EFFECTS OF SIMULATED EROSION AND AMENDMENTS ON GRAIN YIELD AND QUALITY OF WHEAT

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ABSTRACT

Field experiments were conducted in 1991 at Josephburg (Black Chernozem soil) and Cooking Lake (Gray Luvisol soil), Alberta, Canada, to determine the influence of depth of erosion (simulated-erosion approach by artificially removing the topsoil) and amendments on grain yield, protein concentration and thousand kernel weight (TKW) of hard-red spring wheat (*Triticum aestivum* L. cv. Roblin). There were five erosion levels (0, 5, 10, 15 and 20 cm) and four amendments (control, addition of 5 cm of topsoil, addition of fertilizer at 100 kg N/ha and 20 kg P/ha, and cattle manure at 75 Mg/ha on a dry basis). Yield reduction due to topsoil removal was a function of nutrient loss. The applications of fertilizer N and P, and cattle manure improved yield substantially and reduced the impact of yield loss due to erosion. Return of 5 cm of topsoil to the plots made the rate of yield loss an independent function of erosion. At both sites, protein concentration in wheat grain was influenced by the erosion level imposed and the kind of amendment used. The protein concentration at Josephburg decreased from 141 g/kg in the non-eroded treatment to 124 g/kg in the 20-cm erosion treatment. In the same order, the values for the Cooking lake site were 132 and 123 g/kg, respectively. The application of commercial fertilizers at Josephburg resulted in the highest protein concentration (153 g/kg). At both sites, TKW decreased with increasing depth of soil erosion. At Cooking Lake, all amendments produced heavier seeds than the control plots. In conclusion, the productivity of artificially-eroded soil was mostly a function of nutrient removal. The productivity and quality of wheat was partially restored by using either fertilizer or organic amendments.

INTRODUCTION

Many agricultural landscapes in western Canada exhibit features of past erosion by wind and water. Erosion reduces the thickness of topsoil and alters other soil properties. Eroded soils can adversely affect crop yield and quality through increased bulk density, reduced organic matter, low availability of N and other nutrients, and reduced water holding capacity (Eck et al. 1965, Frye et al. 1982, Dormaar et al. 1986, Tanaka and Aase 1989, Malhi et al. 1996, Fowler 1998). Since eroded and non-eroded areas in cultivated fields often occupy different topographic positions, it is very difficult to assess the effect of soil erosion on crop production and quality under natural field conditions. One practical way to determine loss in crop yield and quality due to erosion is to erode the soil artificially by physically removing the surface soil layers. The objective of the study was to determine the influence of depth of erosion (simulated-erosion approach by artificially removing the topsoil) and amendments on grain yield, protein concentration (PC) and thousand kernel weight (TKW) of wheat.

MATERIALS AND METHODS

Field experiments were conducted in 1991 at Josephburg (Black Chernozem soil) and Cooking Lake (Gray Luvisol soil), Alberta, Canada. The mean annual precipitation of the area is

about 500 mm, with 60% occurring in the growing season from May to August. There were five erosion levels (0, 5, 10, 15 and 20 cm) randomly arranged as main-plot treatments; and four amendments (control, addition of 5 cm of topsoil, addition of fertilizer at 100 kg N plus 20 kg P/ha, and cattle manure at 75 Mg/ha on a dry basis) as sub-plot treatments (10 m x 3.65 m). The test crop was hard-red spring wheat (*Triticum aestivum* L. cv. Roblin).

All plots were soil sampled prior to sowing in 1991 and the samples were analyzed for texture, moisture limits, bulk density and nutrients. At maturity, wheat was harvested and the dried plant samples were threshed for grain yield. A grain subsample from each plot was then used to determine TKW and total N. The protein content in grain was estimated by multiplying total N with 5.87.

RESULTS AND DISCUSSION

Soil Properties:

At both sites, soil physical, chemical and biochemical properties changed with depth of simulated erosion (Table 1). Total C, NO₃-N, total N, extractable P, total P and N mineralization potential of soil markedly decreased as depth of topsoil removal increased. Soil bulk density increased with 0-cm topsoil removal to 20-cm topsoil removal from 1.17 to 1.31 Mg/m³ at Josephburg and from 1.25 to 1.38 Mg/m³ at Cooking Lake.

Grain Yield:

Grain yields at both sites markedly decreased with increased erosion depth (Table 2). Mean grain yields (averaged across all amendments) decreased in non-eroded soil to 20-cm erosion treatment from 4314 to 2769 kg/ha at Josephburg and 4228 to 1730 kg/ha at Cooking Lake. The marked decrease in grain yield due to erosion depth was associated with a drastic decline in soil-available N. In this study, there was a close relationship between nutrient loss. These results are in agreement with those reported by other researchers (Dormaar et al. 1986, Shafiq et al. 1988, Tanaka and Aase 1989, Verity and Anderson 1990).

Grain yields improved with all amendments, but the magnitude of yield increase varied with the kind of amendment (Table 2). Commercial fertilizer was most effective to restore productivity of eroded soil, followed by manure and topsoil addition. Return of 5 cm topsoil to the plots made the rate of yield loss an independent function of erosion. The superiority of fertilizer N and P over the other amendments suggests that eroded soil became extremely deficient in plant-available N and P.

Grain Quality:

Protein concentration in wheat grain at both sites was influenced by the erosion level imposed and the kind of amendment used, but the kind of amendment used had a more pronounced effect on grain protein concentration than did the erosion level imposed (Table 2). The protein concentration in wheat grain at Josephburg decreased from 141 g/kg in the non-eroded soil to 124 g/kg in the 20-cm erosion treatment. The values at Cooking Lake were 132 and 123 g/kg, respectively, in the 0-cm and 15-cm erosion treatments. The application of fertilizer N and P at Josephburg resulted in the highest grain protein concentration (i.e., 153 g/kg). The protein concentration in the manure and topsoil treated wheat was lower with respect to wheat in the control plots. At Cooking Lake, wheat from plots receiving fertilizer and other amendments had less protein concentration than the control plots.

At both sites, TKW decreased with increasing level of erosion (Table 2). The mean TKW (averaged across amendments) in non-eroded soil to 20-cm eroded soil decreased from 35.1 to 32.6 g at Josephburg and from 35.6 to 31.2 g at Cooking Lake. At Cooking Lake, all amendments produced heavier seeds than the control plots, but at Josephburg only manure produced the heaviest

seeds.

Plant-available N has a significant effect on grain quality because N is required for the formation of grain storage proteins that have a direct influence on most grain quality measurements. There is a positive relationship between protein concentration in wheat and level of plant-available N (Fowler 1998). Erosion decreases soil-N fertility not only by physically removing organic and inorganic N but also by reducing the mineralization potential of the remaining soil N. This can have an adverse impact on protein concentration. In the present study, the lower protein concentration in wheat on eroded soil treatments compared to non-eroded soil can be attributed to lower amounts of NO₃-N in soil in spring and the reduction in N-supplying capacity of soil during growing season, particularly at grain filling. The protein concentration in grain is determined by the ratio of protein yield to grain yield. When grain yield is relatively increased more than protein yield, then a drop in protein concentration is expected from an amendment compared to the unfertilized treatment. In this study, a decrease in protein concentration in wheat, particularly with manure, happened because of a dilution effect from increased grain yield.

CONCLUSIONS

Crop productivity on artificially-eroded soils was a function of nutrient removal. The lost productivity and quality of wheat was partially restored by using either fertilizer or organic amendments.

REFERENCES

- Dormaar, J.F., Lindwall, C.W. and Kozub, G.C. 1986. Restoring productivity to an artificially eroded Dark Brown Chernozemic soil under dryland conditions. *Can. J. Soil Sci.* 66: 273-285.
- Eck, H.V., Hauser, V.L. and Ford, R.H. 1965. Fertilizer needs for restoring productivity on Pullman silt loam after various degrees of soil removal. *Soil Sci. Soc. Am. Proc.* 29: 209-213.
- Fowler, D.B. 1998. Grain protein concentration responses to plant-available nitrogen. In D.B. Fowler et al. (ed), *Proc. Wheat Protein Symposium*, 9-10 March, 1998, Saskatoon, Saskatchewan, Canada. pp. 281-284.
- Frye, W.W., Ebelhar, S.A., Murdock, L.W. and Blevins, R.L. 1982. Soil erosion effects on properties and productivity of two Kentucky soils. *Soil Sci. Soc. Am. J.* 46: 1051-1055.
- Power, J.F., Sandoval, F.M., Ries, R.E. and Merrill, S.D. 1981. Effects of topsoil and subsoil thickness on soil water content and crop production on a disturbed soil. *Soil Sci. Soc. Am. J.* 45: 124-129.
- Shafiq, M., Zafar, M.I., Ikram, M.J. and Ranjha, A.Y. 1988. The influence of simulated soil erosion and restorative fertilization on maize and wheat production. *Pakistan J. Sci. Ind. Res.* 3 1: 502-505.
- Tanaka, D.L. and Aase, J.K. 1989. Influence of topsoil removal and fertilizer application on spring wheat yields. *Soil Sci. Soc. Am. J.* 53: 228-232.
- Verity, G.E. and Anderson, D.W. 1990. Soil erosion effects on soil quality and yield. *Can. J. Soil Sci.* 70: 471-484.

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- Eck, H.V., Hauser, V.L. and Ford, R.H. 1965. Fertilizer needs for restoring productivity on Pullman silt loam after various degrees of soil removal. *Soil Sci. Soc. Am. Proc.* 29: 209-213.
- Fowler, D.B. 1998. Grain protein concentration responses to plant-available nitrogen. In D.B. Fowler et al. (ed), *Proc. Wheat Protein Symposium*, 9-10 March, 1998, Saskatoon, Saskatchewan, Canada. pp. 281-284.
- Frye, W.W., Ebelhar, S.A., Murdock, L.W. and Blevins, R.L. 1982. Soil erosion effects on properties and productivity of two Kentucky soils. *Soil Sci. Soc. Am. J.* 46: 1051-1055.
- Power, J.F., Sandoval, F.M., Ries, R.E. and Merrill, S.D. 1981. Effects of topsoil and subsoil thickness on soil water content and crop production on a disturbed soil. *Soil Sci. Soc. Am. J.* 45: 124-129.
- Shafiq, M., Zafar, M.I., Iqbal, M.J. and Ranjha, A.Y. 1988. The influence of simulated soil erosion and restorative fertilization on maize and wheat production. *Pakistan J. Sci. Ind. Res.* 31: 502-505.
- Tanaka, D.L. and Aase, J.K. 1989. Influence of topsoil removal and fertilizer application on spring wheat yields. *Soil Sci. Soc. Am. J.* 53: 228-232.
- Verity, G.E. and Anderson, D.W. 1990. Soil erosion effects on soil quality and yield. *Can. J. Soil Sci.* 70: 471-484.

Table 1. Some characteristics of soil (10-cm deep) after various depths of topsoil removal

Site	Topsoil removal (cm)	Bulk density (Mg/m ³)	Total C (g/kg)	NO ₃ -N (mg/kg)	Total P (mg/kg)	Ext. P (mg/kg)	Total P (mg/kg)	N min. potential (mg N/kg)
Josephburg	0	1.17	40	11	3600	23	800	188
	5	1.21	40	11	3110	20	790	161
	10	1.24	34	10	2850	14	720	134
	15	1.28	29	8	2440	12	640	99
	20	1.31	25	6	2050	12	640	74
Cooking Lake	0	1.25	34	16	3000	40	840	328
	5	1.28	29	12	2580	32	720	251
	10	1.30	18	8	1700	12	540	94
	15	1.34	12	7	1300	13	550	57
	20	1.38	8	6	930	2	480	38

Table 2. Effects of erosion level and amendments on grain yield, protein concentration (PC) and thousand kernel weight (TKW) of wheat

Treatment	Josephburg	Cooking Lake	Josephburg	Cooking Lake
Yield (kg/ha)				
Erosion (cm) ^a			Amendment ^b	
0	4314a	4228a	Control	2137d
5	4184a	3624b	Fertilizer	4854a
10	3693b	3133c	Manure	4477b
15	3090c	2256d	Topsoil	2972c
20	2769c	1730e		3640c
PC (g/kg)				
Erosion (cm) ^a			Amendment ^b	
0	141a	132a	Control	140b
5	136ab	133a	Fertilizer	153a
10	131bc	128ab	Manure	122c
15	125c	123b	Topsoil	110d
20	124c	127ab		111c
TKW (g)				
Erosion (cm) ^a			Amendment ^b	
0	35.1a	35.6a	Control	33.5bc
5	34.8a	34.4ab	Fertilizer	33.9b
10	34.3ab	33.4bc	Manure	35.4a
15	33.3bc	32.0cd	Topsoil	33.2c
20	32.6c	31.2d		33.4a

a Averaged across all amendments.

bAveraged across all erosion levels.