ONTARIO

Fertilizer Increases Corn Yield and Soil Organic Matter

By E.G. Gregorich and C.F. Drury

Soil and crop management practices, including fertilization and crop rotation, affect both crop productivity and soil characteristics. For example, at the Rothamsted Experimental Farm in the United Kingdom, monoculture wheat and barley yields have been sustained for 150 years with annual application of organic or inorganic fertilizers, and soil organic matter content of the soil increased under inorganic fertilization.

An Ontario study shows that fertilization and crop rotation not only improve corn yields, but also increase soil organic matter levels under continuous corn with fertilization.

A long-term experiment started in 1959 in southwestern Ontario, Canada, provided the opportunity to study the effects of fertilization, crop rotation, and weather on corn yields, as well as the effects of fertilization on organic matter levels in soil under continuous corn.

Corn Yields

The use of mineral fertilizers in North American crop production increased steadily from 1950 up to the early 1980s. Many studies have demonstrated crop yield increases in response to fertilization, particularly when adequate water is available. Crop rotations have been used to increase soil organic matter, reduce soil erosion, lower the risk of insects and diseases, and, when legumes are included, to supply nitrogen (N) to the soil for the following crop.

We examined the yields of corn grown continuously or in rotation (corn-oats-alfalfa-alfalfa) with and without fertilization (115-60-30 lb/A N-P_2O_5-K_2O) for 35 years. As shown in **Figure 1**, the fertilized rotation corn treatment produced the highest average yields (123 bu/A), followed by the fertilized continuous-corn treatment (96 bu/A). Fertilization increased yields by 279 percent for continuous corn and by 70 percent for rotation corn. Yield fluctuations were largest for unfertilized continuous corn and

FERTILIZED continuous corn plot at left is contrasted with fertilized rotation corn plot at right above.

NON-FERTILIZED continuous corn plot shown at left above shows very limited growth compared to non-fertilized rotation plot at right.

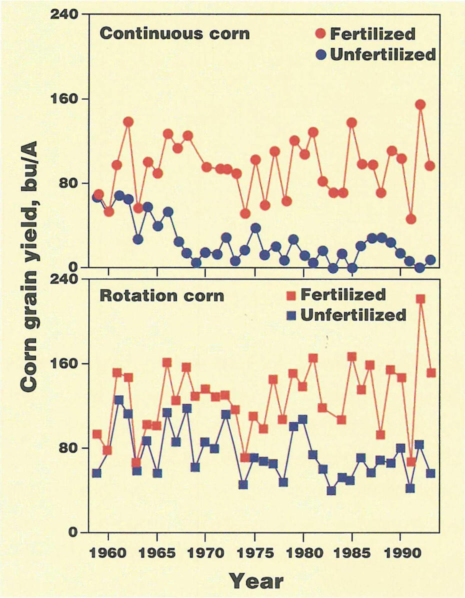

Figure 1. Fertilized-rotation corn produced highest yields over a 35-year period (Ontario).

smallest for fertilized rotation corn. Yields increased over time for the fertilized rotation corn, remained fairly steady for the fertilized continuous corn, and decreased over time with both unfertilized treatments. Growing season precipitation was the only weather variable tested that related significantly to crop yield; July precipitation was proportional to crop yield for both fertilized treatments. However, weather variability had little effect on yields of unfertilized corn.

Crop rotation and fertilization have dramatically changed soil properties such as soil structure and organic matter. These changes have affected soil tilth, water drainage and moisture retention, bulk density, and soil fertility. During the period of this long-term study, crop varieties have also improved. Therefore, yield averages from 1989 to 1993 are useful to assess the long-term effects of these soil and crop management practices on the present day productivity of the soil (**Table 1**).

TABLE 1. Average corn grain yields from 1989 to 1993 and organic matter levels in soils under different management practices.

Management practice	Fertilization $N-P_2O_5-K_2O$, lb/A	Grain yield, bu/A	Organic matter, %
Continuous corn	115-60-30	104	3.5
Continuous corn	0-0-0	12	3.1
Rotation corn	115-60-30	145	4.3
Rotation corn	0-0-0	65	3.2

Soil Organic Matter

The amount of organic matter in soil is related to the amount of plant residues returned to the soil and the rate at which those residues decompose. Fertilization affects the vigor and yield of a crop, thus affecting the amount of crop residues left after harvest and, in turn, the amount of soil organic matter generated by these residues. We looked at the effects of fertilization on the turnover and storage of carbon (C) derived from corn residue in a medium-textured soil that had been under continuous corn for 32 years. Using a ^{13}C isotopic technique, we were able to differentiate between soil organic matter derived from corn, a C_4 plant, and soil organic matter derived from the C_3 plants that grew prior to corn cultivation.

We found that soil under continuous corn, fertilized for more than 30 years, had greater amounts of soil C than systems that were unfertilized (**Table 2**). The difference between the amount of C present in the fertilized and unfertilized systems was attributed to the amount derived from corn (C_4-C). About 22 percent of the organic C was derived from corn in the fertilized soil, whereas only 14 percent of the organic C was derived from corn in the unfertilized soil. The amount of C derived from plants present before the experiment

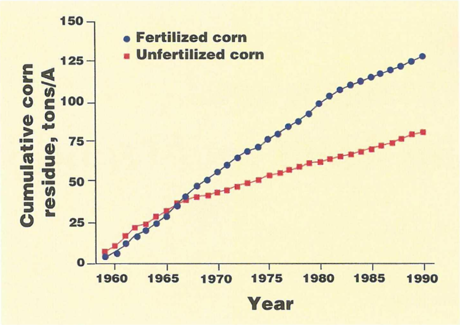

Figure 2. Amount of corn residue returned was estimated at 128 tons/A for the fertilized system and 71 tons/A for the unfertilized treatment.

was initiated (C_3-C) was the same in fertilized and unfertilized soils under continuous corn. This indicated that long-term fertilization did not enhance the decomposition of the native soil organic matter.

The isotopic technique, along with estimates of plant biomass from the annual yield data (**Figure 2**), allowed us to calculate a C budget for the soils. Over the period of the study the total amount of corn residue returned was estimated at 128 tons/A (51 tons/A of C) for the fertilized system and 71 tons/A (29 tons/A of C) for the unfertilized system. The difference between the amount of C returned to the soil (estimated from yields) and the amount remaining in soil (estimated using the isotopic technique) shows that about 80 percent of the C from corn is decomposed and lost from the soil regardless of whether the crop had been fertilized.

We separated the floatable organic matter, called the light fraction, in order to evaluate the effects of fertilization on easily decomposable organic matter that would be a short-term source of nutrients. Between 40 and 70 percent of the light fraction organic matter in the surface 4 inches of both soils was derived from corn residues. However, there was more than twice as much light-fraction C in the fertilized soil as in the unfertilized. This difference was accounted for by the greater amount of C derived from corn residues in the fertilized system.

Conclusions

We concluded from this study that adequate fertilization improves corn yields, and that growing corn in rotation enhances yields further. Without adequate fertilization, crop yields are depressed even when other environmental factors, such as precipitation, are ideal. Yields of corn grown continuously without fertilization decline dramatically over time.

The results of this study also indicate that adequate fertilization contributes to the build-up of organic matter in soil and that fertilization does not significantly alter the turnover of native soil organic matter. BC

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TABLE 2. Amounts of organic C, corn-derived C, and native C in fertilized and unfertilized corn soils.

$N-P_2O_5-K_2O$, lb/A	Total carbon	Corn-derived carbon	Native carbon
		tons/A	
115-60-30	40	9	31
0-0-0	36	5	31