Registration of ‘Tiger’ Wheat

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ABSTRACT

‘Tiger’ (Reg. No. CV-1085, PI 661995) hard white winter wheat (Triticum aestivum L.) was developed at the Agricultural Research Center–Hays, Kansas State University and released by the Kansas Agricultural Experiment Station in 2010. Tiger was selected from the three-way cross KS98H245//Trego//KS98HW518, made in 1999 at Hays, KS. The objective of this cross was to develop a hard white winter wheat cultivar with the adaptation to the dryland production system in western Kansas. Tiger is an F<sub>6</sub>-derived line with the experimental number KS05HW136-3-1. Tiger was released because of its high grain-yield potential under unirrigated conditions in western Kansas, its good disease and insect resistance, and its superior bread-baking and noodle qualities.

Common wheat (Triticum aestivum L.) is classified as hard red winter, hard red spring, soft red winter, soft white, and hard white in the U.S. market. Hard white wheat (HWW), the newest class, has a hard endosperm and lacks a reddish pigment in the outer layer of the wheat kernel. Hard white wheat is similar to hard red wheat in composition except for its white bran; however, HWW has a few advantages over hard red wheat, such as a higher flour extraction rate, a less bitter taste, and a more pleasant appearance in final products. Due to these advantages, HWW is widely used in whole wheat and noodle products. In the United States, Kansas is the largest producer of winter type HWW, with most of its hectares in the southwestern region.

‘Tiger’ (Reg. No. CV-1085, PI 661995) is a HWW developed at the Agricultural Research Center–Hays (ARCH), Kansas State University (KSU), and released by the Kansas Agricultural Experiment Station in 2010. Tiger was selected from the three-way cross KS98H245//Trego//KS98HW518. Parental line KS98H245 is a hard red experimental line developed at ARCH with ‘Ike’ (PI 574488; Martin et al., 1995) and ‘TAM 200’ (PI 578255; Worrall et al., 1995) in the pedigree while Trego (PI 612576; Martin et al., 2001) is a HWW cultivar developed at ARCH and released in 1999. The third parent, KS98HW518 (KS93HW91/KS93HW255), is a hard white experimental line with good end-use quality developed at ARCH. The objective of this cross was to develop a HWW cultivar with adaptation to the dryland production system in western Kansas. Tiger is an F<sub>6</sub>-derived line that was tested with the experimental line number KS05HW136-3-1. Tiger was released because of its high grain-yield potential, its good resistance to the major pests in western Kansas, and its excellent end-use quality for bread and noodles. The name of Tiger was chosen to honor the technicians who worked in the wheat breeding program at ARCH over years, all of whom but one got degrees from Fort Hays State University at Hays, KS, whose mascot is the tiger.

Methods

Tiger was developed using a modified bulk-breeding method. All the early-generation population and line development was conducted at Hays, KS. The top cross (KS98H245//Trego//KS98HW518) was made in the greenhouse in spring 1999 and was bulk harvested that summer. The F<sub>1</sub> plants were grown in the field under irrigated conditions in the fall of 1999 and were bulk harvested in June 2000. The F<sub>2</sub> plants were grown in the field under unirrigated conditions in the fall of 2000 and bulk harvested in June 2001. A subsample of the F<sub>3</sub> seed was planted in the field under unirrigated conditions in the fall of 2001. In 2002, about 150 spikes were selected from the F<sub>3</sub> population on the basis of plant height, lodging, and head size. These spikes were threshed individually and planted in the F<sub>4</sub> headrow nursery under unirrigated conditions in the fall of 2002. Headrows were subjected to selection on the basis of winter injury, plant...
height, maturity, lodging, grain shattering, resistance to stripe rust (caused by *Puccinia striiformis* Westend.) and leaf rust (caused by *Puccinia triticina* Ericks.), test weight, and yield. Six head selections were made from each selected row, and the rest of each row was bulk harvested. The head selections (reselections) were threshed individually and planted as headrows in the reselection nursery under irrigated conditions, and the bulk-harvested seeds (F$_{4:5}$) were planted in the first preliminary yield nursery (PYN1) in the fall of 2003.

In the PYN1, one line with entry number 5369 performed well. Three reselection rows (1, 3, and 5) corresponding to entry 5369 were selected for further testing in 2005 in the second preliminary yield nursery (PYN2). Six head selections were made from each reselection row, and the rest of each row was bulk harvested. Head selections were again individually threshed and planted as headrows in the reselection nursery. The bulked seeds (F$_{6:5}$) from each reselection row were used for the PYN2, and the rest of them were planted in an increase plot under irrigated conditions. The three reselections were tested in the 2005 PYN2 as entries 6134, 6135, and 6136. Entry 6136 performed well and was selected for further testing in the advanced yield nursery (AYN) in 2006. The increase plot of entry 6136 was bulk harvested and its three reselection rows were selected (1, 3, 5) for advancement. Six head selections were made from each reselection row and the rest of each row was bulk harvested. The seeds (F$_{6:5}$) from the increase plot of 6136 were planted in the AYN under the experimental line number KS05HW136. Its head selections were planted in the reselection nursery, and bulked seeds (F$_{1:5}$) from each reselection row were planted in two increase plots. KS05HW136 performed well in the 2006 AYN. One of its three reselections (3; F$_{4}$-derived line) was selected for further testing in the Kansas Intrastate Nursery (KIN) in 2007 under the experimental line number KS05HW136-3, and its three reselection rows (1, 3, 5) were also selected for advancement. Two seed-increase plots were planted for each reselection. Based on the 2007 performance, KS05HW136-3 was selected for further testing in the 2008 KIN and Southern Regional Performance Nursery (SRPN). A plot of 0.04 ha was grown to obtain grain samples for quality tests by the Wheat Quality Council (WQC). In 2009, one reselection (1; F$_{4}$-derived line) was selected for seed increase (0.8 ha). In 2010, KS05HW136-3-1 was released and named Tiger.

Both PYN1 and PYN2 were unreplicated yield trials with the augmented design. The PYN1 was grown at one location (Hays, KS), whereas PYN2 was grown at three locations (Hays, Colby, and Garden City) in western Kansas. The AYN, KIN, and SRPN were replicated yield trials with a randomized complete block design. The AYN and KIN are statewide yield trials and the SRPN is a region-wide yield trial. All the yield trials were conducted under unirrigated conditions except one 2007 KIN trial in Garden City. Entries in the yield trial and their reselections were screened for yield, test weight, maturity, grain shattering, lodging, polyphenol oxidase (PPO) activity, and pest resistance, which includes stripe rust, leaf rust, *Wheat streak mosaic virus* (WSMV), *Soilborne mosaic virus* (SBMV), and Hessian fly (*Mayetiola destructor* Say]). Entries to be advanced were further tested for kernel characteristics (shape, size, color, and protein content), milling quality, noodle color stability, and bread-baking quality by the KSU Wheat Quality Laboratory (Manhattan, KS). In 2008, the end-use quality of Tiger was also tested by the WQC. Seed purification of Tiger started in 2005 by visual identification and manual removal of off-types from seed increase plots.

Data were analyzed with SAS 9.1 (SAS Institute). Grain yield and agronomic traits from AYN, KIN, and SRPN trials were subjected to analysis of variance across locations within years, and combined analysis across location-years. For KIN trials, data from western Kansas locations and eastern Kansas locations were analyzed separately and only results from western Kansas are reported in this paper. The combined analysis included only the common entries across location-years. A mixed model was used in the analysis with genotypes as fixed effects, and years or location-years, and replications as random effects. An F-protected LSD test ($\alpha = 0.05$) was used to compare the least square means for genotype effects. In the KIN trials, grains from the four replications at the same location were mixed for end-use quality test. Therefore, analysis for end-use quality data from the KIN was conducted using location × genotype as experimental errors. The WQC quality data was analyzed with the Student’s paired $t$ test since the grain sample was tested by multiple cooperators.

**Characteristics**

**Agronomic and Botanical Description**

Tiger is an awned, white-chaffed, and hard white-seeded wheat. It has a medium maturity (13.9 d to heading from May 1, Table 1), which is similar to ‘Hatcher’ (PI 638512; Haley et al., 2005), slightly earlier (P > 0.05) than ‘Lakin’ (657998) and ‘Danby’ (PI 648010), and 1 d later (P < 0.05) than ‘Fuller’ (Table 1). Tiger is medium short (84.0 cm), which is similar to Lakin (84.1 cm) and Hatcher (85.2 cm), and 4 to 5 cm shorter (P < 0.05) than Danby (88.1 cm) and Fuller (88.6 cm). Tiger is susceptible to preharvest sprouting (100% sprouted on the 8th d of the germination test), which is the same as Lakin and higher (P < 0.05) than Danby (36.9%) and Fuller (77.9%). No objective data are available for the straw strength and winter hardiness of Tiger, but field observations of its performance in Kansas show that it has very good winter hardiness and moderate straw strength.

Tiger has a prostrate juvenile growth habit. Its coleoptile, stem, and auricle lack anthocyanin. Tiger plants are green at the boot stage and do not have a waxy bloom. The flag leaves of Tiger are recurved, not twisted, and waxy, and stems are hollow and hairless. Tiger has erect peduncles. The heads of Tiger are strap shaped, middense, and recurved at maturity. Its glumes are medium sized with pubescence, wanting shoulders, and medium-width acute beaks. Kernels are ovate shaped and have medium-sized germos, round cheeks, medium-wide and deep creases, and medium-long, and noncollared brushes.

Tiger has been observed for seven generations (from the F$_{4}$ to the F$_{10}$ generation) from 2003 to 2009. It has been
uniform and stable during the last three generations. Tiger remains essentially unchanged in its primary and distinctive characteristics following sexual reproduction. Variants, which are rarely observed, include slightly taller plants (<0.02%) and plants with red kernels (<0.5%). These variants are commercially acceptable.

Field Performance

In the 2007 KIN, Tiger was tested in ten trials (nine dryland and one irrigated) at nine locations across western KS. Six of them, five dryland and one irrigated, were harvested. Tiger yielded an average of 5190 kg ha⁻¹ across the five dryland trials, which was the second highest-yielding entry among the 44 tested and yielded only 31 kg less (∝ 0.05) than that of the highest-yielding entry. The average yield of Tiger was higher (∝ 0.05) than all the ten check cultivars included in the KIN (data not shown). In the 2008 KIN, four out of nine dryland trials in western Kansas were harvested. Tiger yielded an average of 4581 kg ha⁻¹, which was the highest-yielding entry among the 36 tested. The average yield of Tiger was higher (∝ 0.05) than that of the three check cultivars—Lakin (4102 kg ha⁻¹), Fuller (4311 kg ha⁻¹), and ‘Art’ (4035 kg ha⁻¹) and was not significantly (∝ 0.05) different from the other five check cultivars (data not shown). In the combined analysis across the nine dryland trials in western Kansas in the 2 yr, the average yield of Tiger (4785 kg ha⁻¹) was slightly higher (∝ 0.05) than that of Danby (4639 kg ha⁻¹), and significantly (∝ 0.05) higher than that of Hatcher (4437 kg ha⁻¹), Fuller (4383 kg ha⁻¹), and Lakin (4238 kg ha⁻¹) (Table 1). The test weight of Tiger was intermediate. The average test weight (788 kg m⁻³) of Tiger across the 2 yr was similar (∝ 0.05) to that of Hatcher (783 kg m⁻³) and Fuller (792 kg m⁻³), lower (∝ 0.05) than that of Danby (805 kg m⁻³), but greater (∝ 0.05) than that of Lakin (776 kg m⁻³).

Tiger was tested in the 2008 SRPN. Across the 19 trials in the High Plains States of Kansas, Texas, Oklahoma, Colorado, and Nebraska, the average yield of Tiger was 3742 kg ha⁻¹, which was similar to the trial mean (3682 kg ha⁻¹). However, Tiger was the fourth highest-yielding entry across the two locations (Hays and Colby, KS) in western Kansas with an average yield of 4219 kg ha⁻¹.

End-Use Quality

Milling, bread-baking, and noodle quality of Tiger and check cultivars were evaluated according to the approved methods of American Association of Cereal Chemists (AACC, 2000) by the KSU Wheat Quality Laboratory and the WQC. In 2007, grain samples from two locations, each a mixture of four replications in the KIN trial, were tested by the KSU Wheat Quality Laboratory. The quality data for Tiger and check cultivars (Danby, Lakin, and RonL) are presented in Table 2. The kernel protein and ash content of Tiger was comparable with those of all three check cultivars. The flour extraction rate of Tiger was 72.9%, which was also similar to that of the three check cultivars. The falling number of Tiger was longer (∝ 0.05) than for all the three check cultivars, which might be due to Tiger’s susceptibility to the preharvest sprouting. In the baking test, Tiger had similar water absorption as the three check cultivars. The mixing time of Tiger was similar (∝ 0.05) to that of RonL and longer (∝ 0.05) than that of Danby and Lakin. The loaf volume of Tiger was larger (∝ 0.05) than that of Danby and RonL and significantly (∝ 0.05) larger than that of Lakin. In the noodle quality test, the noodle lightness of Tiger at 0 h of rest time was comparable with that of Lakin and RonL and brighter (∝ 0.05) than Danby’s. After 24 h of rest time, the noodle lightness of Tiger was comparable with that of Lakin and RonL and brighter (∝ 0.05) than Danby’s.

Table 1. Summary of yield and agronomic traits for Tiger and check cultivars grown in Kansas intrastate nursery across western Kansas locations in 2007 and 2008.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Class</th>
<th>Grain yield</th>
<th>Test weight</th>
<th>Plant height</th>
<th>Heading date</th>
<th>Preharvest sprouting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg ha⁻¹</td>
<td>kg m⁻³</td>
<td>cm</td>
<td>d from 1 May</td>
<td>%</td>
</tr>
<tr>
<td>Tiger</td>
<td>HWW</td>
<td>4785</td>
<td>788</td>
<td>84.0</td>
<td>13.9</td>
<td>100</td>
</tr>
<tr>
<td>Danby</td>
<td>HWW</td>
<td>4639</td>
<td>805</td>
<td>88.1</td>
<td>14.6</td>
<td>36.9</td>
</tr>
<tr>
<td>Hatcher</td>
<td>HRW</td>
<td>4437</td>
<td>783</td>
<td>85.2</td>
<td>14.1</td>
<td>—</td>
</tr>
<tr>
<td>Fuller</td>
<td>HRW</td>
<td>4383</td>
<td>792</td>
<td>88.6</td>
<td>13.0</td>
<td>77.9</td>
</tr>
<tr>
<td>Lakin</td>
<td>HWW</td>
<td>4238</td>
<td>776</td>
<td>84.1</td>
<td>14.3</td>
<td>100</td>
</tr>
<tr>
<td>CV (%)</td>
<td></td>
<td>12.3</td>
<td>4.2</td>
<td>3.9</td>
<td>8.9</td>
<td>11.6</td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td></td>
<td>258</td>
<td>15</td>
<td>2.4</td>
<td>0.9</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Average of five dryland locations in 2007 and four dryland locations in 2008.
Average of two locations in 2007 and one location in 2008.
Average of one location in 2007 and one location in 2008.
HWW, hard white wheat; HRW, hard red wheat.
Not tested.

Table 2. Quality parameters for Tiger and check cultivars grown in the Kansas intrastate nursery at Garden City and Colby, KS in 2007.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Kernel protein</th>
<th>Kernel ash</th>
<th>Flour yield</th>
<th>Falling number</th>
<th>Noodle color</th>
<th>Water absorption</th>
<th>Mixing time</th>
<th>Loaf volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>kg ha⁻¹</td>
<td>L0 L24 ΔL</td>
<td>%</td>
<td>min cc</td>
<td>%</td>
<td>cc</td>
</tr>
<tr>
<td>Tiger</td>
<td>11.5</td>
<td>1.3</td>
<td>72.9</td>
<td>358 82.3 73.8 8.5</td>
<td>69.6</td>
<td>4.4</td>
<td>912</td>
<td></td>
</tr>
<tr>
<td>Danby</td>
<td>11.8</td>
<td>1.3</td>
<td>72.0</td>
<td>483 79.9 68.4 11.5</td>
<td>69.7</td>
<td>2.8</td>
<td>821</td>
<td></td>
</tr>
<tr>
<td>Lakin</td>
<td>11.3</td>
<td>1.3</td>
<td>73.1</td>
<td>428 82.8 74.8 8.0</td>
<td>69.8</td>
<td>3.3</td>
<td>796</td>
<td></td>
</tr>
<tr>
<td>RonL</td>
<td>11.5</td>
<td>1.3</td>
<td>72.8</td>
<td>447 82.5 71.8 10.7</td>
<td>70.8</td>
<td>4.1</td>
<td>829</td>
<td></td>
</tr>
<tr>
<td>CV (%)</td>
<td>2.8</td>
<td>2.1</td>
<td>1.4</td>
<td>5.9 0.9 1.3 6.9</td>
<td>2.1</td>
<td>11.1</td>
<td>5.4</td>
<td></td>
</tr>
<tr>
<td>LSD (0.05)</td>
<td>0.7</td>
<td>0.06</td>
<td>2.1</td>
<td>59 1.5 2.0 1.3</td>
<td>3.1</td>
<td>0.8</td>
<td>97</td>
<td></td>
</tr>
</tbody>
</table>

Noodle color †
L0: noodle lightness at 0 h of rest time; L24: noodle lightness at 24 h of rest time; ΔL: the change of noodle lightness after 24 h of rest time.

#Not tested.
 Average of one location in 2007 and one location in 2008.
 Average of two locations in 2007 and one location in 2008.
 Average of five dryland locations in 2007 and four dryland locations in 2008.
was similar to Lakin’s and brighter (P < 0.05) than Danby’s and RonL’s. The noodle color change of Tiger over 24 h was comparable with that of Lakin and less (P < 0.05) than that of Danby and RonL, which can be explained by the low PPO level in both Lakin and Tiger. In 2008, Tiger and the check cultivar Danby were further tested for bread-baking and noodle quality by the WQC. The results showed that Tiger had a longer (P < 0.05) mixing time, a larger (P < 0.05) loaf volume, and less (P < 0.05) color change than Danby (data not shown), which is consistent with the report from the KSU Wheat Quality Laboratory. In the WQC test, the PPO concentration in Tiger was 0.223 (spectrophotometric absorbance at 475 nm), which was less than half of Danby (0.568). Because of its brightness and low PPO level, Tiger was rated as a good noodle flour by the WQC.

**Disease and Insect Resistance**

Tiger has been characterized for disease and insect resistance in the Kansas trials and through cooperative evaluations in the SRPN. Tiger was developed for western Kansas, where the major pests are WSMV, leaf rust, stripe rust, SBMV, and Hessian fly. Tiger was moderately resistant to WSMV under natural infestation in the field trials in Hays, KS. Tiger also showed SBMV resistance in the naturally infested field trials in Manhattan, KS. Tiger showed resistance to the Great Plain biotype of Hessian fly in seedling evaluations under greenhouse conditions in Manhattan, KS. In both the 2007 and 2008 KIN in Hays, KS, Tiger showed resistant reactions to leaf rust while the check cultivars Danby and Hatcher were susceptible, with severity ranging from 10 to 50%. In the 2007 KIN in Hays, KS, Tiger showed resistance to stripe rust while the check cultivar Hatcher was rated as moderately susceptible and Lakin as susceptible. In the 2008 SRPN, Tiger was further tested against various pathogens through cooperative evaluations. Leaf rust, stripe rust, and stem rust (caused by *Puccinia graminis* Pers.:Pers. f. sp. *tritici* Eriks. & E. Henn) were evaluated under both greenhouse and field conditions. Tiger showed resistance to leaf rust in the six field trials across Texas, Indiana, Oklahoma, Minnesota, and Kansas. Seedling reaction to leaf rust was tested in the greenhouse at the USDA Cereal Disease Laboratory in St. Paul, MN. Tiger showed resistance to all eight isolates tested: MLDS, THBJ, MJB, MFPS, TDBJ, TDBG, MHDS, and KFBJ. Tiger was evaluated in both seedling and adult-plant stages with stripe rust isolate PST-100 in the greenhouse in Manhattan, KS. Tiger was susceptible to PST-100 in the seedling stage, but it showed moderate resistance (infection type 4 to 5, on a scale of 0–9 where 0 = most resistant and 9 = most susceptible) with an average severity of 18% in the adult-plant stage. Tiger was found susceptible to stripe rust races PST-17, PST-37, PST-45, and PST-116 in the seedling stage in the greenhouse test in Pullman, WA. However, Tiger showed resistant reactions under natural infection (infection type of 0, 2, or 3 on a scale of 0–9, severity ranged from 0 to 30%) to stripe rust in five field trials in Montana and Washington. Tiger was resistant to the U.S. stem rust races QFCS, QTHJ, RCRS, RKQQ, TPMK, and TTTT in the greenhouse seedling tests. Tiger also showed no symptoms of stem rust in the field trial conducted in St. Paul, MN, whereas the most susceptible line in the trial was rated as 80S (80 = 80% of severity, S = susceptible). However, Tiger was susceptible (60S) to the stem rust in a Kenya field trial, indicating its susceptibility to the Ug99 race. Cooperative evaluations in the 2008 SRPN also showed that Tiger was highly resistant to SBMV and Hessian fly and susceptible to the Russian aphid [*Diuraphis noxia* (Kurdjumov)] biotype 1 and greenbug [*Schizaphis graminum* (Rondani)].

**Availability**

The KSU ARCH will maintain the breeder seed of Tiger. Multiplication and distribution rights of other classes of certified seed have been transferred from KSU to the Kansas Wheat Alliance (1990 Kimball Ave., Manhattan, KS 66502). Foundation, registered, and certified seed of Tiger are protected under the U.S. Plant Variety Protection Act. A seed sample has been deposited with the National Plant Germplasm System, where it will be available for distribution for research purposes 5 yr after the date of publication. Before that time, a small quantity of seed for research purpose may be obtained from the corresponding author with a Material Transfer Agreement.

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**References**


