Effects of Awns on Wheat Yield and Agronomic Characteristics Evaluated in Variety Trials

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ABSTRACT

The relationship between awnedness (awned or awnless head types) and yield and other agronomic characteristics has been studied periodically for over a century. The results have been mixed or inconclusive and there are few studies investigating this with soft red winter wheat (*Triticum aestivum* L.), particularly in recent decades or with modern varieties. The objective of this study was to determine differences in grain yield, test weight, plant height and heading date among head types by evaluating variety trial data from the annual University of Kentucky Wheat Variety Tests over a 10 year period. This study utilized data from 533 awned varieties and 411 awnless varieties from 23,724 field plot observations. Awned varieties tended to have higher grain yield (1 Bu/A) than awnless varieties. Awnless varieties had taller plant height (1.6 in) and lodging (25%) and slightly higher test weight (0.2 lbs/Bu) than awned varieties. There has been a trend of wheat varieties changing from predominantly awnless types to awned types over the 10 year duration of this study. The higher yield potential, coupled with the wildlife (deer damage) protection benefits of awned head types indicate that head type should be part of the variety selection decision for growers.

INTRODUCTION

The relationship between awnedness (awned [bearded] or awnless [smooth] head types) and yield and other agronomic characteristics in wheat has been studied periodically for over a century. The results have been mixed or inconclusive and there have been few studies investigating this relationship with soft red winter wheat, particularly in recent decades or with modern varieties. Wheat variety agronomic characteristics have changed over the past century and it would be beneficial for the scientific community and for farmers to know if there are agronomic differences among head types of modern wheat varieties.

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Although studies on the relationship between awnedness and yield have been mixed, there is an underlying consensus that awnedness is related to yield potential and that may be related to the photosynthetic capacity of the awns. The awn is an important source of photosynthesis. Grundbacher (1963) suggested that wheat awns play an important compensation role as a source of assimilate supply in an environment where the flag leaf is stressed. It was also suggested that the close proximity of the awn to the seed would be an advantage in photosynthate translocation. In barley, awns were reported to contribute up to 19% of the grain yield (Schaller et al., 1975; Scharen et al., 1983). Miller et al. (1944), Saghir et al. (1968) and Duwayri (1984) showed that awn removal decreased yield, seed number and seed weight. These findings indicate that the photosynthetic capacity of awns have the potential to affect yield or compensate for reductions in flag leaf assimilate supply.

Some studies have shown a yield advantage associated with awnedness, and environmental factors may influence the yield response to awnedness. Patterson et al. (1962), Knott (1986), and Scharen et al. (1983) reported that awned isolines had higher yield than awnless lines of soft red winter wheat, durum wheat and winter barley, respectively. Though Rebetzke et al. (2016) reported no difference averaged across many environments, awned spring wheat isolines showed higher yields in warmer, drier environments. McKenzie (1972) summarized the work of Grundbacher (1963); Miller et al., (1944) and Vervelde (1953) by stating that the general consensus is that the advantage of awns is greatest in warm and semiarid climates. Atkins and Norris (1955) showed awned wheat lines to have higher yield, test weight and seed size with effects being greatest during drought years. Patterson et al. (1962) and Sunesan et al. (1948) suggested however, that the positive effect of awns on yield was greater in ideal growing environments and independent of moisture supply.

Other studies have shown no relationship between awned and awnless head types and grain yield. Atkins (1911), Aamodt and Torrie (1934), and Martin et al. (2003) showed an inconsistent response between awned and awnless spring wheat varieties and hard red winter wheat lines, respectively. Rebetzke et al. (2016) assessed performance of awned and awnless spring wheat isolines across 23 contrasting environments and noted little difference in yield among head types. Additionally, they reported that awnless lines produced higher seed number, but smaller seed size than awned lines, thus resulting in no difference in yield.

In some cases, awnless lines have been associated with higher yields. McKenzie (1972) showed higher yields for awnless spring wheat lines and Clark and Quisenberry (1929) showed that awnless plants from an awnless x awned spring wheat cross out yielded their awned counterparts.

Test weight is an important component of grain quality. Weyhrich et al. (1994) noted significant decreases in test weight in awnless lines. Patterson et al. (1962) showed that awned lines consistently expressed higher test weight than awnless lines. They also reported significantly higher seed weight in awned lines, as did (Knott, 1986; Scharen et al., 1983; Weyhrich, et al., 1994). Patterson et al. (1962) also noted that these test weight and seed weight findings were consistent with other studies (Lamb, 1937; Bayles and Sunesan, 1940, Atkins and Norris et al., 1955; Sunesan, et al., 1948).

It has been reported by growers (personal communication) that awned varieties move better through the combine. Additionally, awns may help reduce lodging by physically supporting neighboring grain heads. Awnless head types are recommended for forage production, particularly when harvesting at the soft-dough stage, to improve palatability (Bruening, 2017; Bruening, et al., 2019). White-tailed deer have been shown to browse more on awnless head types (Springer, et al., 2013) which can dramatically reduce yield (Harper, 2015). Bruening et al. (2019) reported deer damage (head removal) ratings on 83 wheat varieties and showed that all 21 awnless varieties sustained deer damage ranging from 5 to 88% with an average of 54% of the heads removed. Among the 59 awned varieties, only 3 showed damage ranging from 1 to 3%. Bears also prefer awnless wheat as seen in North Carolina (D. Bowman, unpublished data).

The few research reports of the evaluation of the effect of awns on yield and other agronomic characteristics of soft red winter wheat were conducted in the early to mid-1900's and the results were inconclusive. Many agronomic improvements in wheat varieties have evolved over time as a result of breeder's efforts which could affect this relationship. A large scale evaluation of the relationship between the presence of awns and yield and agronomic characteristics using modern varieties is needed for today's growers, seed companies and the scientific community. There are currently approximately 100 varieties of soft red winter wheat available to growers. Information on advantages of awned or awnless types would be useful for variety selection. Data from modern wheat variety trials can be utilized to evaluate the relationship between modern awned and awnless varieties. This study used University of Kentucky wheat variety trial data from 2008 to 2018 to determine the potential advantages of awns to wheat production.

METHODS

Differences in grain yield, test weight, plant height and heading date among head types were evaluated using variety trial data from the annual University of Kentucky Wheat Variety Trials. The UK wheat variety testing program tests soft red winter wheat varieties which are submitted annually for testing by national public breeders and seed companies. From the years 2008 to 2018, head type (Awned or Awnless) data was reported in the UK variety tests. The data for each year was summarized across locations using Agrobase software (Agronomix Inc.) and varietal head type data was matched with averaged yield, test weight, plant height and heading date data (there were 5-7 locations analyzed annually, with 4 reps per test location). Varieties with head types recorded as Tip-Awned (neither fully awned nor awnless) were excluded from the analysis. 2009 data was excluded because severe head scab epidemic affected variety specific yields and other test results. From the 10 year period, a total of 944 mean values (533 awned and 411 awnless varieties [summarized from 23,724 plots]) were utilized, making this a very robust data set.

The varietal mean values from each year's tests were utilized as replicated data points for the analysis (i.e., in 2008 there were 19 reps (varieties) of awned data and 50 reps (varieties) of awnless data (Table 1). Data was analyzed for each year using PROC GLM model in SAS. Because the data sets used in the analysis for each year were the summary of multiple variety test locations, location and GxE interaction effects could not be part of this study. Likewise, this study did not encompass differences among specific varieties, but rather labeled varieties as either awned or awnless.

Meta-analysis of the complete set of varietal mean values (n = 944) was used to evaluate differences among head types across the 10 year period. The number of varieties evaluated annually varied from 69 in 2008 to 112 in 2014. In addition the percentage of awnless vs. awned head types varied annually from 72% awnless head types in 2008 to 27% awnless types in 2018 (Table 1). Because yields and test weights vary annually, relative yield and relative test weights were calculated and used for analysis across years. To calculate relative yield values, the average yield value across all 10 years was first determined to be 82 bu/A. For each year, yields of varieties were adjusted to an average of 82 bu/A to eliminate the confounding effects of annual differences in yield. For example, 2018 had the lowest average yield, but 73% of 2018 varieties were awned, which would disproportionately drag down overall yield of awned varieties. The same method was used to calculate relative test weight values. Data was analyzed across years using PROC GLM model in SAS using 533 awned reps and 411 awnless reps.

RESULTS

The relative yield of awned varieties across all 10 years was significantly greater (82.4 vs. 81.4 bu/A) than awnless varieties (Table 1). It is not surprising that the difference (1 bu/A), though relatively small was significant given the high number of observations utilized in this study.

Table 1. Head Type Differences in Yield.

Year	n Varieties	n (reps) Awned	n (reps) Awnless	Awnless Varieties (%)	Pr > F Yield	Yield (Bu/A) Awned	Yield (Bu/A) Awnless
2008	69	19	50	72	0.5210	84.6	85.3
2010	77	28	49	64	**0.0002**	**86.8**	**82.6**
2011	100	48	52	52	0.1180	93.4	91.6
2012	104	55	49	47	0.6150	77.2	77.9
2013	99	55	44	44	0.9599	91.7	91.7
2014	112	64	48	43	**0.0464**	**96.6**	**94.7**
2015	103	71	32	31	0.3054	85.4	84.4
2016	93	64	29	31	**0.1000**	**85.9**	**84.3**
2017	103	68	35	34	**0.0810**	**87.2**	**84.9**
2018	84	61	23	27	0.9310	70.7	70.6
	944	533	411		**0.0029***	**82.4***	**81.4***

* Relative Adjusted Yield 2008-18 (excluding 2009)

Among individual years, yield of awned varieties was significantly greater in four (2010, 2014, 2016, 2017) of the ten years. There was no significant difference in the other six years. In the four years when awned varieties showed higher yields, there were not any consistent environmental factors that would account for differences in yield. During the month of May, which typically encompasses the critical grain filling period in Kentucky, it was on average warmer and wetter in 2010, warmer and drier in 2014, cooler and wetter in 2016, and normal in 2017 (data not shown). It was warmer and drier during May in 2012, 2014 and 2015 indicating no trend for awned advantages in drier, warmer climates as previously reported (Atkins and Norris 1955; McKenzie 1972; Rebetzke et al. 2016). The data presented here suggest that there appears to be no relationship with climatic conditions and yield differences among head types, consistent with that reported by Patterson et al. (1962) and Sunesan et al. (1948). Though beyond the scope of this study, the awns photosynthetic capacity and importance documented in the literature may be a factor supporting higher yields in awned varieties.

The length of the reproductive growth period (estimated by the length of time between recorded heading dates and harvest dates across all test locations [data not shown]) was not a factor in yield response to head type. In the four years where awnedness favored yield, 2016 and 2017 had relatively long reproductive growth periods where as 2014 had one of the shorter periods.

The relative grain test weight values of awnless varieties across all 10 years was significantly, though minutely greater (58.1 vs. 57.9 lbs/bu) than awned varieties (Table 2). This tiny difference is likely not within the expected level of measurement error for any given test weight measuring device and its significance is likely the result of the high number of observations analyzed.

Table 2. Head Type Differences in Test Weight.

Year	n (reps) Awned	n (reps) Awnless	Pr > F Test Wt.	Test Weight (lbs/Bu) Awned	Test Weight (lbs/Bu) Awnless
2008	19	50	**0.0001**	**59.5**	**58.2**
2010	28	49	0.2520	58.1	57.8
2011	48	52	**0.0390**	**57.0**	**57.6**
2012	55	49	**0.0620**	**59.8**	**60.2**
2013	55	44	**0.0072**	**57.6**	**58.4**
2014	64	48	0.7945	58.9	58.9
2015	71	32	0.7737	60.1	60.1
2016	64	29	**0.0117**	**57.5**	**58.2**
2017	68	35	**0.0720**	**58.4**	**58.7**
2018	61	23	0.7140	57.6	57.7
	533	411	**0.0115***	**57.9***	**58.1***

* Relative Adjusted Test Weight 2008-18 (excluding 2009).

Among individual years, test weights for awnless varieties was significantly greater in five (2011, 2012, 2013, 2016, 2017) of the ten years. These findings are in contrast to the bulk of the literature which indicated that awned lines generally have higher test weight. In 2008, awned types did have higher test weight, and there was no difference in the other four years. As with the yield data, there were no consistent environmental factors, nor differences in the length of reproductive growth period that would account for the reported difference in test weight. It is not clear why these current findings are not consistent with that which has been reported in the literature, but this may be an artifact of the breeding programs and not necessarily related to awns.

Awned varieties were significantly shorter than awnless varieties (Table 3). Across the 10 year period, awnless varieties were 1.6 inches taller (36.6 vs. 35.0). Significant differences for height were observed in 8 of the 10 years, with no difference in the other two years. It cannot be determined if this is a result of awnedness or a result of breeding. It is possible, though speculative that awnless forage wheats were bred to be taller to potentially yield greater plant biomass.

Lodging was observed in 8 of the 10 years. In four of the eight years where lodging occurred, the taller, awnless lines had significantly higher levels of plant lodging (Table 3). It is not clear whether lower levels (25% - data not shown) of lodging among awned varieties is directly related to the shorter plant stature or that the awns intertwine and add communal structural support for neighboring plants, thus there is no clear picture to draw conclusions.

There was no difference in heading date between awned and awnless varieties (Table 3).

Table 3. Head Type Differences in Plant Height, Heading Date and Lodging.

	n (reps)		Pr > F	Height (in)		Pr > F	Pr > F
Year	Awned	Awnless	Height	Awned	Awnless	Heading Date	Lodging (%)
2008	19	50	**0.0002**	**35.5**	**37.4**	0.8390	0.2919
2010	28	49	**0.0053**	**33.7**	**35.2**	0.1970	0.9413
2011	48	52	**0.0092**	**35.8**	**36.7**	0.4892	**0.0123**
2012	55	49	**0.0001**	**34.5**	**37.1**	0.3742	**0.0044**
2013	55	44	**0.0001**	**37.9**	**40.2**	0.7233	**0.0001**
2014	64	48	**0.0001**	**34.6**	**36.8**	0.1326	**0.0011**
2015	71	32	**0.0001**	**34.5**	**35.8**	0.0625	n/a
2016	64	29	**0.0234**	**37.2**	**38.0**	0.4775	n/a
2017	68	35	0.8996	34.8	34.9	0.3070	0.6420
2018	61	23	0.4720	31.8	32.1	0.1010	0.5503
2008-18*	533	411	**0.0001**	**35.0**	**36.6**	**0.3183**	**0.0019**
*excludes 2009							

The trend of varieties in the variety test changing from primarily awnless head types in 2008 to primarily awned types in 2018 was noteworthy (Table 1). It is not clear why there was a dramatic shift in head type over the period. Varieties tested in the variety trial are submitted from multiple public and private breeding programs. Over the past decade, there has been much effort to increase resistance to Fusarium Head Blight (FHB) in wheat. Identification of FHB resistant genes and utilization of molecular marker technology has resulted in Fusarium Head Blight resistance being bred into a majority of modern wheat varieties. It is possible that the awned head-type trait may be linked to the FHB genes bred into modern varieties, thus accounting for the dramatic increase in awned varieties during the duration of the study. Wheat breeders, however suggest (personal communication) that there was probably no gene linkage between these 2 traits.

In summary, evaluating agronomic differences in soft red winter wheat head types across 10 years of variety trial data showed that awned varieties tended to have higher yield than awnless lines. Awnless lines had higher plant height and lodging than awned head types, and slightly higher test weight, which was contrary to what the literature reported. It is not clear why the proportion of soft red wheat varieties tested changed over the ten year period from a majority being awnless to a majority being awned. With the advantages of awns for wildlife protection and potential for increased yields and reduced lodging, soft red winter wheat growers should consider factoring in awnedness as part of variety selection decision.

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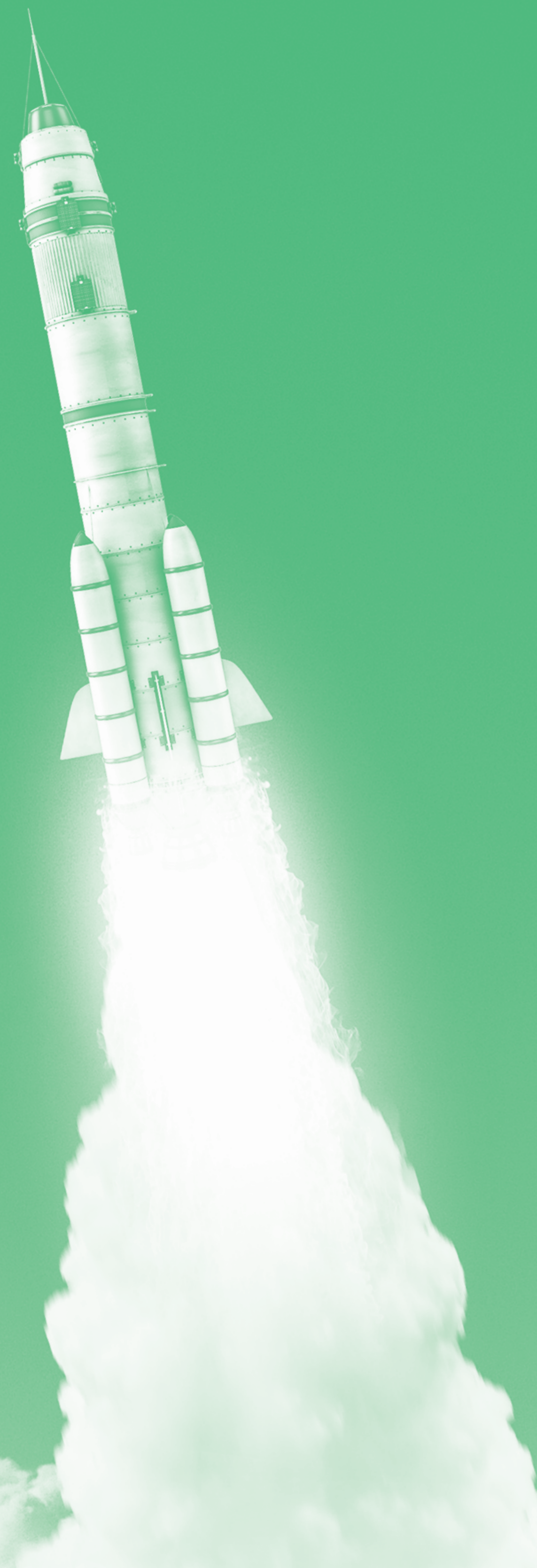

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