Effects of Cultivar, Environment, and their Interaction on Seed Quality of Hard Red Winter Wheat from Production Fields[1]

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ABSTRACT

Seedling vigor and grain yield of wheat (*Triticum aestivum* L.) is influenced by the size and nitrogen content of the seed from which it is produced. We investigated the genetic and environmental factors affecting the size and composition of wheat seed samples from producers' fields in Kansas to identify ways in which wheat seed quality can be improved. One hundred seventy-one uncleaned seed samples of hard red winter wheat *(Triticum aestivum L.)* were obtained from approved seed conditioners in Kansas. Samples were evaluated for test weight and were separated into small, medium, and large fractions by screening. Nitrogen (N) and phosphorus (P) percentages and 200-kernel weight were recorded for each fraction of each sample. A linear function of seed quality variables (P1) developed by principal component analysis, was used as an overall index of seed quality. Mean 200-kernel weight and 200-kernel N weight (grams of N per 200 kernels) were highest for the large fractions and lowest for the small fractions. The reverse was true for N and P percentages. There were significant differences among cultivars for all seed quality variables. Cultivar x region interactions were significant for test weight and P1. In general, seed of highest quality was produced in western Kansas, though for some cultivars, eastern Kansas was optimum. For some cultivars, the improvement in seed quality resulting from production in an optimum region was as large as that resulting from screening. Effects of management of seed production fields on seed quality were small.

Additional index words: Seed cleanout percentage, kernel weight, kernel protein, least squares means, principal components.

INTRODUCTION

Seed quality strongly influences stand establishment, seedling vigor, and grain yield of wheat *(Triticum aestivum L)*. Vigor and grain yield can be influenced by kernel weight, kernel protein percentage and, perhaps most importantly, weight of protein per kernel (Paulsen, 1984; Kiesselbach, 1924; Grabe, 1976; Lopez and Grabe, 1971; Lowe and Ries, 1971; Taylor, 1928; Ries and Everson, 1973; Evans and Bhatt, 1977). The wheat seed industry considers large seed size an important factor in marketing certified seed (Lowell Burchett, Kansas Crop Improvement Association, personal communication). The size of wheat kernels depends on the cultivar, but is modified by environment and gentotype x environment interactions (Fjell et al., 1984).

Paulsen (1984) noted that the increased yielding ability of recent hard red winter wheat cultivars has been achieved partly by increasing the number of kernels per spike, with some decrease in mean kernel weight. He outlined the possible negative effects of this trend on wheat production in Kansas and recommended that wheat breeders consider kernel weight in the selection process.

Another strategy to decrease the impact of low seed size on wheat production would be to produce certified seed of each wheat cultivar in an environment that optimizes seed quality. The objective of this study was to evaluate hard red winter wheat seed samples obtained from approved seed conditioners in Kansas to determine the effects of cultivar, environment, and their interaction on quality and separation characteristics of seed from producers' fields. Such fields may be influenced by factors different from those affecting experimental plots.

MATERIALS AND METHODS

We requested that all Kansas approved seed conditioners provide five randomly obtained, uncleaned samples of wheat seed (2.3 kg). Each sample was to be accompanied by cultivar name and information regarding cultural practices under which the seed was produced. The latter information, which was not obtained for all samples, included the following variables: seeding date and rate and fertilizer rate (N, P, K). There are nine Kansas crop reporting districts:

Table 1. Mean percentage of wheat kernels falling into the large, medium, and small fractions, averaged over 171 samples, with mean 200-kernel weight, nitrogen and phosphorus percentages, and 200-kernel N weight of each fraction.

Fraction	Percentage of Sample	200-Kernel Weight	Nitrogen	Phosphorus	200-Kernel N Weight
		(g)	(%)	(%)	(g)
Large	66	7.7	1.95	0.37	0.12
Medium	19	5.9	2.01	0.41	0.09
Small	15	4.4	2.11	0.44	0.03
LSD.05		0.1	0.06	0.02	0.004

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Table 2. First principal component eigenvector (P1 coefficients) and correlation coefficients among four seed quality variables.

Variable	P1 Coefficients	Correlation with Percentage Large Kernels	Correlation with 200-Kernel Weight	Correlation with 200-Kernel N Weight
Test Weight	0.45	0.50**	0.56**	0.38**
Percentage large kernels	0.53		0.86**	0.44**
200-Kernel Weight	0.57			0.59**
200-Kernel N Weight	0.44			

** Significantly different from zero at the 1% level of probability.

three eastern, three central, and three western. The 171 samples, supplied by approximately 45% of all approved seed conditioners, were designated as originating in one of these three regions.

Subsamples were taken to determine test weights, then hand-screened with two screens (2.38 mm × 19.05 mm and 1.98 mm × 19.05 mm). Screening resulted in three seed fractions: large, medium and small. These fractions were weighed and large, medium and small seed percentages determined. From each seed size fraction, 200 kernels were counted and weighed. These 200-kernel samples were analyzed for nitrogen (N) and phosphorus (P) percentages. The samples were digested using the method of Linder and Harley (1942) and the total N and P were determined by colorimetric methods using a Technicon Auto-Analyzer (Anonymous, 1977). Two-hundred-kernel N weight was computed as (200-kernel weight) × (N percentage).

Statistical Analysis

Principal component analysis (e.g., Karson, 1982) transforms a set of p variables measured on a population into p uncorrelated linear functions of the original variables. The principal components are ordered according to the proportion of the total variation for which they account. We performed principal component analysis based on the correlation matrix of seed quality traits to obtain a score for overall seed quality.

Significance of variation among regions and cultivars and their interaction as well as variation among cultivars within regions was determined by analysis of variance based on generalized least squares, since cultivars were unequally represented in each region. We assumed that the covariance between cultivars and environments within regions was zero. Means of cultivars across regions and of regions across cultivars were least-squares estimates of marginal means, which are estimates of means that would be obtained if all cultivar-region combinations were equally represented.

The effects of seeding rate and date and nitrogen, phosphorus, and potassium fertilization within regions were determined using multiple regression analysis, which also included cultivar as an independent variable. Tests of significance were based on ratios of mean squares computed from partial sums of squares. Thus, effects were evaluated by the degree of reduction in sums of squares after all other variables were fitted.

RESULTS

Screening separated the samples into seed fractions with significantly different mean kernel weights and compositions (Table 1). The large and small fractions, respectively, displayed the lowest and highest nitrogen and phosphorus percentages. The large fraction had the highest 200-kernel N weight.

Principal component analysis was applied to data from the 171 samples using four variables related to seed quality: test weight, percent large kernels, whole-sample 200-kernel weight, and whole-sample 200-kernel N weight. The objective of the analysis was to find an overall score (P1) that accounted for most of the variation in seed quality among samples. Thus, information on several traits could be combined into a single indicator of seed quality. There were significant positive correlations among all four variables (Table 2). P1 accounted for 67% of the variation among samples for the four variables. The P1 score, (0.45 × test weight) + (0.53 × percent large kernels) + (0.57 × 200-kernel weight) + (0.44 × 200-kernel N weight), for standardized variables, was used as a seed quality index for each sample.

All quality factors except test weight varied significantly among cultivars (Table 3). Variation among regions (eastern, central, and western Kansas) was significant only for test weight and 200-kernel weight of the large fraction. Region × cultivar interaction was significant for test weight and the quality index P1.

Variation among cultivars was significant most often in eastern Kansas and cultivar variation was significant in all regions for 200-kernel N weight of whole samples and for 200-kernel weight of the large fraction (Table 4).

Cultivar and region means for seven variables, including P1, are presented in Table 5. Means for 200-kernel weight and 200-kernel N weight of the large fraction closely followed the corresponding whole-sample variables. On the average, higher quality seed was produced in western Kansas than in other regions (bottom of Table 5), though F-tests for regions were significant only for test weight and 200-kernel N weight of large seed. On the basis of P1, 'NK 835', 'Larned' and 'Eagle' ranked highest among cultivars for seed quality. The significant region × cultivar interactions for test weight and P1 are evident in Table 5. For example, P1 generally increased from east to west for most cultivars but decreased for 'Hawk', NK 835, and 'Triumph'. Though the interaction was nonsignificant for percentage large

Table 3. Analyses of variance for seven seed quality variables.

Source	df	Mean Squares						
		Test Weight	Percentage Large Kernels	200-Kernel Weight	200-Kernel N Weight ($\times 10^{-4}$)	Large 200-Kernel Weight	Large 200-Kernel N Weight ($\times 10^{-4}$)	P1
Regions	2	37.1*	250	1.66	4.67	1.16*	6.45	3.69
Cultivars	30	11.6	600**	1.42**	6.67**	1.14**	4.67*	6.19**
Regions × Cultivars	17	16.3*	370	0.73	2.59	0.32	3.34	2.76*
Residual	115	8.6	280	0.56	1.95	0.28	2.66	1.74

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

Table 4. Analyses of variance within regions of Kansas for seven seed quality variables.

Region	Source of Variation	df	Mean Square						
			Test Weight	Percentage Large Kernels	200-Kernel Weight	200-Kernel N Weight ($\times 10^{-4}$)	Large 200-Kernel Weight	Large 200-Kernel N Weight ($\times 10^{-4}$)	P1
Eastern	Cultivars	12	13.5*	1321**	2.20**	7.5**	1.06**	4.47	7.66**
	Residual	37	5.5	260	0.49	2.2	0.25	3.32	1.65
Central	Cultivars	21	17.0	404	0.93	3.3*	1.01**	4.87*	2.42
	Residual	47	14.5	284	0.60	1.7	0.29	2.21	1.98
Western	Cultivars	14	4.2	408	1.17	5.4*	0.72*	5.27*	2.75
	Residual	31	3.5	289	0.60	1.9	0.31	2.56	1.49

*Significant at the 5% level of probability.
**Significant at the 1% level of probability.

kernels and 200-kernel weight, it appears on the basis of these variables that seed quality of 'Newton', 'Vona', and 'PL 145' was highest in western Kansas and seed quality of Hawk, 'TAM 105', and Triumph was highest in eastern Kansas.

Effects of seeding rate and date and N-, P-, and K-fertilization of production fields were evaluated within the central and eastern regions. Fertilization was practiced too seldom in western Kansas for data to be utilized. Regression analysis showed no effect of cultural practices on any seed quality variable, with one exception: nitrogen fertilization increased 200-kernel N weight in eastern Kansas at the 5% significance level.

DISCUSSION

Seed production fields provide data on seed quality in environments that may differ considerably from experimental plots in the way they are sown, managed, and harvested. It would be premature, on the basis of survey data, to recommend that seed of particular cultivars be produced in particular regions of the state. However, the differential effects of region of production on seed quality of different cultivars suggest the need for experiments to determine optimum seed production areas for widely grown cultivars. For some cultivars, the optimum production area for seed quality may not coincide with the area of greatest yield potential. Newton, for example, is most adapted to eastern and central Kansas, but the highest-quality seed of Newton was produced in western Kansas (Table 5).

Our data indicate little about the effects of seeding rate and date or fertilization of seed production fields because of the sparse and erratic nature of the information on these factors.

Screening improved the quality of seed samples (Table 5; compare whole-sample and large-fraction 200-kernel weights). However, changing the seed production environment can result in similar improvements. For example, 200-kernel weight and 200-kernel N weight of Vona seed from eastern Kansas were improved by 1.2 and 0.02 g, respectively, by

Table 5. Means of seven seed quality variables for nine wheat cultivars in three regions of Kansas.

Cultivar	Region	No. Samples	Test Weight	Percentage Large Kernels	200-Kernel Weight		200-Kernel N Weight		PI
					Whole Sample	Large Fraction	Whole Sample	Large Fraction	
			kg/hl		g				
Newton	Eastern (E)	14	75.9	64	6.8	7.7	0.14	0.15	-0.29
	Central (C)	20	74.9	63	6.8	7.6	0.14	0.15	-0.40
	Western (W)	7	79.8	79	8.0	8.5	0.15	0.15	1.45
	Mean†	41	76.6	67	7.1	7.9	0.14	0.15	0.11
Vona	E	8	73.0	30	5.6	6.8	0.11	0.13	-2.99
	C	4	78.5	55	6.9	7.9	0.14	0.16	-0.16
	W	1	77.1	63	7.1	7.9	0.13	0.15	-0.06
	Mean	13	75.9	41	6.3	7.3	0.12	0.14	-1.58
Hawk	E	6	75.9	78	7.6	8.2	0.14	0.15	0.64
	C	9	73.2	71	7.6	8.4	0.15	0.17	0.49
	W	4	75.3	64	7.5	8.4	0.15	0.17	0.45
	Mean	19	74.8	73	7.6	8.4	0.15	0.16	0.63
PL 145	E	2	66.0	47	5.9	7.2	0.12	0.15	-2.68
	C	4	74.7	65	7.1	7.9	0.14	0.16	-0.04
	W	-	-	-	-	-	-	-	-
	Mean	6	72.8	61	6.9	7.8	0.14	0.15	-0.62
TAM 105	E	7	74.1	66	6.7	7.5	0.12	0.14	-0.83
	C	9	74.2	58	6.6	7.5	0.13	0.15	-0.89
	W	3	79.2	60	7.0	7.9	0.14	0.16	0.10
	Mean	19	75.5	62	6.8	7.6	0.13	0.14	-0.54
NK 835	E	2	78.2	84	7.6	8.1	0.16	0.17	1.49
	C	-	-	-	-	-	-	-	-
	W	2	79.3	80	7.5	8.1	0.15	0.16	1.14
	Mean	4	72.8	81	7.5	8.1	0.15	0.16	1.21
Triumph	E	3	77.4	89	7.4	7.7	0.15	0.16	1.29
	C	4	71.5	77	7.0	7.6	0.15	0.16	-0.06
	W	-	-	-	-	-	-	-	-
	Mean	7	76.0	84	7.4	7.8	0.15	0.16	0.85
Eagle	E	-	-	-	-	-	-	-	-
	C	1	80.0	85	7.7	8.1	0.14	0.15	1.38
	W	10	78.8	83	7.9	8.3	0.16	0.16	1.71
	Mean	11	77.1	80	7.5	8.1	0.15	0.15	1.07
Larned	E	-	-	-	-	-	-	-	-
	C	3	78.4	81	7.8	8.3	0.14	0.15	1.12
	W	6	78.4	78	8.1	8.8	0.16	0.17	1.72
	Mean	9	77.4	77	7.8	8.4	0.15	0.16	1.13
Mean†	E	42	75.3	68	6.7	7.4	0.13	0.15	-0.38
	C	54	75.3	67	6.9	7.6	0.14	0.15	-0.10
	W	33	78.4	72	7.4	8.0	0.15	0.16	0.81

†Least-squares estimates of marginal means

screening, but a mean of 70% of the seed was discarded in the process (i.e., mean percentage large seed was 30). The same improvement was accomplished by producing Vona seed in central or western Kansas before screening (Table 5). Thus, for each cultivar, seed production in an optimum area under good management may be the most efficient way to obtain superior seed quality with minimum loss during cleaning.

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