Crop Rotation Influence on Soil Quality and Fertility

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Background

It is commonly stated that organic crop production systems are more sustainable than conventional cropping systems and improve soil quality and health. This has not been documented in northern Ontario, so this study was initiated to compare those systems without chemical inputs to typical livestock based rotations.

Methods

The study was initiated in 1990 at two (2), Ontario Ministry of Agriculture and Food (OMAF), research sites in NW Ontario - on an Oskondaga silt loam in Thunder Bay district and Emo clay loam in Rainy River district.

Three cropping systems were evaluated:

1. A typical livestock based rotation (barley, barley seeded down, and 3 years of alfalfa) using herbicides for weed control and fertilizer, manure and legume N credits to meet nutrient needs.
2. Continuous cereal rotation (barley) using herbicides for weed control and fertilizer to meet nutrient needs.
3. Low Input, Sustainable Agriculture or LISA (faba beans, barley underseeded to red clover, red clover forage, mixed grain of barley, oats and peas, and buckwheat plowdown followed by ryegrass covercrop) using covercrops and tillage to control weeds and rock phosphorus, manure and legume N credits to meet nutrient needs.

The study was conducted between (1990-94) for 5 years for a full rotation with every crop included in the rotation every year.

The plots were a RCB design with 4 replicates and individual plots were 20' wide by 100' deep.

Livestock and continuous barley used commercial fertilizer as per OMAF recommendations. The last alfalfa crop received 10t/ac beef manure before fall plowing.

At the beginning of the study, Kapuskasing Rock Phosphate was applied at 0.4 t/ac to one half of each LISA plot. At 32.1% total P_2O_5 and 1.4% available P_2O_5 this supplied 290 lb total P_2O_5 /ac or 12 lb available P_2O_5 /ac. Manure followed fababean harvest at 10 t/ac beef manure

On average, the beef manure supplied 60lb N, 24 lb P_2O_5 and 135 lb K_20/ac at Thunder Bay and 90 lb N, 46 lb P_2O_5 and 260 lb K_20/ac at Emo.

Manure being applied to last year of alfalfa in the livestock rotation

Measurements

- Soil samples were taken at 0-6" depth from 15 pokes/plot following harvest each fall. Samples were analysed at the OMAF lab at Ridgetown College for pH, Olsen P, exchangeable K and organic matter.
- Nitrogen analyses of soil and tissue were done when differences were visible.
- Earthworm populations were determined in 1994 through extraction with dilute formaldehyde within a 1 m^2 frame. Statistical analysis was conducted on lognormal transformed data.

Rotation influence on soil nutrient levels and organic matter

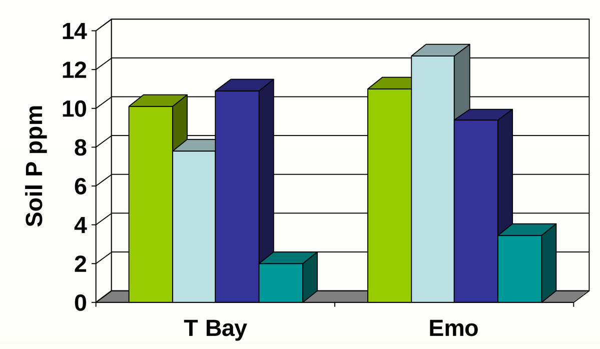


Figure 1. Change in Soil P levels (Na bicarbonate or Olsen P) between initiation 1990 and final 1994.

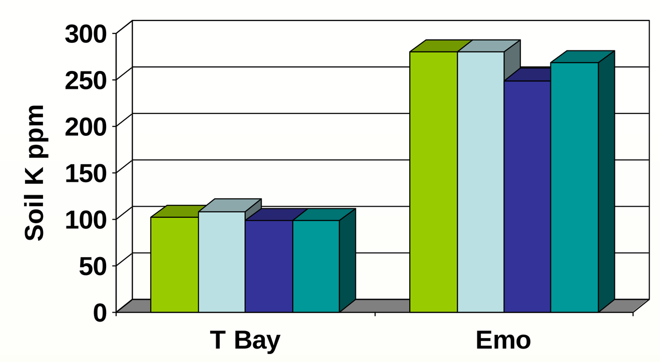


Figure 2. Change in Soil K levels (ammonium acetate exchangeable K) between initiation 1990 and final 1994.

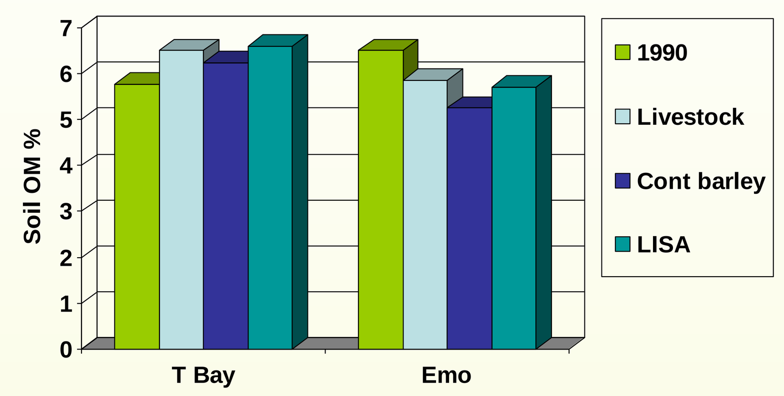


Figure 3. Change in Soil Organic Matter levels between initiation 1990 and final 1994

- Soil P levels were maintained at original levels under the livestock and continuous cereal rotations, but declined significantly under the LISA rotation. (Fig 1)
- Soil K and OM levels changed little, with some decline under continuous cereals at Emo. (Fig 2 & 3)

Rock Phosphate influence on soil/crop performance

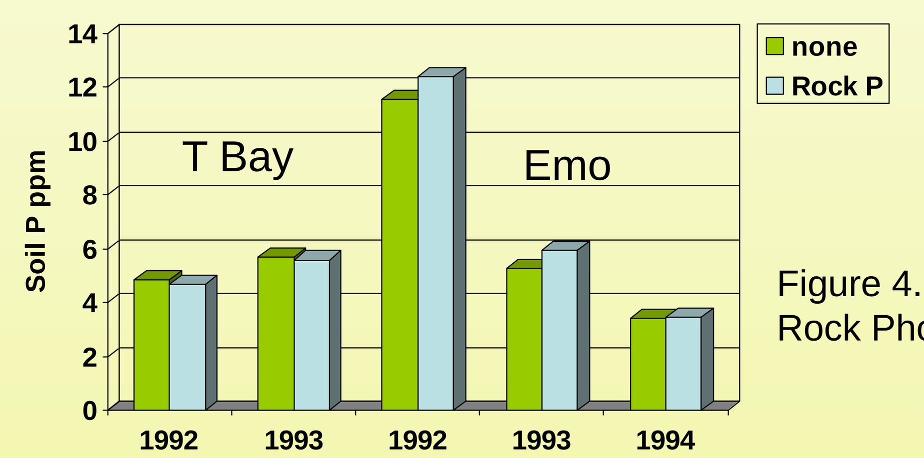
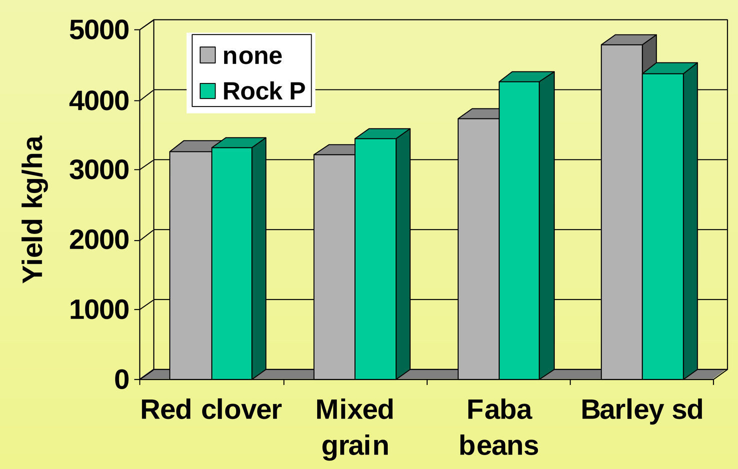


Figure 4. Soil P levels as affected by Rock Phosphate application.



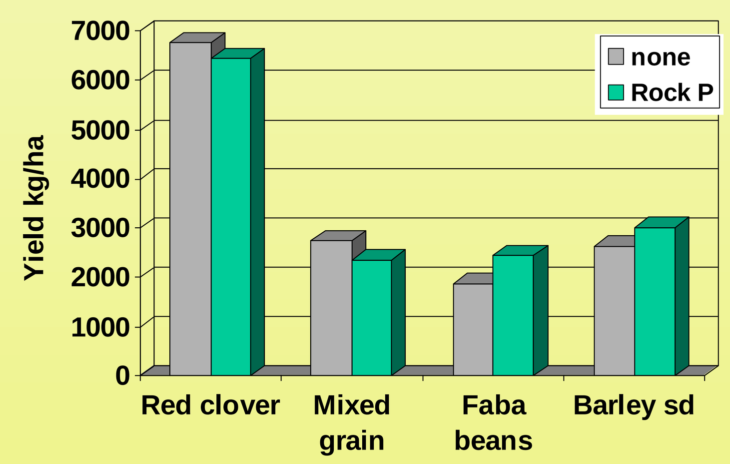


Figure 5. Crop Yields as affected by Rock Phosphate at a) Emo and b) Thunder Bay (1992-94).

Rock phosphate had no impact on soil P levels (Fig. 4), and had little if any affect on crop yield: Only faba beans increased in yield with added rock P. (Fig. 5).

Rotation influence on soil and plant nitrogen

Figure 6. Nitrogen nutrition of barley – LISA barley on left underseeded to red clover vs continuous barley on right suffering N deficiency and leaf diseases.

Measurement of soil nitrate and plant tissue N levels were similar for LISA and livestock rotations (data not shown).

Nitrogen nutrition does not appear to be limiting for cereal growth and yield in the LISA rotation, due to legume and manure use.

Earthworm Populations

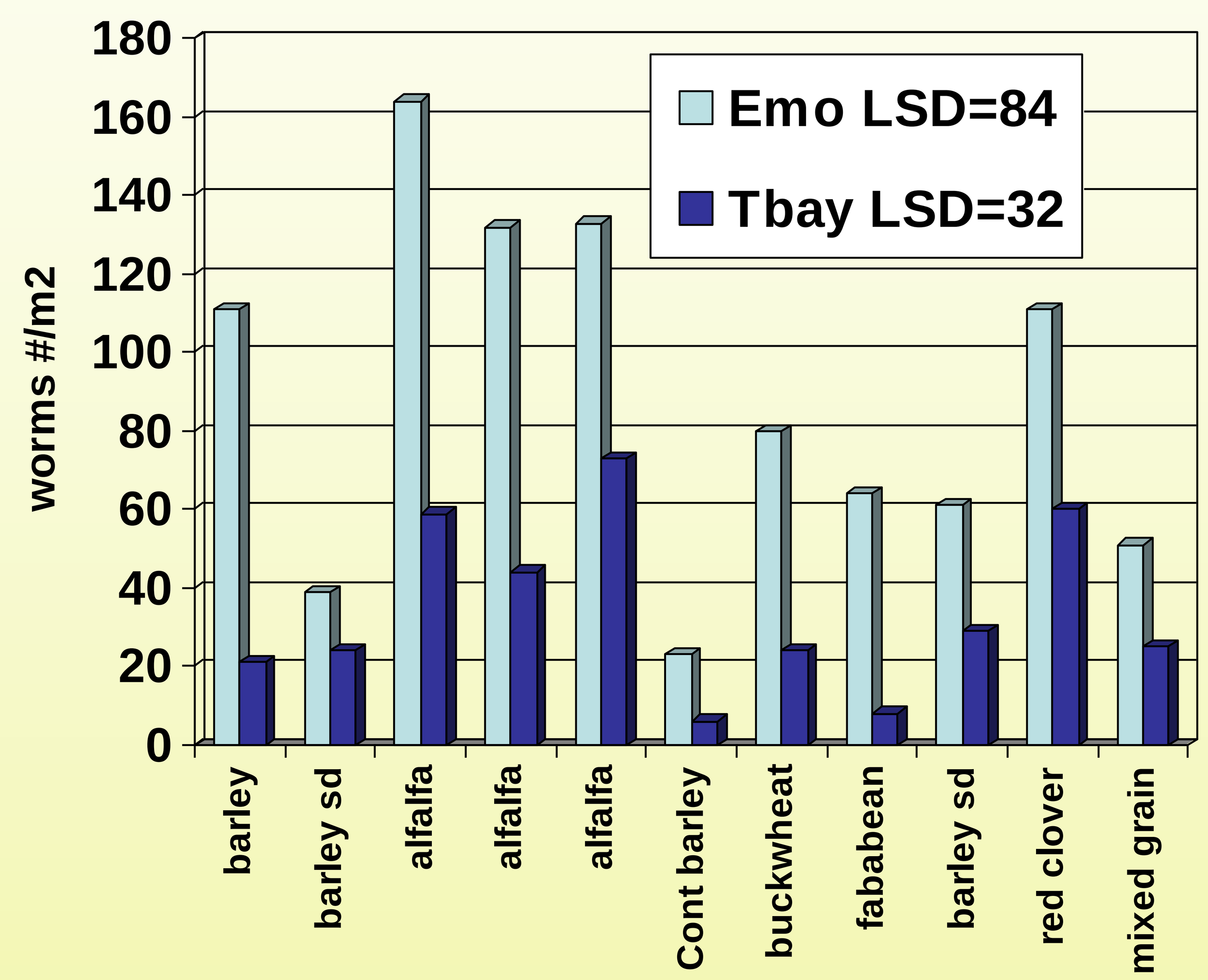


Figure 7. Earthworm numbers determined in 1994.

Extracted earthworms were almost exclusively surface or topsoil dwellers. Differences are noted in Figure 7.

Orthogonal contrasts indicated :

- More earthworms under the livestock than LISA rotation
- More earthworms under forages than the annually tilled crops
- More earthworms under livestock forages than LISA red clover at Emo
- Earthworm numbers were lowest in cereals but did not differ among rotations

(Note: 100 earthworms/m2 is considered a healthy soil)

Summary

- Nitrogen sufficiency may be achieved under LISA production with manures and legumes in rotation, but P mining may be a serious impediment to long-term productivity. Rock P largely was ineffective in supplying P.
- Soil organic matter levels were best maintained in those rotations with forages and manure application compared to continuous cereals. Similarly manure application helps maintain soil K levels.
- Earthworm numbers were affected more by tillage than the type of rotation. Previous fall and spring tillage reduced numbers dramatically.
- The soil quality, as determined by general nutrient, OM and earthworm numbers was greatest under the livestock rotation. Lowest soil OM and earthworm numbers were under the annually-tilled cereal monoculture.