Yield and Nutrient Uptake of Wheat on Oil Well Sites: Effects of Topsoil Depth and Organic Amendments.*

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ABSTRACT

This study was conducted to determine the effect of different depths of topsoil replacement and organic amendments on the productivity of well sites. The experiment was initiated in 1997 on three oil well sites at Strathmore, Hesketh and Rosedale using a split-plot design with the depth of topsoil replacement as the main plot (0, 50%, 100% and 150% of recommended replacement depth). The subplot treatment was organic amendments: compost, fresh manure, alfalfa hay, wheat straw and a control as one-time applications in 1997. There was no effect of topsoil depth on grain yield, but yields from straw-amended plots were significantly lower than other amendments. Also topsoil depth did not influence nitrogen nutrition of wheat but phosphorus uptake was lower at the lower topsoil depths due to the tie-up of phosphorus by the subsoil. Alfalfa, compost and manure increased the nitrogen uptake of wheat, while compost and manure increased phosphorus uptake. The wheat straw amendment reduced both nitrogen and phosphorus uptake possibly via immobilization leading to a reduced yield. The results indicate that the application of topsoil is beneficial for crop growth but that diminishing returns set in at high topsoil replacement depths. A minimum topsoil replacement depth may be needed to prevent the negative impact of subsoil on P nutrition.

INTRODUCTION

An estimated 350,000 ha of land is leased in Alberta by the oil and gas industry for well sites, pipeline rights-of-way and plant sites. Approximately 40,000 ha of these becomes available each year for reclamation. Alberta Environmental Protection (AEP) requires restoration of specific levels of salvaged topsoil to wellsites before they are turned over to farmers or other land users. For wellsites constructed before 1983, AEP requires that 60 percent of the original depth of topsoil be replaced. The requirement is 70 percent for those constructed after 1983, and 80 percent for those built after April 30, 1994. Current regulations require topsoil to be salvaged and stored, but many older sites have little or no topsoil available for reclamation. In those cases, topsoil usually needs to be transported to the site, a practice that is expensive and can be limited by a lack of topsoil of suitable

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quality. In situations where sufficient topsoil is not available to meet the required replacement depth, application of amendments is recommended. While several amendments are mentioned in the guideline, there is no indication of the amount required to compensate for the shortfall of topsoil.

This three-year study was conducted to provide a baseline for substituting organic amendments for topsoil replacement. A knowledge of the appropriate depth of topsoil replacement and amounts of amendment needed to restore productivity to disturbed soil is important to the success of a reclamation exercise. With hard scientific data, AEP and industry will better be able to judge the effects of both topsoil and organic amendments on restoring soil productivity to wellsites. This could lead to more flexibility in the requirements and an overall improvement of reclamation practices."

The experiment was initiated in spring 1997 on three oil well sites at Strathmore, Hesketh and Rosedale. Preliminary results in the year of establishment was summarized by Klaassen et al (1998). Akinremi et al. (1999) provided information on the midseason biomass and yield in 1998. This report contains results of crop yield and nutirent uptake obtained in 1998 as influenced by depth of topsoil and orgainc ammendments

MATERIALS AND METHODS

Details of experimental design, research methodology and sampling techniques were provided previously (Klaassen et al.1998; Akinremi et al 1999). Briefly, the experiment was initiated in spring 1997 on three oil well sites at Strathmore, Hesketh and Rosedale using a split-plot design with depth of topsoil replacement as the main plot (0, 50%, 100% and 150% of recommended replacement depth). The subplot treatment was organic amendments: composted cattle manure, fresh cattle manure, alfalfa hay, wheat straw and a control as one-time applications in 1997. The plots were seeded to spring wheat in 1997 and 1998.

RESULTS

Grain Yield

Final harvest were obtained only at Strathmore and Rosedale as a result of the loss of the crop at Hesketh. Topsoil depth had no significant effect on grain yield, but the amendment effect was significant at the two sites in 1998 (Fig. 1). Crop on plots amended with wheat straw performed poorly and the treatment produced significantly lower yields than all other amendments including the check treatment (Fig. 1b). On average, yield from wheat straw amendment was about 50% of yields from other amendments at Strathmore and 66% of yields from other amendments at Rosedale. Grain yields from compost, manure and alfalfa hay were not significantly different from yield from the check treatment. Significant topsoil depth and amendment effects were obtained at mid-season (Akinremi et al. 1999) but this did not carry through to final harvest.

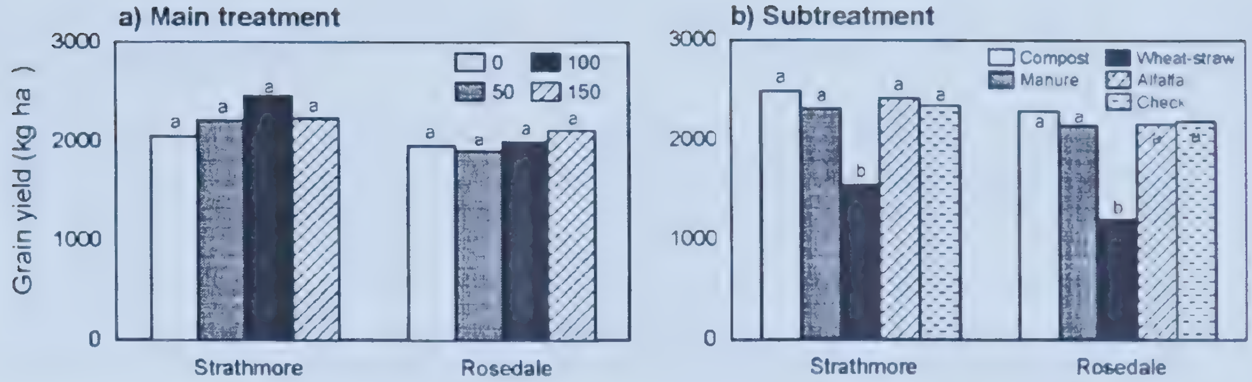

Figure 1. Means of grain yield by topsoil depth (a) and by amendment (b) in 1998. Means with the same letter are not significantly different (P<0.05).

Straw Yield

Straw yield was significantly affected by the topsoil depth and amendment at Strathmore and Rosedale in 1998 (Fig. 2). When averaged across amendments, the 100% topsoil depth produced the largest straw that was significantly different from the 0% depth (4262 versus 3080 kg ha^{-1}) at Strathmore. At Rosedale, both 100% and 150% topsoil depths produced straw yields that were significantly higher than the straw produced by the 0% depth.

When averaged across topsoil depths, straw yield from wheat straw-amended plot was significantly lower than yield from other amendments at Strathmore. Compost and alfalfa- amended plots produced significantly higher straw yields than the check plot. At Rosedale, wheat straw-amended plot produced straw yield that was significantly lower than other amendments but there was no significant difference between other organic amendments and the check treatment.

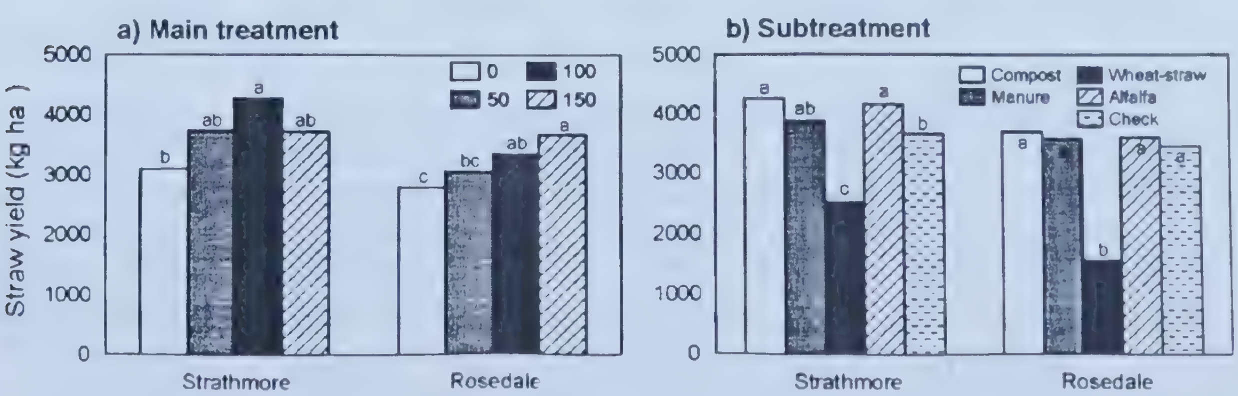

Figure 2. Means of straw yield by topsoil depth (a) and by amendment (b) in 1968. Means with the same letter are not significantly different (P<0.05).

Moisture Use Efficiency

Moisture use efficiencies (MUE) were calculated as a ratio of grain yield to moisture use during the growing season at Strathmore and Rosedale (Table 1). The MUE obtained in this study are comparable to those reported in previous studies (Larney et al, 1994). There was no significant effect of topsoil depth on MUE at any site. As well, no trend in MUE with increasing topsoil depth was apparent in 1998 at both sites.

There was a significant effect of amendment on MUE at both sites. Wheat straw-amended-plots used moisture less efficiently compared to other amendments. There was no significant difference between the MUE of other organic amendments and the check treatment, however, compost-amended plot had the highest MUE of about 16 kg ha^{-1} mm^{-1} at both sites.

Table 1. Moisture use efficiency (kg ha^{-1} mm^{-1}) in 1998

	Compost	Manure	Straw	Alfalfa	Check	Main-Plot
Strathmore - Site 1						
0	20.1	13.8	10.3	14.2	17.4	**15.2 a**
50	12.9	13.9	10.9	15.2	13.8	**13.3 a**
100	15.4	15.5	12.4	14.5	14.2	**14.4 a**
150	14.7	14.2	10.1	13.6	15.8	**13.7 a**
SUBPLOT	**15.8 a**	**14.4 ab**	**11.0 b**	**14.4 ab**	**15.3 ab**	
Rosedale - Site 3						
0	12.8	13.3	6.2	15.5	15.1	**12.6 a**
50	19.8	20.1	8	17.3	13.7	**15.8 a**
100	15.8	13.3	8	15.6	15.6	**13.6 a**
150	15.6	12.7	11	13.1	13.6	**13.2 a**
SUBPLOT	**16.0 a**	**14.8 a**	**8.3 b**	**15.4 a**	**14.5 a**	

Total Grain Nitrogen

The total grain nitrogen at Strathmore was higher than at Rosedale (Table 2) due to slightly higher yields (Fig 1a). There was no significant effect of topsoil depths on grain nitrogen at both sites in 1998. There was a significant effect of amendment on total grain N at both sites as the

Table 2. Total grain nitrogen (kg ha^{-1}) in 1998

	Compost	Manure	Straw	Alfalfa	Check	Main-Plot
-Strathmore - Site 1						
0	78	67	37	76	64	**64 a**
50	79	73	50	79	74	**71 a**
100	84	81	62	87	78	**78 a**
150	80	76	54	78	78	**73 a**
SUBPLOT	**81 a**	**74 a**	**51 b**	**80 a**	**74 a**	
Rosedale - Site 3						
0	72	63	26	72	72	**61 a**
50	72	73	27	66	59	**60 a**
100	75	64	37	75	73	**65 a**
150	75	70	55	80	72	**70 a**
SUBPLOT	**73 a**	**68 a**	**36 b**	**73 a**	**69 a**	

wheat straw-amended plots produced significantly lower N uptake than other treatments (Table 2). This is an indication of continued immobilization of nitrogen by the added wheat straw.

Total Straw Nitrogen

The effects of topsoil depth and amendments on total straw N in 1998 parallels their effects on total grain nitrogen (Tables 3 versus Table 2). Topsoil depth had a significant effect on total straw nitrogen only at Rosedale as the 150%, 100% and 50% topsoil depths produced significantly higher values than the 0% topsoil depth. There was a significant effect of amendments on total straw nitrogen at both sites with the superior amendment being alfalfa and the inferior treatment was wheat straw.

Table 3. Total wheat straw (kg ha^{-1}) in 1998

	Compost	Manure	Straw	Alfalfa	Check	Main-Plot
Strathmore - Site 1						
0	20	14	7	21	14	**15 a**
50	24	20	16	26	17	**21 a**
100	28	27	15	30	22	**24 a**
150	24	23	12	27	22	**21 a**
SUBPLOT	**24 ab**	**21 bc**	**12 d**	**26 a**	**19 c**	
Rosedale - Site 3						
0	17	14	5	17	17	**14 c**
50	22	18	5	24	17	**17 b**
100	22	19	7	23	21	**18 b**
150	28	25	11	30	18	**23 a**
SUBPLOT	**22 a**	**19 b**	**7 c**	**23 a**	**18 b**	

Total Grain Phosphorus

There was a significant effect of topsoil depth on total grain P at Strathmore where 40 kg ha^{-1} of P fertilizer was added with the 100% topsoil depth having significantly higher P than the 0% (Table 4). At Rosedale where no P was added, topsoil depth effect was not significant. Organic amendments had significant effect on total grain P with compost and manure producing significant higher P at Strathmore and compost at Rosedale (Table 4). Wheat straw-amended plots had the lowest total grain P in spite of a high P content indicating nutrient enrichment rather than the enhancement of P uptake on wheat straw-amended plot.

Total Straw Phosphorus

Similar to total grain P (Table 4a) there was a significant topsoil depth effect on total straw P at Strathmore (with added P fertilizer) but none at Rosedale. The 100% topsoil depth had a significant higher straw P than the 0% topsoil depth. The response of total straw P to organic amendments is similar to that of grain P. Compost and manure significantly increased the total straw P above that of wheat straw, alfalfa, and check treatments.

Table 4. Total grain phosphorus (kg ha^{-1}) in 1998

	Compost	Manure	Straw	Alfalfa	Check	Main-Plot
Strathmore - Site 1						
0	7.8	7.8	4.1	7	7	**6.7 b**
50	9.4	8.5	5.6	7.5	8.2	**7.9 ab**
100	9.2	9.8	7.3	9	8.3	**8.7 a**
150	8.7	8.5	6.2	7.6	7.8	**7.7 ab**
SUBPLOT	**8.8 a**	**8.6 a**	**5.8 c**	**7.8 b**	**7.8 b**	
Rosedale - Site 3						
0	8.1	7.9	3.4	6.8	7.8	**6.8 a**
50	8.6	7.9	3.5	6.4	6.2	**6.5 a**
100	8.7	7.2	4.3	6.8	7.1	**6.8 a**
150	8.5	7.8	6.4	7.4	7.6	**7.5 a**
SUBPLOT	**8.5 a**	**7.7 b**	**4.4 c**	**6.8 b**	**7.2 b**	

Table 5. Total straw phosphorus (kg ha^{-1}) in 1998

	Compost	Manure	Straw	Alfalfa	Check	Main-Plot
Strathmore - Site 1						
0	0.94	1.09	0.5	0.64	0.66	**0.77 b**
50	1.08	1.11	0.99	0.89	0.7	**0.95 ab**
100	1.87	1.65	0.99	1.28	0.99	**1.36 a**
150	1.46	1.32	0.89	1.1	0.93	**1.14 ab**
SUBPLOT	**1.34 a**	**1.29 a**	**0.84 b**	**0.97 b**	**0.82 b**	
Rosedale - Site 3						
0	1.26	1.18	0.91	0.68	0.8	**0.97 a**
50	1.94	1.42	0.98	0.99	1.04	**1.27 a**
100	1.68	1.73	0.91	1.08	0.85	**1.25 a**
150	1.8	1.8	1.07	1.29	0.83	**1.39 a**
SUBPLOT	**1.71 a**	**1.53 b**	**0.97 b**	**1.01 b**	**0.88 b**	

SUMMARY

The results obtained in 1998 show that treatment effect not only depends on the site but also on the time of sampling due to the modifying effect of available soil moisture and rainfall pattern. The topsoil depth did not influence nitrogen nutrition of wheat but phosphorus uptake was lower at the lower topsoil depths possibly due to the tie-up of phosphorus by the subsoil. The significant topsoil effects were found at Strathmore where supplemental amount of P was added and not at Rosedale where fertilizer P was not added in 1998. Alfalfa, compost and manure increased the nitrogen uptake of wheat, while compost and manure increased phosphorus uptake. The wheat straw amendment reduced both nitrogen and phosphorus uptake possibly via immobilization leading to a reduced yield.

The results indicate that the application of topsoil is beneficial for crop growth but that diminishing returns set in at high topsoil replacement depths. The biggest "bang for the buck" appears to be the first topsoil depth increment after which gains from increasing topsoil diminish. Of the organic amendments, compost appears to be superior followed closely by alfalfa hay and manure.

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REFERENCES

Akinremi, O. O., Larney, F. J., Lemke, R. L. and Klaassen, V. 1999. Effect of topsoil depth and organic amendments on productivity of oil well sites. 36th Annual Alberta Soil Science Workshop Proceedings February 16-18 1999. Calgary Alberta.

Klaassen V., Lemke, R. L., and Larney, F. J. 1998. Topsoil replacement and organic amendments for oil well site reclamation. 35th Annual Alberta Soil Science Workshop Proceedings February 17-19 1998. Edmonton Alberta pp124-129.

Larney, F. J., and Janzen, H. H. 1996. Restoration of productivity to a de-surfaced soil with livestock manure, crop residue, and fertilizer amendments. Agron. J. 88: 921-927.

Larney, F. J., Janzen.H. H., and Clapperton, M. J. 1994. Soil erosion-crop productivity relationships in southern Alberta. Final Report CAESA Project Number: RES-006-93.

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