Seed Quality of Hard Red Wheat Damaged by Frost during Maturation

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ABSTRACT

Late frost during maturation of winter wheat (*Triticum aestivum* L.) may decrease seed quality. Wheat growers in Kansas were particularly concerned whether seed damaged by frost during 1992 was suitable for planting. This study was conducted to evaluate the seed quality and performance of frost damaged seed lots. Eleven seed lots of cv. TAM 107 with a range of test weights were sized, quality was measured by seed size and weight, seed performance was measured by germination and accelerated and natural ageing, and seedling performance was measured by emergence from different planting depths. Frost damage decreased test weight and the percentage of large seeds and increased the percentage of small seeds. Germination after harvest and ageing was high for large seeds, regardless of degree of frost damage to the seed lots, whereas germination of small seeds decreased as frost injury increased. Emergence of seedlings was also high from large seeds and low from small, damaged seeds. Quality of seed damaged by frost during maturation could be increased by cleaning to remove small seeds, or higher sowing rates could be used to compensate for small seeds. Frost damaged seed can be stored without further deterioration.

Additional index words: seed weight, seed ageing, seed storage, seedling emergence, test weight.

INTRODUCTION

Germination and seedling vigour are affected greatly by weather conditions during maturation of wheat seed (Schlehuber and Tucker, 1967). Unfavourable weather may decrease the suitability of harvested seed for planting and diminish establishment of productive stands (Paulsen, 1987). Wheat in northwestern Kansas was damaged by temperatures of -2 to -4°C for several hours between 25 and 29 May 1992. The growth stage of the crop ranged from 10.5.4 (flowering completed) to 11.3 (hard dough) (Feekes scale). Damage to seeds and, consequently, to yield ranged from slight to severe. The suitability of this seed for sowing the succeeding crop was unknown, and little information was available in the literature for guidance.

Growers were advised to check the germination of seed from frost injured plants and to avoid using seed that was shrivelled or had low test weight (Paulsen, Heyne and Wilkins, 1982). However, this advice was based on general considerations of seed quality, because specific characteristics of frost damaged seeds were unknown. The only experimental results available were from a Canadian spring wheat study (Shebeski, Banting and Wu, 1951), where wheat injured by frost was classified in four categories: A-sound seeds, no frost damage; B-bran frost damage only; C-deep seated frost damage, seeds with or without slight shrivelling and usually dark coloured with a fairly high test weight; and D-shrivelled or shrunken seeds with a low test weight. Increasing severity of frost damage progressively decreased the test weight and germination of seeds and emergence of seedlings (Shebeski *et al*, 1951).

The objective of this study was to investigate the suitability of frost-damaged seed for planting. Naturally frosted seed was used from production fields. The severity of frost damage was estimated by test weight, and performance of the seed was ascertained after accelerated and natural ageing and under adverse planting conditions. Parts of the study were reported in a popularised publication for wheat producers (Foster, Burchett and Paulsen, 1997).

MATERIALS AND METHODS

Sample Selection

Uncleaned seed lots for this study, each approximately 4.5 kg, were collected from certified seed producers from the northwestern Kansas counties of Cheyenne, Decatur, Rawlins, Thomas and Wallace in July 1992. Eleven seed lots were selected to cover a range of test weights, the major criterion for severity of frost injury (Shebeski *et al.*, 1951). Other factors that might affect test weight, such as diseases and drought, were largely absent from the area. A sample of sound wheat from Wallace County that had a high test weight (800 kg m^{-3}) appeared to be unaffected by frost was used as the control. Only the cultivar TAM 107, the most widely grown in the region, was used to avoid interactions with genetic effects.

Seed Characterisation

Test weight was measured on four replicates (subsamples) of each seed lot by methods described in the Federal Grain Inspection Handbook (Anon., 1990).

Seed lots contained a range of seed sizes and were sized with 2.4x9 mm (6/64x3/4 in.) and 2.0x9 mm (5/64x3/4 in.) slotted screens. Portions of the seed lots from each screen size were weighed, and the percentages calculated.

Seed Performance

Germination percentage of each seed size in all seed lots was determined on four replicates of 100 seeds. Samples were prechilled at 5°C for 5 days to break dormancy and then held at 20°C for 7 days on moistened, heavy-weight germination paper (Anchor Paper, St. Paul, MN). Samples were evaluated for normal and abnormal seedlings and nonviable seeds (AOSA, 1990). Germination was measured similarly after the seed was stored at room temperature for 15 months, except that the prechilling period was omitted.

Accelerated ageing tests were conducted on all seed lots using a time and temperature combination of 72 h at 41°C (AOSA,

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accelerated ageing and prechilling, germination tests were conducted as described above.

Seedling Performance

Emergence studies were conducted under greenhouse conditions (22-27°C, 40-75% RH). The growth medium was masonry sand in 28 x 20 x 11-cm opaque acrylic boxes (Tri-State Plastics, Dixon, KY). Four replications of 25 seeds from each seed size per seed lot were sown at 2.5, 5.1, 7.6, and 10.2-cm depths. The sand was moistened as needed, and emerged seedlings counted twice weekly.

Statistical Analyses

Randomised complete block designs were used in all parts of the study. Data were analysed by analyses of variance (ANOVA) (SAS, 1989) and means were compared by least significant differences (P = 0.05).

RESULTS

Seed Characteristics

Test weight ranged from 800 kg m^{-3} (62.2 lbs bu^{-1}) to 664 kg m^{-3} (51.6 lbs bu^{-1}) before the seed lots were sized, indicating wide variation in frost injury (Table 1). Percentages of large seeds usually declined and percentages of small seeds generally rose as severity of frost injury increased and test weight decreased. No trend in distribution of percentages of medium seeds was evident. Weights of large and medium seeds paralleled the decrease in test weights in most instances.

Medium seeds varied more in germination than large seeds after harvest, and a general trend of low viability of samples with low test weight was evident (Table 2). Overall germination of medium seeds fell by similar amounts (5%), after accelerated ageing and natural ageing. However, some seed lots declined more than others, with little apparent relationship to the severity of frost injury. Two of them - those with test weights of 677 and 709 kg m^{-3} - had particularly low germination after harvest and accelerated or natural ageing. The same seed lots also had low kernel weights (Table 1).

Germination of small seeds was below 90% for all seed lots after harvest, and was particularly low for those that had low test weight (Table 2). Mean germination of all seed lots was reduced 7% by accelerated ageing and nearly 2% by natural ageing. The results suggested that performance of frost-injured seed lots was adversely affected by two concurrent trends, an increase in the proportion of small seeds (Table 1), and a decrease in the germination percentage of those seeds (Table 2).

Seedling performance

Emergence of seedlings from large seeds varied significantly among some seed lots but was always high regardless of test weight or sowing depth (Table 3). Emergence of seedlings from medium seeds also varied significantly among seed lots and especially among sowing depths. Medium seeds of high test weight produced seedlings that emerged well regardless of sowing depth, whereas medium seeds of low test weight produced seedlings that always emerged poorly. The same trend occurred in seedlings from small seeds, which had lower overall emergence and were affected even more adversely by deep sowing as test weight decreased.

Table 1: Test weight before sizing, and the percentage and seed weight distribution after sizing of control and frost-damaged seed lots of wheat cv. TAM 107 retained above a 2.4x19 mm² (large seeds) screen, above a 2.0x19 mm³ (medium seeds) screen, and passed through a 2.0x19 mm (small seeds) screen.

County	Test wt. kg m^{-3}	Above 2.4x19 mm	Above 2.0x19 mm	Below 2.0x19 mm	Seed weight, mg $seed^{-1}$		
		--------	---%---	--------	Large	Medium	Small
Wallace[1]	800	60	26	14	42	27	17
Thomas	786	72	19	9	41	26	16
Thomas	772	65	28	8	36	25	18
Cheyenne	764	54	34	12	35	24	16
Thomas	752	75	14	11	46	24	16
Thomas	732	68	18	14	39	24	12
Decatur	726	57	31	12	37	25	17
Rawlins	709	54	21	25	35	20	12
Thomas	694	59	19	22	36	21	12
Thomas	677	50	29	21	36	19	14
Thomas	664	46	22	33	34	19	12
LSD P<0.05	12	7	3	6	1	1	2

[1] Non-frosted seed used as control; [2] = 6/64x3/4 in; [3] = 5/64x3/4 in

Seed Performance

Germination percentage of large seeds was high and varied only slightly after harvest regardless of the test weight of the seed lot (Table 2). Accelerated ageing decreased mean germination of large seeds by 5% but the magnitude of the change differed somewhat among seed lots. Natural ageing decreased mean germination by only 3%.

DISCUSSION

Two effects, a marked increase in the proportion of small seeds and a decrease in their viability, were associated with frost injury during maturation. These effects have important implications for use of frost-damaged wheat for seed.

Table 2: Germination of large, medium, and small frost-damaged wheat seeds after harvest, after accelerated ageing, and after natural ageing.

Test wt. kg m^{-3}	Seed Size: Large			Medium			Small		
	Germination %								
	1[1]	2[2]	3[3]	1	2	3	1	2	3
800	98	95	97	98	91	97	83	76	85
786	98	84	95	93	70	85	46	21	51
772	98	95	96	98	94	89	87	70	84
764	99	99	99	97	94	87	75	76	79
752	94	81	88	73	73	71	51	47	54
732	94	92	86	92	91	83	61	49	38
726	94	88	88	86	68	84	39	34	39
709	95	92	93	57	64	43	18	8	12
694	96	94	97	82	88	93	23	22	27
677	94	85	94	49	50	50	18	29	21
664	98	96	88	76	62	63	19	11	11
LSDP<0.05	2	7	2	7	9	3	9	7	4

[1] 1 = germination after harvest.
[2] 2 = germination after accelerated ageing at 41°C for 72h.
[3] 3 = germination after 15 months storage under ambient conditions.

Table 3: Percentage emergence of seedlings from frost-damaged wheat seeds cv. TAM 107 at four different sowing depths.

Test wt kg m^{-3}	Sowing depth cm	Seed Size: Large	Medium	Small
		Emergence %		
800	2.5	95	94	83
	5.1	94	92	77
	7.6	95	91	78
	10.2	97	92	69
786	2.5	94	90	51
	5.1	92	87	53
	7.6	92	86	57
	10.2	90	86	30
772	2.5	97	95	81
	5.1	95	87	76
	7.6	97	96	82
	10.2	94	82	72
764	2.5	97	95	79
	5.1	93	93	72
	7.6	97	98	62
	10.2	93	94	58
752	2.5	89	73	48
	5.1	91	70	50
	7.6	87	67	43
	10.2	94	60	31
732	2.5	95	92	45
	5.1	93	89	44
	7.6	94	90	41
	10.2	91	75	41
726	2.5	93	90	52
	5.1	92	82	49
	7.6	93	87	59
	10.2	82	78	44
709	2.5	94	58	23
	5.1	94	54	16
	7.6	90	50	8
	10.2	86	44	4
694	2.5	91	75	30
	5.1	91	85	29
	7.6	91	70	23
	10.2	91	56	16
677	2.5	92	57	35
	5.1	89	42	26
	7.6	91	58	25
	10.2	92	50	23
664	2.5	96	68	23
	5.1	97	64	14
	7.6	98	58	10
	10.2	95	59	10
LSDP<0.05	2.5	5	12	8
	5.1	5	10	9
	7.6	2	6	7
	10.2	3	6	6

the seven seed lots that had test weights of 720 kg m^{-3} (56 lbs bu^{-1}) and above met requirements for certification (Kansas Crop Improvement Association Certification Standards, 1992) and recommendations for planting (Paulsen, 1987). These seed lots, as represented by their proportional composition of large, medium and small seeds, had high germination percentages and excellent seedling emergence. Two seed lots, those with test weights of 677 and 709 kg m^{-3}, exemplified the hazards of using seed lots below the benchmark of 720 kg m^{-3}. Unduly low germination of medium seeds from those seed lots suggested that frost damage exceeded the level indicated by the low test weight. Poor germination of these medium seeds was associated with low seed weight and resulted in generally depressed emergence from most sowing depths.

Seed lots with substandard test weights could be sized to remove damaged seeds to achieve high germination and emergence levels. Large seeds performed well regardless of the level of frost damage to the seed lot as a whole. They also were equally resistant to the effects of ageing. Alternatively, damaged seed lots might be used directly by increasing sowing rates to compensate for the smaller seeds (Kiesselback, 1924). However, the yield potential might be less for plants from small seeds than for plants from large seeds (Schlehuber and Tucker, 1967).

Sizing or increasing sowing rates to remove or compensate for small seeds is possible because frost injury was selective, affecting some seeds but leaving others in a largely undamaged condition. This selectivity probably was associated with differences in maturity among spikes or among seeds within spikes. Vulnerability of wheat to frost injury is highest at anthesis and decreases as the grain fills and its moisture content diminishes (Paulsen *et al.*, 1982). Seeds in spikes of late tillers and seeds at the ends of spikes of normal tillers were probably immature and sensitive to frost, whereas mature seeds were unaffected.

The need for caution when sowing frost-damaged seed under adverse conditions, represented in our study by deep placement, was evident. Adverse conditions place added stress on seedlings and decrease emergence and stand establishment (Shebeski *et al.*, 1951; Paulsen, 1987). Small seeds such as those resulting from frost damage, also produce seedlings with short coleoptiles that might not reach the soil surface (Schlehuber and Tucker, 1967).

The nearly constant germination percentages of all seed lots after harvest, after ageing for 15 months, and after accelerated ageing, suggested that frost-damaged wheat seed could be stored without further deterioration in quality. Germination of large seeds was particularly stable, regardless of the degree of frost injury to the seed lot.

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