Rebuilding the Fertility and Productivity of Eroded Knoll Soils in South-Central Saskatchewan: Third-Year Results

Ryan Hangs and Jeff Schoenau

Department of Soil Science, University of Saskatchewan, Saskatoon, SK

INTRODUCTION

- Historical erosion (water, wind, and tillage) of knolls within hummocky fields typically leads to upper-slope soils with low organic matter content, poor fertility, along with reduced water infiltration and holding capacity.
- Few studies have compared the effect of various amendment rehabilitation methods on rebuilding soil fertility at these eroded higher landscape positions.

OBJECTIVE

- Evaluate the crop (spring wheat, field pea, and canola) and soil response on two eroded knoll locations, to the addition of different phosphorus (P), copper (Cu), and zinc (Zn) containing amendments, to determine their potential for reclaiming the fertility and productivity of upper-slope regions of farm fields in Saskatchewan.

MATERIALS & METHODS

- A three-year rotational field study was established in 2020 on an eroded convex knoll landscape position in two adjacent agricultural fields located near Central Butte, SK. The clay loam soils are Orthic Regosols with mean E.C. 0.2 dS/m, pH 8.2, and extractable (kg/ha; 0-15 cm) nitrogen (N; 30), P (13), Cu (3.5), and Zn (0.7).
- In addition to the unamended control, nine treatments were imposed prior to seeding the 2020 crops: i) side-banded (S-B) mono-ammonium phosphate (MAP; 65 kg P/ha), ii) S-B zinc sulfate ($ZnSO_4$; 5 kg Zn/ha), iii) S-B copper sulfate ($CuSO_4$; 5 kg Cu/ha), iv) S-B $ZnSO_4$ + $CuSO_4$, v) S-B MAP + $ZnSO_4$ + $CuSO_4$, vi) composted feedlot pen solid cattle manure (SCM; 65 kg P/ha) broadcast and incorporated (15 cm depth), vii) broadcast and incorporated SCM followed by S-B $ZnSO_4$ + $CuSO_4$, viii) S-B Zn-containing recycled-tire char (5 kg Zn/ha), and ix) eroded topsoil mechanically transplanted back onto the knoll from an adjacent depressional area. In subsequent years (2021 and 2022), only recommended rates of N, potassium (K), and sulfur (S) fertilizers were applied to the crops.
- Basal rates (kg/ha) of N (75), K (40), and S (17) were applied in 2022, to prevent nutrient deficiencies other than P, Cu, and Zn. Hard red spring wheat (var. AAC Connery) and canola (InVigor L233P var. Argentine) were seeded and the growing season was drier than normal: 136 mm (≈ 5.5") of rain between May to September.
- Measurement variables reported in this poster: crop biomass (grain and straw), nutrient uptake, and water-use efficiency; soil organic carbon (SOC) content; saturated soil hydraulic conductivity (K_{fs}); and post-harvest simulated snowmelt runoff of NO_3-N and soluble reactive PO_4-P.

RESULTS AND DISCUSSION

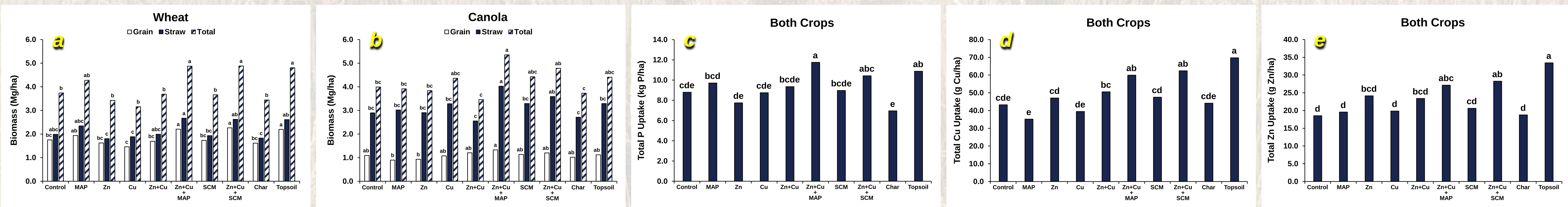

Figure 1. Mean (n=4) harvested biomass of wheat (a) and canola (b), along with combined (n=8) crop total (grain + straw) P (c), Cu (d), and Zn (e) uptake when grown on eroded knolls at field sites near Central Butte, SK in 2022 without (control) or with different soil fertility treatments (see Materials & Methods section for specific information). Note: for each figure and biomass type, bars with the same letter are not significantly different (P >0.05) using LSD.

- In 2022, the combination of Zn+Cu (with either MAP or SCM) and transplanted topsoil increased wheat grain (26.7%) and total (29.8%) biomass compared with the unamended control (Fig 1a). There were no treatment effects on canola grain yield, due to grasshoppers feeding on pods, while the application of Zn+Cu+MAP increased canola straw (38.9%) and total (34.1%) biomass compared with the control (Fig. 1b). As in previous years, reduced crop growth under drought, especially on a knoll landscape position, likely inhibited the full expression of treatment effects and, therefore, limited the differences observed among treatments, regardless of crop.
- Over the entire three-year period (2020-2022), the transplanted topsoil increased the cumulative grain (33.5%), straw (47.8%), and total (42.2%) biomass compared with the control, along with producing more grain (28.1%), straw (39.0%), and total (35.0%) biomass than the other treatments (data not shown). The greater biomass production in the transplanted topsoil plots during this study, primarily reflects the combined effects of better soil structure, fertility, and water-holding capacity associated with its thicker topsoil. Both Zn+Cu+MAP (straw and total) and Zn+Cu+SCM (grain, straw, and total) also increased the three-year grain (16.2%), straw (18.9%), and total (16.2%) biomass production compared with the control (data not shown); indicating the importance of providing adequate soil P and micronutrient supplies within calcareous soils like these.
- For the third consecutive year, crop growth was not affected by char alone. The ineffectiveness of the recycled-tire char was probably due to a combination of the low rate applied and restricted plant availability of its recalcitrant Zn in these soils.
- The observed trends in crop nutrient uptake were primarily controlled by biomass yield, with the Zn+Cu (with either MAP or SCM) and transplanted topsoil treatments increasing the crop N (29.8%; data not shown), P (25.2%), Cu (48.1%), and Zn (59.8%) uptake compared with the control (Figs. 1c-e).
- After three years, averaged across both knolls, the improved water-use efficiency (57.6% higher), SOC content (41.5%), and K_{fs} (2.4× greater) following topsoil replacement (data not shown), is consistent with the enhanced water retention, high organic matter content, and increased porosity associated with its lower bulk density.
- There were no treatment effects on NO_3-N or PO_4-P within runoff water at either knoll (data not shown). The undesirable elevated snowmelt PO_4-P runoff export observed with the MAP after the first growing season was no longer apparent in 2022; likely due to the strong P-fixation within these calcareous soils.

CONCLUSION

- Despite sub-optimal growing season moisture levels for three consecutive years greatly inhibiting wheat, field pea, and canola growth, restoring eroded topsoil back on the knolls clearly was the most effective amendment for increasing annual crop productivity on these degraded knoll landscape positions. Although the practicality and/or economic feasibility of topsoil replacement was not assessed in this study, this treatment serves well as a top end "optimal control" for comparison with other treatments.
- Depending on the crop, positive growth responses to applied MAP, Zn, and SCM initially, in addition to delayed response to combinations of $ZnSO_4$+$CuSO_4$ (with either MAP or SCM) in year three, indicate potential short- and longer-term benefits from these amendments.
- The imposed treatments had less impact on improving field pea growth compared with wheat and canola; probably reflecting field pea's lower water requirement and an effective root system proficiently scavenging for soil nutrients such as P and micronutrients, as well as fixing N from the air.

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