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Can a white wheat become red? Depends where it's grown!

Summary **A new class of hard white spring wheat, Canada Western Hard White Spring (CWHWS), has been introduced to the western Canadian Prairie region. Under certain growing conditions, the white seed coat can become sufficiently red as to cause difficulty in distinguishing this white class from the red spring (CWRS) class. This could have serious implications in visual grading, and pricing of wheat at the time of delivery, and on the long-term integrity and marketing of the CWHWS (and CWRS) class.**

Genotypes appear to vary in their susceptibility to this phenomenon. Stability in seed coat colour to local growing conditions should be a factor in selection during breeding of the CWHWS class of spring wheat. The "degree of whiteness" can be determined by near-infrared spectroscopy (NIRS), using the visible-near-infrared wavelength range. This range is the same wavelength as that used by the protein-testing NIRS instruments at grain receiving and shipping points. Consequently, colour could be determined by NIRS simultaneously with protein and moisture contents simply by adding appropriate calibrations to existing instruments.

The prevalent wheat classes grown in the major wheat-producing countries of the world are of red seed-coat colour. In these countries, wheat production is dominated by hard red winter wheat, although significant volumes of hard red spring and soft red winter types are also grown. While the predominant class of wheat grown in western Canada is hard red spring (Canada Western Red Spring, CWRS) wheat, there is increasing interest in the promotion of a hard white spring wheat. Although other countries produce some white wheat, Australia stands alone as the major global producer.

White wheat types are capable of matching red wheats in all quality parameters. They tend to be preferred by millers in regions where wheat is milled to high extraction (80 % or higher), because the presence of increasing amounts of bran imparts less colour to the flour and processed doughs than do particles of bran from red wheats. The market potential of hard white wheats

Figure 1. Represents the variation in colour in one genotype of CWHWS grown in two different locations in the same year

of good and consistent processing quality is likely to increase, as the demand for wheat rises in Third World countries, where wheat is frequently milled to high extraction.

Visual evaluation of 90 advanced plant breeders' lines of CWHWS wheat, harvested in 1997, indicated that some of the lines were not truly "white", in the same sense as is Canada Western Soft White Spring (CWSWS) wheat. The 90 lines displayed degrees of whiteness (e.g., Fig. 1). It appeared that there was an interaction between growing location and genotype, to the extent that the seed-coat colour of some of the CWHWS lines approached that of CWRS wheat. Some randomly-selected samples of the 90 lines were actually graded as CWRS wheat by a senior grain inspector. This phenomenon, and the possibility of difficulty in differentiating between the two classes by visual inspection alone could affect grading and pricing of wheat at receiving and shipping points. This in turn could affect the long-term integrity of both CWRS and CWHWS classes of western Canadian wheat. The purpose of this article is to record the occurrence of this singular genotype/environment interaction.

Experimental

The work was carried out at the Canadian Grain Commission's Grain Research Laboratory in Winnipeg. Samples of hard white spring lines were supplied by breeders at Agriculture and AgriFoods Canada Cereal Research Centres at Winnipeg, Manitoba, and Swift Current, Saskatchewan. The 1997 lines were advanced lines grown at six locations (Portage la Prairie, Morden, and Brandon, Manitoba, and Melfort, Indian Head and Swift Current, Saskatchewan). Four CWRS standard varieties were grown as checks at all locations. The 1998 lines were of the F2-derived F4 and F3-derived F5 generations and were grown at three locations (Indian Head and Swift Current, Saskatchewan and Lethbridge, Alberta).

Kernel colour parameters were determined on whole wheat kernels using a Minolta Chromometer (Konica Minolta Business Solutions (Canada) Ltd., Mississauga, Ontario). Values were recorded for L* (brightness), a* (red/green), and b* (blue/yellow). Both L* and b* values appeared to be correlated with the visual appearance of the samples. Visual appraisal showed that the a* values bore a less clear relationship to the actual colour of the kernels than did the L* and b* values. The L* and b* values were closely correlated with each other (r^2 = 0.93). The a* values were not highly correlated with either the L* or b* values and were not considered further.

Samples (100g) of the intact kernels were scanned in a Foss/NIRSystems Model 6500 Visible/Near-infrared scanning spectrophotometer (Foss NIRSystems, Laurel, MD). The rectangular sample cell was used in ¾-full mode. Calibrations were developed for the prediction of L* and b*. In this study, both L* and b* values were used as an estimate of the "degree of whiteness". Software used was WinISI version II/1.50 (Infrasoft International, State College, PA). Wavelength range was 570 – 1098 nm, and the raw log 1/R spectral data were used with no mathematical pretreatments.

Results and Discussion

Degree of "whiteness". Results for the determination of colour (Minolta L* and b* values) are summarized in Table 1, which also gives the range within a variety or line. The higher the Minolta values, the greater is the degree of whiteness. The overall ranges in individual values among both CWRS and CWHWS wheats were from 55.2 and 20.2 respectively for L* and b* (white) to 47.0 and 14.1 (very red).

Table 1. Average L* and b* values for CWRS and CWHWS wheat classes

Genotype	L*					b*				
	High	Low	Mean	SD	CV %	High	Low	Mean	SD	CV %
AC Barrie	51.8	48.6	50.26	1.26	2.50	16.3	15.1	15.63	0.48	3.07
AC Domain	51.5	47.0	49.35	1.66	3.37	16.5	14.1	15.26	0.80	5.26
Katepwa	53.0	48.2	51.02	1.99	3.91	16.6	14.5	15.68	0.85	5.43
Roblin	53.0	48.2	50.96	1.80	3.53	16.5	14.2	15.57	0.88	5.63
Mean CWRS[1]	**52.32**	**48.00**	**50.42**	**1.68**	**3.33**	**16.48**	**14.48**	**15.55**	**0.75**	**4.85**
Varieties LSD (P = 0.05) = 0.74						LSD (P = 0.05) = 0.30				
RL 4860	53.3	49.2	51.39	1.53	2.98	19.2	15.8	17.57	1.25	7.09
RL 4859	54.2	50.6	52.49	1.34	2.58	19.2	16.3	18.13	1.15	5.17
RL 4875	55.2	51.4	53.05	1.43	2.71	19.6	16.4	18.10	1.10	6.11
RL 4874	54.3	50.4	52.42	1.45	2.77	19.8	16.2	18.20	1.27	6.96
RL 4867	55.2	50.5	53.10	1.87	3.53	20.0	16.5	18.21	1.20	6.60
RL 4866	54.5	50.6	52.68	1.50	2.85	19.4	16.7	18.02	0.99	5.33
RL 4869	54.4	51.1	52.57	1.26	2.40	19.9	16.7	18.65	1.08	5.80
RL 4862	53.5	50.5	52.25	1.20	2.29	19.4	16.7	18.04	0.91	5.04
RL 4864	54.8	50.6	53.14	1.60	3.01	20.2	17.1	18.60	1.05	5.62
RL 4872	54.4	50.8	52.81	1.60	3.01	19.9	17.2	18.71	1.01	5.42
RL 4873	54.6	50.7	52.89	1.39	2.64	19.4	16.4	18.26	0.99	5.46
Mean CWHW	**54.42**	**50.59**	**52.66**	**1.47**	**2.80**	**19.64**	**16.54**	**18.21**	**1.05**	**5.77**
Genotypes LSD (P = 0.05) = 0.66						LSD (P = 0.05) = 0.38				

1. CWRS = Canada Western Red Spring; CWHWS = Canada Western Hard White Spring; SD = standard deviation; CV % = coefficient of variability.

The CWHWS lines were more variable in seed-coat colour than were the CWRS varieties. Based on the Minolta data, the average degree of whiteness was clearly different and whiter than that of the CWRS varieties. While the mean L* values of the CWHWS lines were comparable with the highest values for CWRS varieties, the lowest L* values of the CWHWS samples were all lower than the highest values, and comparable to the mean L* values of the CWRS samples. The mean of the lowest b* values for CWHWS samples was comparable to the highest b* values of the CWRS varieties. On the basis of these data, the L* values appeared to be the most suitable for identification of CWHWS lines that could cause problems in grading, due to the sensitivity of seed-coat colour to growing conditions.

Influence of growing location. The CWHWS lines differed in both mean L* and b* values and in the variability over the six locations. Table 2 gives the ranking by growing location, according to Duncan's multiple range test, and Figures 2 and 3 show the impact of growing location on the seed-coat colour (Minolta values). The CWRS varieties also differed in degrees of redness, depending on where they were grown, and followed the same trend as the CWHWS lines (data not shown).

Table 2. Ranking of 1997 material by location according to Duncan's multiple range test

Location	L*	Location	b*
Swift Current	54.38a	Swift Current	19.64a
Morden	53.37b	Indian Head	18.88b
Brandon	53.16b	Brandon	18.40c
Indian Head	52.97b	Morden	17.93d
Portage	50.99c	Melfort	17.84d
Melfort	50.91c	Portage	16.54e

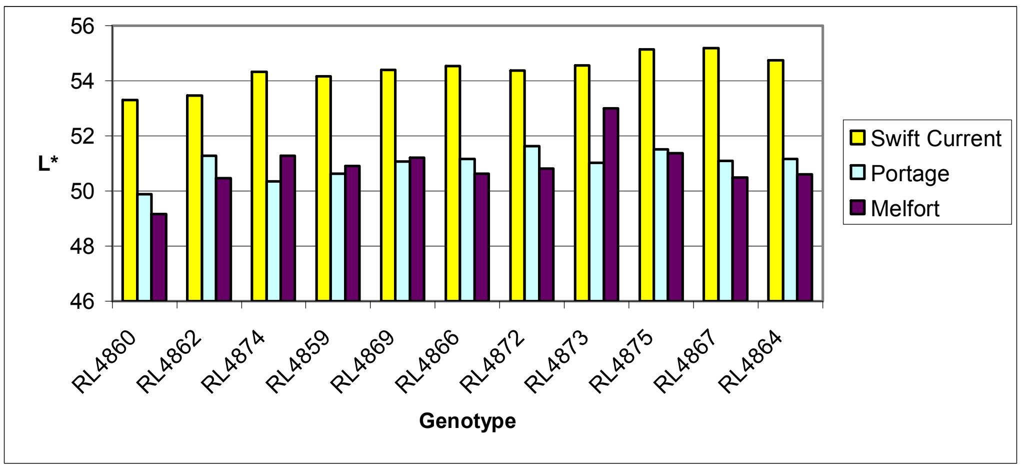

Figure 2. Influence of growing location on Minolta L* of CWHWS genotypes

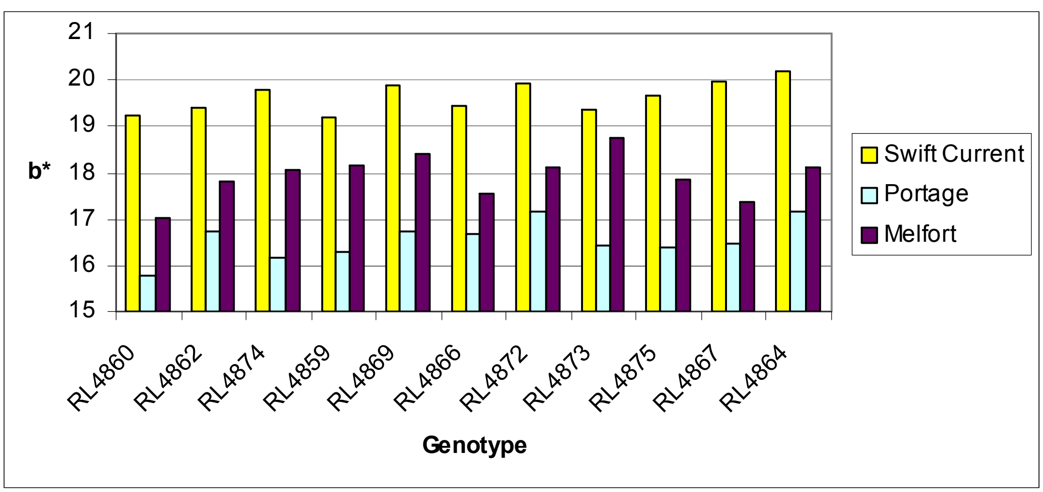

Figure 3. Influence of growing location on Minolta b* of CWHWS genotypes

Prediction of degree of whiteness (L* and b*) values by NIR spectroscopy.

Minolta values were predicted in samples of CWHWS wheat from the 1997 and 1998 growing seasons by NIRS. The 1998 data were derived from nearly 1000 lines from earlier generations of the CWHWS breeding programme in Swift Current, SK, grown on three locations (Indian Head and Swift Current, Saskatchewan and Lethbridge, Alberta). The samples were genetically different from the 1997 samples, but differences among the three locations were statistically significant from one another.

McCaig et al (1993) demonstrated that near-infrared spectroscopy (NIRS) can be used to differentiate between seed coat colour among wheat types. In the present study, NIRS calibrations were developed for the prediction of the degree of whiteness, based on the Minolta L* and b* values. Most of the wheat receiving and shipping points in western Canada (including the terminal elevators on the west coast) use Foss Infratec NIR transmittance instruments for the determination of protein content for segregation. This instrument operates in transmittance mode over the wavelength range of 570-1098 nm. A calibration for prediction of seed-coat colour would be most useful if the calibration could be developed over the same wavelength range as the Infratec. Calibrations for prediction of kernel colour were developed over the range of 576-1098 nm in reflectance mode. Earlier work (Williams and Sobering 1993) had shown that similar results could be achieved for a range of commodities and constituents, using either reflectance or transmittance. Table 3 summarizes the results of prediction of L* and b* values in the samples from 1997, 1998 and in samples from the two years combined.

Table 3. Prediction of Minolta L* and b* values, using NIR spectroscopy

Year	L*					b*				
	r^2	SEP	RPD[1]	Bias	SET[2]	r^2	SEP	RPD[1]	Bias	SET
Wavelength range 576-1092 nm: log 1/R										
1997	0.963	0.389	5.00	0.112	0.255	0.950	0.365	4.45	0.026	0.116
1998	0.989	0.430	8.40	0.013	0.241	0.985	0.312	8.13	-0.046	0.219
1998[3]	0.989	0.478	7.31	-0.360		0.953	0.575	4.41	-0.971	
1997/8[4]	0.977	0.447	6.50	0.076		0.955	0.458	4.71	0.038	

1. RPD = ratio of standard deviation of reference data to SEP. Values of >5 are suitable for any application
2. SET = standard error per test
3. Prediction of 1998 b* values, using 1997 calibration
4. Predicting combined 1977 and 1978 samples using calibration based on both years.

In both years, the SEPs were lower than the LSD values between lines or locations. The standard error per test for L* was 0.255, and for b* 0.116 units in 1997, changing to 0.241 (L*) and 0.219 (b*) for the 1998 samples. The value of using NIRS, as distinct from the Minolta instrument, which consumes about the same time per test, is that by using NIR spectroscopy it is possible to predict protein and moisture contents and Minolta colour factors simultaneously.

Conclusions

Considerable variability has been demonstrated in the seed coat colour of wheat genotypes submitted from two Canada Western Hard White Spring wheat breeding programmes. A highly significant effect of growing location on the degree of whiteness of the seed-coats was observed. These factors should be taken into consideration during development of advanced lines of Hard White Spring wheat.

Table 2 showed that individual CWHWS lines differed considerably in the variability among growing locations. This emphasized the importance of testing the reaction of potential CWHWS lines to the influence of growing location. Lines showing excessive variability in seed-coat colour should be discarded before the advance testing stage. The implication of these data is that certain areas of the Prairies may be more suitable than others for the future growing of CWHWS wheat. Should this type of material enter the statutory grades of western Canadian wheat, it could cause serious confusion in assigning grades (and prices) at both Primary and Terminal elevators. This could affect customer confidence in the integrity of both the CWRS and CWHWS wheat classes.

Seed-coat colour can be established with precision using NIRS instruments using the same wavelength range as the range used for the determination of protein content. The simultaneous determination of protein content and seed-coat colour would be particularly useful at wheat receiving and shipping points. This capability can be realized simply by adding appropriate calibration models to existing NIRS instruments at grain handling points.

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