Read the following article and take the exam to become eligible for one Crop Management Continuing Education Unit for the Certified Crop Advisor Program.

The Effect of the Environment on the Grain Colour and Quality of Commercially Grown Canada Hard White Spring Wheat, *Triticum aestivum* L. 'Snowbird'

One of the most pressing problems in the development of hard white spring wheat for western Canada is the issue of kernel colour variation in grain grown in different environments. A major aspect of registration and grading in Western Canada is the use of visual distinguishability with each class of wheat having a specific size, shape, colour and appearance and similar end-use performance. It is imperative that new varieties developed for the Canada Western Hard White Spring wheat class (CWHWS) appear white regardless of the environmental conditions under which they are grown. Interest in hard white wheat is primarily from international customers, particularly in the Asia-Pacific region. Australian white wheat is a benchmark for seed coat colour in these regions and the darker seed may be viewed as a detriment. Results have shown that there is extreme variability in kernel colour of white-seeded varieties when they were grown over multiple years and locations. White-seeded varieties can range from very white and pasty or chalky to dark gray and reddish in colour and vitreous in appearance making them hard to distinguish between soft white and hard red wheat. Visual grain colour may also be affected by variations in other grain traits such as protein content, hardness, vitreousness and kernel shape and size, which may further complicate the grain colour variation issue.

One of the main quality advantages of hard white wheat compared with red wheat is their lighter and brighter grain colour. Flour colour is affected by two components, bran colour and endosperm colour, which in turn affect end-product colour along with interactions that occur during processing.

In this study we aim to document the quality variation in commercial samples of the Canadian hard white wheat, Snowbird. The emphasis of the study was on the influence of the environment on the grain colour and its impact on the wheat grade.

MATERIALS AND METHODS

Materials

More than 1,100 commercial samples of the hard white wheat cultivar, Snowbird, were collected in the 2003 through 2007 crop years. A combination of province and provincial crop insurance risk/growth zones were used to define the growing areas or agro-climatic zones. Grain was delivered to a total of 58 elevators distributed over 18 agro-climatic zones. The elevator locations were categorized by degrees of latitude and longitude and by elevation. Fig. 1 describes the elevator locations with respect to physical location coordinates, number of years of delivery and their division into appropriate agro-climatic zones.

Grain Analyses

Grain samples were analyzed for colour, test weight and kernel diameter, length, weight and hardness index. Grain was milled on a cyclone sample mill to produce a wholemeal, which was analyzed for protein content and particle size index (PSI) by near-infrared reflectance and soundness by falling number. Grain and wholemeal colour were measured to determine L* (brightness), a*(redness) and b*(yellowness).

Data Analyses

In the statistical analysis the component year, year x agro-climatic zone and year x elevator (agro-climatic zone) were considered random factors, while agro-climatic zone was considered as the fixed factor for the grain and PSI parameters. The contribution of each variance component was calculated as a percentage by summing the mean squares of the appropriate terms to give an estimate of the total variance and then dividing the specific variance component of the significant terms by the total variance.

SOURCE: This article is adapted from the research paper "The Effect of the Environment on the Grain Colour and Quality of Commercially Grown Canada Hard White Spring Wheat, Triticum aestivum L. 'Snowbird'" by Odean M. Lukow, Kathy Adams, Jerry Suchy, Ron M. DePauw, and Gavin Humphreys published in the Canadian Journal of Plant Science, 2013, 93(1): 1-11, 10.4141/cjps2012-102

RESULTS AND DISCUSSION

Agro-Climatic Zones and Climatic Conditions

The variance component analyses indicated that the agro-climatic zones contributed between 8.6 and 38.5% to the variation in grain quality parameters (Table 1). However, the grain parameters such as grain protein content, test weight and hardness index did not differ between agro-climatic zones (Table 1). The effect of year was significant and accounted for 29.4-79.8% of the variation in the grain parameters (Table 1). There were some significant interactions between agro-climatic zone and year which accounted for 5.9, 5.6 and 10.1% variations in the grain colour L* and b* and protein content, respectively. Inverse relationships between the latitude and longitude of the elevators and the growing season mean, extreme minimum and mean minimum temperatures are illustrated (data not shown). Precipitation had also an inverse relationship with longitude. The combination of low precipitation and high mean maximum and extreme maximum temperatures would make agro-climatic zones #11 and #12 on average the driest in Western Canada over the five years.

Agro-Climatic Zones and Climatic Effects on Grade and Yield

Grain producers are concerned with grade, which in addition to grain yield and grain protein content, directly affects farm profit. Wheat in Western Canada is graded at the delivery elevators according to specifications and tolerance levels established by the Canadian Grain Commission. Of the total number of grain samples analysed less than 1% had protein contents below 10% resulting in no agro-climatic zone having a mean protein level less than the minimum allowed for grade No. 1 CWHWS. Each grade also has a specification for soundness, which relates to frost-damaged (frosted mature grain) kernels, mildew and degree of maturity. These parameters are difficult to measure objectively and are assessed visually against a standard sample. The soundness parameters of frost-damaged kernels and mildew had values assigned to levels of the graders comments, i.e., very light mildew, light mildew and mildew, were rated 1, 2 and 3, respectively. There were significant differences between agro-climatic zones in the levels of mildew present with zones #83 and 31 having the highest mean mildew levels and agro-climatic zones #61, 12, 23, 53 and 73 not reporting any mildew (data not shown). There were also differences between agro-climatic zones for frost damaged kernels with the most northern zones in Alberta (#51 and 61) having the highest reported damage. All of the other agro-climatic zones in Alberta reported frost damage as well. Most of the grading documentation supplied included graders' comments only with respect to the presence of green kernels instead of a percentage. In these cases values were assigned by using the tolerance limit allowed for the grade i.e., No. 1 CWHWS allows 0.75% green kernel while grade No. 2 CWHWS allows 2%. In all of the agro-climatic zones where frost damage was reported there were also green kernels present. Using the means of the assigned wheat grades along with the visual soundness specifications, green kernel presence and the grade qualifiers supplied for each sample (data not shown) a map was developed indicating the agro-climatic zones that exhibited good and poor levels of each grade (Fig. 2A). The grade results in Fig. 2A are supported by the positive correlation of latitude to grade ($r \geq 0.27$). Agro-climatic zones attributed 8.6% to the variation in grade and 21.8% in yield while year contributed 86 and 59.9%, respectively (Table 1). Agriclimatic zone was also significant for the grain traits of mildew, fusarium and frost-damaged kernels, and green kernels (Table 1).

Grade correlated inversely with growing season maximum mean temperature ($r \geq -0.53$), extreme maximum temperature ($r \geq -0.52$) and mean temperature ($r \geq -0.48$). Comparison of the grain yield results shows the possibility of inverse relationships with all of the temperature parameters. A high negative correlation of kernel colour a* values to grade ($r \geq -0.65$) along with a

Table 1. *Variance components for grain and wholemeal ... parameters*, as a percentage***

	df	Grade	Yield	GPC	Test Weight	Frost Damage	Mildew Damage	Fusarium Damage	Green Kernels	Kernel Colour Colour L*	Kernel Colour Colour a*	Kernel Colour Colour b*
Agro-Climatic Zones (A)	17	8.6	21.8	13.5	8.3	24.1	22	34	21	14.2	13	17.9
Year (Y)	4	86	59.9	69.7	79.8	57.8	62.5	47.6	55.6	73.2	78.6	71.3
Y x A	40	2.7	9.7	10.1	6.5	9.6	9.5	16.3	8.8	5.9	4.1	5.6
Y x Elevator (A)	71	16	5.3	3.6	2.8	6.6	3.9	1.3	10.8	3.4	2.7	3.1
Error	1017	1	3.3	3.1	2.5	1.9	2.2	0.8	3.8	3.4	1.5	2.1

	df	Kernel length	Kernel diameter	Kernel weight	Hardness index	df	PSI	df	FN (s)	UDY colour L*	UDY colour a*	UDY colour b*
Agro-Climatic Zones (A)	17	33	35.3	29.6	7.2	17	1.8	17	8.2	23	4.6	34.2
Year (Y)	4	32.1	29.4	41.8	83.3	4	95.1	4	86	59.2	70.8	31.1
Y x A	40	14.8	14.7	12.3	6.2	40	1.7					
Y x Elevator (A)	65	9.9	8.8	7.5	1.4	65	0.8	105	3.8	12.6	6.1	27.7
Error	845	3.6	5.9	3.9	1.4	852	0.5	848	2	5.2	18.5	7

** GPC, grain protent content; PSI, particle size index; FN, falling number*

*** (specific variance component of the significant terms divided by the total variance) x 100* lower correlation of kernel colour b* values to grade (r ≥ -0.39) indicated that better quality grain (Fig. 2A) tends to be more red (Fig. 3B) and more yellow (Fig. 3C) without a change in grain brightness (Fig. 3A). Stepwise regression showed that variation in kernel redness (a*) explained over 45% variation in wheat grade. The inclusion of percent green kernels, growing season mean maximum temperature, test weight, midge damage, kernel length, weight, yellowness and protein content, mildew and latitude only explained an additional 23% in grade variation. Grain yield was affected primarily by kernel weight. Stepwise regression attributed 22% of the variation in yield to kernel weight with other variables affecting yield being midge damage, latitude and mean minimum growing season temperature.

Agro-Climates and Climatic Effects on Kernel Colour

There were significant differences in kernel colour as measured by the CIE L*a*b* scale between agro-climatic zones. Agro-climatic zones #11, 12 and 73 produced the brightest and most yellow grain as indicated by the kernel colour L* and b* values (Fig. 3A and C, respectively). These agro-climatic zones had also the reddest seed (Fig. 3B) along with agro-climatic zones #51 in Alberta and #43 in Manitoba. Agro-climatic zone accounted for 13-17.9% of the variance in kernel colour, while year accounted for 71.3-78.6%. Variation was also accounted for by the interactions of year x agro-climatic zone and year x elevator (agro-climatic zone) (Table 1).

Kernel brightness L* values were highly correlated with kernel yellowness b* (r = 0.79). Kernel colour L* and b* values were also negatively correlated with grain protein content. Results from this study, based on a single genetic source and pre-selected protein content, may indicate that there was an effect of protein content on hard white grain colour. Results from the stepwise regression analysis indicated that hardness index, kernel diameter, protein content, mildew and extreme maximum temperature account for over 51% of the variation in the kernel brightness L*.

Kernel colour a* values correlated with both growing season maximum mean and extreme maximum temperatures (r =0.53) and with growing season mean temperature (r =0.49). Stepwise regression indicated that the growing season maximum mean temperature had the greatest effect (32%) on kernel redness, while mildew, green kernels, hardness index and altitude had smaller individual effects (≤ 5%) on the kernel redness. Our results indicate a moderate correlation of kernel yellowness b* values with both growing season mean maximum temperature (r =0.42) and extreme maximum temperature (r =0.42). Mean maximum temperature accounted for 21% of the variation in grain b* colour. The other parameters accounting for up to 57% variation in kernel colour b* were protein content, hardness index, kernel diameter and weight and altitude.

Agro-Climatic Zones and Climatic Effects on Grain Protein Content

Even though mean grain protein content ranged from 12.6% in agro-climatic zone #42 (northern Saskatchewan) to 14.4% in agro-climatic zone #43 (southern Manitoba) there were no significant differences between the protein contents, (data not shown). The variance component analyses also indicated that agro-climatic zone did not account for any of the variation in grain protein while year and the year x agro-climatic zone interaction did (Table 1).

According to stepwise regression, the protein content variability was moderately attributed to the extreme maximum temperature (5.6%) and precipitation (2.2%). Other grain traits, such as hardness index and kernel weight, mildew and extreme minimum temperature, were shown to contribute poorly (17%) to the protein content variation according to the stepwise regression model. Although there was not a significant response between protein content and yield in this study, there were positive effects of temperature on the protein content and negative effects of temperature on yield (data not shown). In this study there was a negative effect of precipitation on protein content as well.

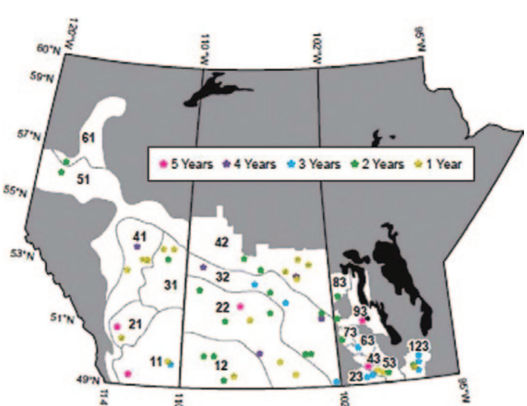

Fig. 1. *Map of Western Canada showing the agro-climatic zones, elevator locations and number of delivery years.*

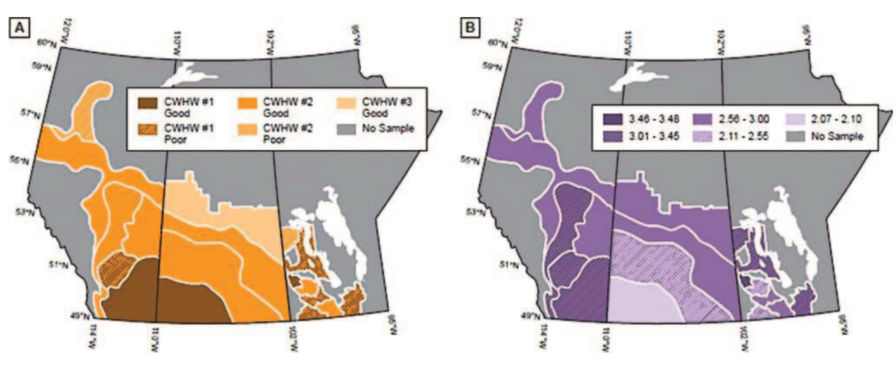

Fig. 2. *Environment average grades (A) and yields (B) in Western Canada.*

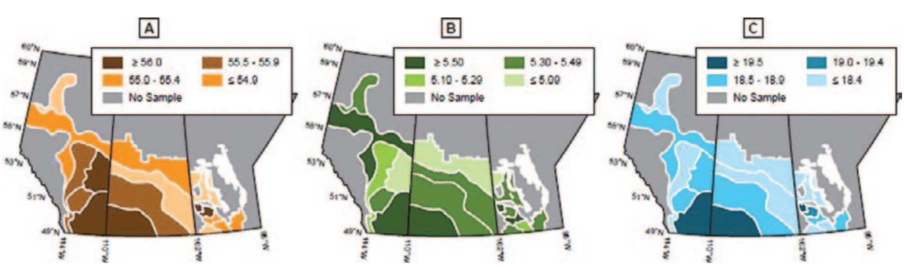

Fig. 3. *Maps of Western Canada showing average grain colour parameters: brightness L* (A), redness a* (B), and yellowness b* (C).*

Agro-Climatic Zones and Climatic Effects on Wholemeal Characteristics

Wholemeal brightness L* ranged from 82.65 in agro-climatic zone #42 to 83.89 in agro-climatic zone #12, wholemeal redness a* ranged from 0.70 in agro-climatic zone #51 to 0.90 in agro-climatic zone #73 and wholemeal yellowness b* ranged from 12.30 in agro-climatic zone #31 to 13.83 in agro-climatic zone #53 (data not shown). The brightness and yellowness of the wholemeal samples were affected by the agro-climatic zone, while the redness of the wholemeal was not (Table 1). Pearson correlations indicate positive relationships between growing season extreme maximum, maximum and mean temperatures and falling number ($r \geq 0.40$) and wholemeal colour ($r \geq 0.30$).

Relationships Between Grain and Wholemeal

Stepwise regression showed that wholemeal L* had 41% of its variability accounted for by kernel a* and b* with an additional 8% by mildew, kernel L*, SKCS hardness, growing season extreme minimum temperature and precipitation. Wholemeal a* variability was due to 12 components but they only contributed 25%. Variability in wholemeal b* could only be accounted for by five components, together contributing 29%. Kernel L* contributed 12% to the variability in PSI with another 21% accounted for by additional eight components.

CONCLUSIONS

This five-year study concentrated on finding the effect of the environment on the quality of grain of the Canadian hard white spring wheat cultivar, Snowbird, grown under commercial conditions. Areas of Western Canada were divided into climatically distinct areas, agro-climatic zones, which are used by the appropriate provincial seed industry associations and farmers for crop insurance purposes. Agro-climatic zones had a significant effect on most of the Snowbird grain properties including grain colour. However, annual fluctuations in temperature and precipitation had an even greater effect on the grain properties. The presence of interactions between agro-climatic zones and growing year suggest differential response of the environment with respect to grain properties. Agro-climatic zones located in lower latitudes and higher longitudes in western Canada tended to be on average warmer and drier areas which produced darker grain, with more red and yellow seed appearance. Grain produced in these areas graded on average better than in the other agro-climatic zones, most likely due to the lack of significant frost damage and disease presence. Those on average warmer and drier production areas, however, have the disadvantage of reduced grain yields, although at a higher protein content.

This CCA Continuing Education opportunity is a joint project of:

CAAR Canadian Association of Agri-Retailers · CERTIFIED CROP ADVISER · MONSANTO imagine™