Does Wheat Cultivar Choice Affect Crop Quality and Soil Microbial Communities in Cropping Systems?

Nelson, A.[1], Frick, B.[2], Clapperton, J.[3], Quideau, S.[4] & Spaner, D.[1]

Key words: wheat, soil microbial community, breadmaking quality, organic and conventional management

Abstract

Wheat (Triticum aestivum L.) *cultivars may have differential effects on soil microbial communities and the breadmaking quality of harvested grain. We compared six Canadian spring wheat cultivars under organic and conventional management systems for yield, breadmaking quality and soil phospholipid fatty acid analysis (PLFA) profile. Yields were lower, but protein levels were higher in the organic system. Cultivars differed for quality traits, but all cultivars had acceptable levels for processing. There were small differences in PLFA profiles for cultivars in the conventional system, but none in the organic system. More significant correlations between grain quality and PLFA measures were present in the organic system. Protein levels and breadmaking quality at least equal to conventional systems can be achieved in organic systems. Wheat cultivars differed for grain quality in both organic and conventional systems, and culivars altered the soil microbial profile in conventional systems. Microbes may play a greater role in determining crop quality in organic systems than in conventional systems.*

Introduction

Demand for organic foods has been increasing in Canada, in part because consumers perceive organic foods as having unique and/or superior quality than conventionally produced foods (Yiridoe et al. 2005). Research into the nutritional differences and sensory profiles of organic and conventional products has not yielded consistent results (Bourn and Prescott 2002).

Soil microbial communities play an important role in soil fertility and nutrient cycling, and are affected by production practices. Cropping systems management (organic and conventional) may (Bossio et al. 1998) or may not (Girvan et al. 2003) alter soil microbial communities. Crop cultivar selection can also affect soil microbial diversity (Germida and Siciliano 2001).

Understanding the effects of cultivar choice on soil microbial communities and crop quality may result in production systems with consistently high food quality. Our objectives were to determine the effect of spring wheat (*Triticum aestivum* L.) cultivar choice on soil microbial communities, crop productivity and breadmaking quality in both organic and conventional systems.

---

[1] Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, AB, T6G 0M6, E-Mail agnelson[a]ualberta.ca

[2] Organic Agriculture Centre of Canada, University of Saskatchewan, Saskatoon, SK, S7N 5A8

[4] Agriculture and Agri-Food Canada, Lethbridge, AB, T1J 4B1

[3] Department of Renewable Resources, University of Alberta, Edmonton, AB, T6G 2H1

Materials and methods

Six western Canadian spring wheat cultivars (Elsa, Glenlea, Go, Marquis, Park and Superb) were grown in four-replicate randomized complete blocks on two nearby sites (one organically managed and one conventionally managed) in 2005 and 2006 in Edmonton, AB, Canada (55°34´N, 113°31´W). The two sites had similar soil types.

Quality measures on grain included a number of processing measures which relate to final product quality. Protein levels over 12% are considered adequate in western Canada. Flour yield (FLY) is a measure of milling quality. Falling number (FN) indicates the sprouting resistance of the grain, affecting dough quality; grain over 400 has high sprouting resistance. Particle size index (PSI) indicates kernel hardness, with values generally 50-55 PSI. Mixing development time (MDT) is a measure of how long it takes to develop the dough; values between 2-3 minutes are desired. Soil biological biomass, % Gram- and Gram+ bacteria, % fungi, richness, evenness and diversity was determined using phospholipid fatty acid analysis (PLFA) on 5 soil samples randomly removed from each plot during crop growth (Clapperton et al. 1997).

Proc Mixed in SAS v.9.0 was used to analyze the combined experiment as a split plot, with management system as the main plot and cultivar as the subplot, replicated in time (year). The data were also analyzed separately by management system combined over years. For both analyses, years and blocks were considered random and management system and cultivar were considered fixed effects. Pearson correlations were conducted on site-year lsmeans.

Results

Tab. 1: Results of combined and separate statistical tests of breadmaking quality traits of wheat cultivars grown organically and conventionally

Cultivar	Yield (t ha^{-1})	Grain protein (%)	FLY (%)	FN	PSI (%)	MDT (min.)
	Conventional					
Conventional mean	5.3	15.1	73	486	52	2.7
F test $_{cultivar}$ (df=5)	***	***	***	***	***	***
SE $_{cultivar}$	0.49	0.20	1	22	1	0.26
	Organic					
Organic mean	2.1	16.9	70	472	49	2.4
F test $_{cultivar}$ (df=5)	ns	***	***	***	***	***
SE $_{cultivar}$	0.77	0.46	1	78	2	0.16
	Combined ANOVA					
F test $_{mgmt}$ (df=1)	*	*	NS	NS	NS	NS
SE $_{mgmt}$	0.53	1.01	1	32	1	0.16
F test $_{cultivar}$ (df=5)	**	NS	NS	*	***	***
SE $_{cultivar}$	0.52	0.94	1	43	1	0.21
F test $_{mgmt*cultivar}$ (df=5)	*	NS	NS	NS	*	NS

NS=not significant (P≥0.10), * significant at P<0.10, *** significant at P<0.01, FLY=Flour yield , FN=Falling number, PSI=Particle size index, MDT=Mixing development time, SE=Standard error

When the management systems were analyzed separately, cultivars differed ($P<0.01$) for all breadmaking quality measures, except yield in the organic system (Table 1). Although cultivars differed for quality measures, most exhibited quality measures falling within accepted standards. However, Glenlea in the conventional system, and Go in the organic system had falling numbers below 400, suggesting these cultivars may have inferior dough under certain management systems.

In combined analyses, management had a significant effect on yield and grain protein. Yields under organic management were about half of those under conventional management. Grain protein levels were 12% higher in the organic system compared to the conventional system. Cultivar was a significant source of variation for all breadmaking quality traits except protein and FLY, with most values within standards.

The interaction of management × cultivar was significant ($P<0.10$) for yield and PSI. Superb yielded more grain than Marquis in the conventional system. Marquis yielded the lowest of the six varieties in both systems.

In the separate analysis for the PLFA measures, cultivar altered ($P<0.05$) % fungi, PLFA evenness and diversity in the conventional system (Table 2). Superb had higher % fungi, PLFA evenness and diversity than the other cultivars. Cultivar did not alter ($P>0.10$) any of the PLFA measures in the organic system.

Tab. 2: Lsmeans of cultivars under conventional management for % fungi, PLFA evenness and diversity from management-separated statistical tests

Cultivar	% Fungi	Evenness	Diversity
Elsa	0.93 b	0.82 ab	2.63 ab
Glenlea	0.90 b	0.80 b	2.61 b
Go	1.02 ab	0.82 ab	2.68 ab
Marquis	0.91 b	0.82 ab	2.68 ab
Park	1.05 ab	0.79 b	2.57 b
Superb	1.37 a	0.85 a	2.81 a

Lsmeans followed by the same letter within columns are not significantly different at the $P<0.05$ level, with Tukey's adjustment. Lsmeans separation was carried out using the pdiff option in SAS.

Correlation analysis suggested some relationships between grain quality and the soil microbial community in both systems, with more correlations in the organic system. Eighteen of 42 correlations were significant in the organic system, and only seven of 42 correlations were significant in the conventional system (data not shown). The % fungi was positively associated with yield under organic management ($r=0.9^{***}$) and under conventional management ($r=0.7^{**}$).

Discussion

Protein content of grain is an important factor in breadmaking quality, and was higher in the organic system. Other experiments have reported protein levels in organic systems to be lower (Poutala et al. 1993) or the same (Ryan et al. 2004) as conventional systems. Lower yields and heavy applications of compost for many years prior to the wheat crops in the organic system may explain the higher protein content in organic wheat. However, this experiment demonstrates that it is possible to have similar protein levels in organic and conventional systems.

Cultivars chosen for this experiment differed for some measures of quality as well as yield in both organic and conventional systems. The oldest cultivar, Marquis, yielded lowest in both the organic and conventional system, indicating that breeding has improved yields over the last century. Cultivar choice also affected some measures of the soil microbial community, but only in the conventional system. Management system did not affect microbes. It appears that factors other than cultivar are important in determining microbial community structure in organic systems.

More significant relationships between grain quality and soil microbes in the organic system may indicate that soil microbes play a greater role in determining crop quality in the organic system than the conventional system. The positive correlation between yield and % fungi may be due in part to mycorrhizal fungi (Olsson et al. 1999), as mycorrhizae can benefit plant nutrient uptake and crop productivity.

Conclusion

Yields were lower in the organic system, but protein levels and breadmaking quality at least equal to conventional systems can be achieved in organic systems. Cultivar choice altered grain quality and yield in both systems, but did not have an effect on soil microbial communities in the organic system. Soil microbes may play a greater role in determining crop quality in organic systems than in conventional systems.

Acknowledgments

We gratefully acknowledge the financial support of the Natural Sciences and Engineering Research Council, Alberta Ingenuity and a research grant from the Alberta Crop Industry Development Fund. Thanks to K. Strenzke and A. Navabi for technical and scientific support.

References

Bossio D.A., Scow K.M., Gunapala N., Graham K.J. (1998): Determinants of soil microbial communities: effects of agricultural management, season, and soil type on phospholipid fatty acid profiles. Microb Ecol. 36:1-12.

Bourn D., Prescott J. (2002): A comparison of the nutritional value, sensory qualities, and food safety of organically and conventionally produced foods. Crit Rev in Food Sci Nutr. 42:1-34.

Clapperton M.J., Janzen H.H., Johnston A.M. (1997): Suppression of VAM fungi and micronutrient uptake by low-level P fertilization in long-term wheat rotations. Am J of Alter Ag. 12: 59-63.

Germida J.J., Siciliano S.D. (2001): Taxonomic diversity of bacteria associated with the roots of modern, recent and ancient wheat cultivars. Biol Fertil Soils. 33:410-415.

Girvan M.S., Bullimore J., Pretty J.N., Osborn A.M., Ball A.S. (2003): Soil type is the primary determinant of the composition of the total and active bacterial communities in arable soils. Appl Environ Microbiol. 69:1800-1809.

Olsson, P.A., Thingstrup I., Jakobsen I., Bååth F. (1999): Estimation of the biomass of Arbuscular mycorrhizal fungi in a linseed field. Soil Biol Biochem. 31:1879-1887.

Poutala R.T., Korva J., Varis E. (1993): Spring wheat cultivar performance in ecological and conventional cropping systems. J Sustain Agric. 3:63-83.

Ryan M.H., Derrick J.W., Dann P.R. (2004): Grain mineral concentrations and yield of wheat grown under organic and conventional management. J Sci Food Agric. 84:207-215.

Yiridoe E.K., Bonti-Ankomah S., Martin R.C. (2005): Comparison of consumer perceptions and preference toward organic versus conventionally produced foods: a review and update of the literature. Renew Agr Food Syst. 20:193-205.