse testing of seedlings, OK09915C is susceptible to tan spot, and moderately susceptible to septoria glume blotch.

Fusarium head blight: The only testing done of OK09915C related to Fusarium head blight (scab) was DNA marker testing, which indicated absence of the gene for resistance to FHB.

Please contact me if clarification or additional information is needed.

Sincerely,

Bob Hunger

Dr. Bob Hunger
Professor & Extension Wheat Pathologist

Disease Reactions of OK09915C

Wheat Soilborne Mosaic Virus (WSBMV)/Wheat Spindle Streak Mosaic Virus (WSSMV)

Year/location	Symptoms (1-4)	ELISA WSBMV	ELISA WSSMV
2012 NID 93 #26	1 1	0.12 0.10	>3.00 >3.00
2012 RGON #86	1 2 2	0.12 0.14 0.14	3.00 3.00 0.63
2012 RGON #86 (DNA markers)	Sbm1 (4)		
2011 NID 90 #2	2 2 1 2	0.26	3.00
2011 NID 88 #3	2 2 2 2	0.50	3.00

Leaf Rust

Year/location	Seedling	Field
2012 NID 93 #26	X3-; 3 X:3= (MS)	
2012 NID 93 #26 (GR; 26-Apr)		0.0 (0-9; 2 reps; range=0.0-7.0; avg=1.3)
2012 NID 93 #26 (STW-BSI; 27-Apr)		0 (0-9; range=0-4; avg=1.1)
2012 RGON #86	3	
2012 RGON #86 (CAS-TX)		90S (R-100S)
2012 RGON #86 (DNA markers)	Non-Lr21 Lr34(exon11) Lr34(exon11) Lr34(exon12) Non-Lr34-JaggerMutant(excLr34(intron4) Lr34 Non-Lr46	
2011 NID 90 #2	3 3+ 3	
2011 NID 90 #2 (STW-BSI on 06-09 May)		1 (0-9; range=1-4; avg=1.7)
2011 NID 88 #3	3 3 3	
2011 NID 88 #3 (STW-BSI on 09-May & 18-May)		1 (1-9; range=1-4; avg=2.5) 2 (0-9; range=1-7; avg=3.6)
2010 NID 86 #7 (STW-BSI)		1.7 (0-4; range=0-4; avg=2.0)

Stripe Rust

Year/location	Seedling	Field
2012 NID 98 #33 (GR; 18-Apr)		2 (0-5; range=0-4; avg=1.4)
2012 NID 98 #33 (LA; 25-Apr)		1 (0-5; range=0-4; avg=1.3)
2012 NID 93 #26 (MA; 13-Apr)		0.0 (0-5; range=0.0-2.7; avg=1.3)
2012 NID 93 #26 (GR; 18-Apr)		1.0 (0-5; range=0.0-3.2; avg=1.5)
2012 NID 93 #26 (LA; 25-Apr)		1.5 (0-5; range=0.0-4.0; avg=1.3)
2012 NID 93 #26 (STW-BSI; 27-Apr)		3 (0-9; range=0-8; avg=2.8)
2012 RGON #86 (field @ RSV-KS)		4 (IT; range=1-8; avg=4.6) 5 (SEV; range=0.1-95; avg=10.3)
2012 RGON #86 (Kenya)		MS (range=S-R)
2012 RGON #86 (DNA markers)	Yr2A Non-Yr2B	

Stem Rust

Year/location	Seedling (0-4)	Field
2012 RGON #86 (CDL-MN)	S (bulk) 4 (TTKSK)	20MR 60MS-S (2 fields; 0-90S)
2012 RGON #86 (Kenya – 2 dates)		50% S (IT) 50% S (IT) (% & IT ranges=0-70; S-R)
2012 RGON #86 (DNA markers)	Non-Sr2(3) Non-Sr22 Non-Sr35 Non-Sr35(5) Non-Sr36(4) Non-Sr39(3) Non-Sr40(3)	

Other Diseases

Year/location	Seedling	Field
Powdery mildew:		
2012 NID 93 #26	3.1/4.0	4 3 (0-4)
2012 RGON #86		3 4 3 (0-4) (MS)
2012 RGON #86 (DNA markers)	Het-Pm3a Non-Pm3e	
Tan spot:		
2012 NID 93 #26	35% (S) [RC, K92, 2174, T64, T105 = 10, 16, 14, 20, 20%]	
Septoria:		
2012 NID 93 #26	60% (MS) [2137, DEL, NWT, T64 = 13, 66, 66, 91%]	
Fusarium head blight:		
2012 RGON #86 (DNA markers)	Non-FHB 3BS/Fhb1	
Barley yellow dwarf virus:		
2012 NID 93 #26		2 3 0.13 0.80 (I)
2012 RGON #86		2 3 2 1.05 1.73 0.52 (MR)
2012 – Duster – all trials		2.3 (=s average of 28 ratings; range=2.0-4.0)

Summary of Reactions of OK09915C to Wheat Diseases

Disease	OK09915C
Soilborne mosaic (SB)/spindle streak (SS) complex	R (SB)/MS (SS)
Wheat leaf rust**	I-MR
Wheat stripe rust**	I
Wheat stem rust	MS
Powdery mildew	MS
Tan spot	S
Septoria leaf blotch	MS
Barley yellow dwarf virus	MR
Fusarium head blight (scab)	NI
Wheat streak mosaic virus	NI
Triticum mosaic virus	NI

*Disease reactions defined as:

R=resistant
MR=moderately resistant
I=intermediate
MS=moderately susceptible
S= susceptible
NI=no information

**There is indication that resistance in OK09915C to this disease may be overwhelmed by continuous favorable environment in conjunction with heavy inoculum level.