# Does Fertilizer N "Burn Up" Soil Organic Matter?

By J.H. Grove, E.M. Pena-Yewtukhiw, M. Diaz-Zorita, and R.L. Blevins

**This long-term Kentucky study evaluated the impact of tillage and N rates on crop yield and soil organic matter (SOM). After 29 years of continuous corn with a winter cereal cover crop, the combination of no-till cropping and fertilizer N use resulted in SOM levels similar to those in adjacent grass sod. There was no evidence that fertilizer N caused SOM loss.**

Historically, soil scientists thought soil organic carbon (SOC) and N to be inextricably, and positively, coupled. Soil science textbooks note losses of SOM and "associated nutrients", including N, P, and S when discussing soil productivity degradation. Though much research effort is now directed towards soil quality and C sequestration, most recent research reports on these topics are not accompanied by information regarding changes in the status of the other organic-bound soil nutrients.

Current emphasis on soil C storage means that understanding soil/crop management practices contributing to SOM gain/loss is important. Again, textbooks generally teach that crop productivity is increased when a needed nutrient (or any other limiting factor) is provided. Plant growth provides the residual C that eventually becomes SOC. Because, next to water, fertilizer N is the largest driver of cereal crop growth, it is generally believed that needed plant nutrition contributes positively to SOM. In contrast, Khan et al. (2007), using historical and new data from the long-term Morrow plots at the University of Illinois, reported that their "research findings implicate fertilizer N in promoting the decomposition of crop residues and soil organic matter…" This challenges the established view.

Close reading of the paper by Khan et al. (2007) indicates that the changes in SOM that were observed result from a number of co-incident and confounding practices/processes. The Morrow Plots were converted from tall-grass prairie in 1876, tile-drained in 1904, subjected to complete crop residue removal until 1955 (all plots) or 1967 (some plots), and chisel plowed rather than moldboard plowed after 1997. Soybean replaced oats in one of two rotations in 1967. Selected plots were converted from co-applications of organic C and other nutrients (as manure) to inorganic fertilizer nutrient sources in 1955 (some plots) and 1967 (some more plots). Such confounding begs sampling appropriate temporal and spatial 'controls'.

Our objective was to examine the agronomic and soil evidence needed to test the hypothesis that long use of fertilizer N has resulted in a depletion of SOC. We determined profile SOC levels resulting from: 1) the conversion of an established sod to continuous corn production; 2) the continuous use of no-tillage (NT) or moldboard plow (MP) soil tillage management; and 3) the continuous application of zero, adequate, or excessive quantities of fertilizer N.

## Methodology

This field trial was started in 1970 on the University of Kentucky research farm near Lexington. The site was a bluegrass (*Poa pratensis* L.) pasture for the previous 50 years. The soil is a well-drained Maury silt loam (fine, mixed semi-active, mesic Typic Paleudalfs). The experiment is continuously summer cropped to corn (*Zea mays* L.) for grain, followed by a winter annual cereal cover crop. Moldboard plowing, to a depth of 8 to 10 in., is done in the third or fourth week of April, about 1 to 2 weeks before planting corn. The NT crop is seeded through prior corn and cover crop residues using a cutting coulter-double disk opener planter equipped with row cleaners. The fertilizer N source, ammonium nitrate, is surface broadcast within 1 week of planting. Corn is harvested in late September or early October, and a NT drill is used to plant the winter cereal cover crop through the combine-shredded residues left over the surface of the entire experiment.

**Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; S = sulfur; ave = average.**

**Experimental area:** post tillage and pre-plant.

**Experimental area:** vigorous mid-vegetative growth.

**Table 1.** Average corn grain yields: First 15, last 15, and all 39 years.

| Tillage system | Fertilizer N rate, lb/A | ------ Corn grain yield, bu/A ------ First 15 years (1970-1984) | Last 15 years (1994-2008) | All 39 years (1970-2008) |
|---|---|---|---|---|
| Moldboard plow | 0 | 86 | 44 | 60 |
| | 75 | 120 | 101 | 106 |
| | 150 | 123 | 116 | 116 |
| | 300 | 128 | 123 | 122 |
| No tillage | 0 | 71 | 52 | 61 |
| | 75 | 116 | 112 | 110 |
| | 150 | 126 | 133 | 126 |
| | 300 | 128 | 130 | 126 |

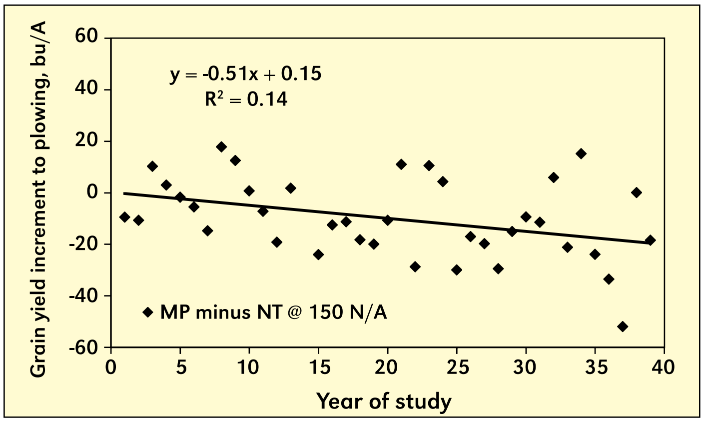


**Figure 1.** Grain yield increment to moldboard plowing at 150 lb N/A over the course of the study.

The experiment contains four replications of two tillage treatments, NT and MP, and four fertilizer N rates (0, 75, 150, and 300 lb N/A/year). Tillage and N rate treatments have been maintained on the same plots for the duration of the experiment. Three intact soil cores were taken, to a depth of 40 in., from the 0, 150, and 300 lb N/A/year plots and from the unfertilized surrounding grass sod at each of the four corners of the trial. Cores were divided into 4 in. depth increments, composited, and sub-sampled for gravimetric moisture content and subsequent calculation of soil bulk density. The remainder was air-dried and crushed. Air-dried samples were used to determine SOC by dry combustion.

## Observations

Corn growth differences due to fertilizer N are often dramatic (bottom photo, previous page), as are growth differences in the winter cover crop (top photo, previous page), though the latter are rarely measured. Averaged over 39 years of study, there is little difference in corn yield response to N for the two different tillage systems, but that response has changed over time **(Table 1)**. The first 15 years, NT corn was more N responsive, but MP corn has become more N responsive the last 15 years. Generally, 150 lb N/A has been the nearly optimal N rate, in both tillage systems **(Table 1)**. The annual yield response to plowing, at 150 lb N/A, was positive in 12 of 39 years, but is declining with time, at 0.5 bu/A/year **(Figure 1)**. As suggested by the decline in unfertilized corn

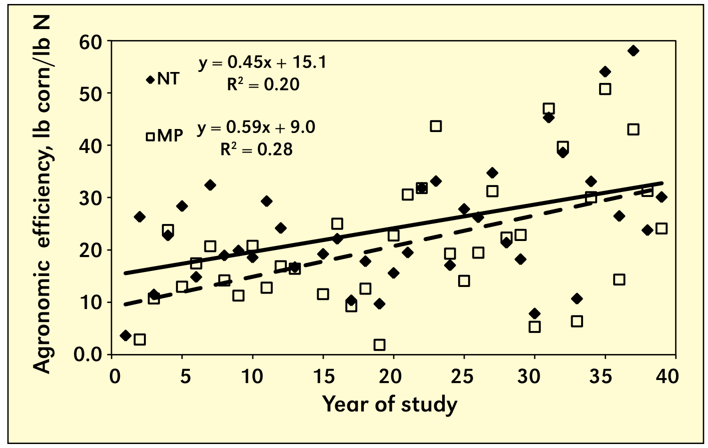


**Figure 2.** Corn agronomic efficiency (lb corn/lb N) for the first 150 lb N/A, over the time course of the study.

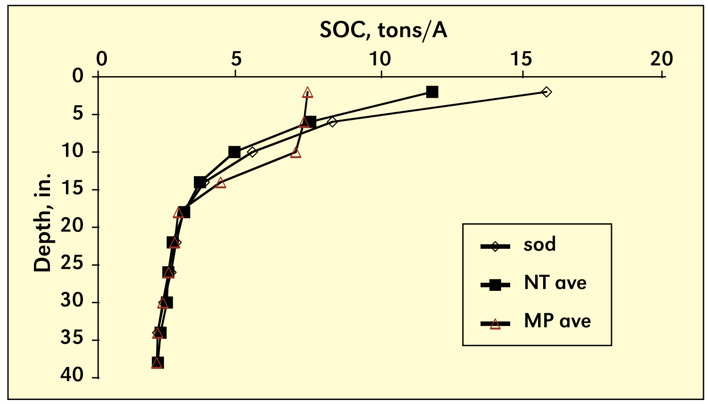


**Figure 3.** The impact of tillage systems (averaged across fertilizer N rates) on the distribution of SOC within the soil profile.

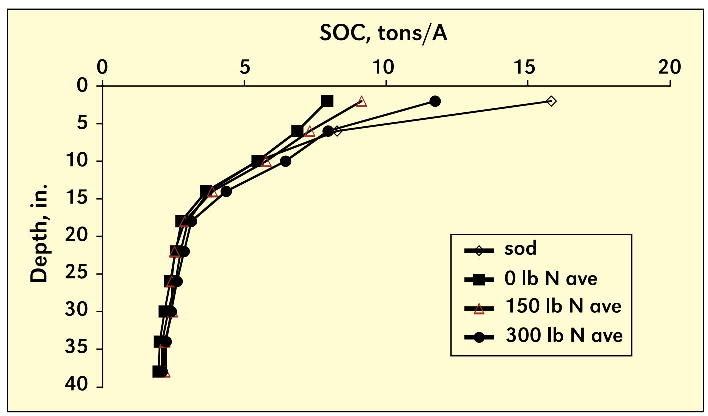


**Figure 4.** The impact of fertilizer N rates (averaged across tillage systems) on the distribution of SOC within the soil profile.

yields in **Table 1**, the agronomic efficiency for fertilizer N (lb corn/lb N) has increased with time, in both tillage systems **(Figure 2)**. Initially, the annual fertilizer N yield response was greater with NT, but that for MP rose 25% faster, and has become similar.

**Figures 3 and 4** illustrate how the long-term treatments have caused differences in the distribution of C within the sampled soil profiles. The impact of tillage on SOC, relative to the surrounding sod, is limited to the upper 16 in. of the profile **(Figure 3)**. Continuous no-till corn production has resulted in a SOC distribution similar to that of the surrounding sod. Moldboard plow tillage causes a more uniform SOC distribution

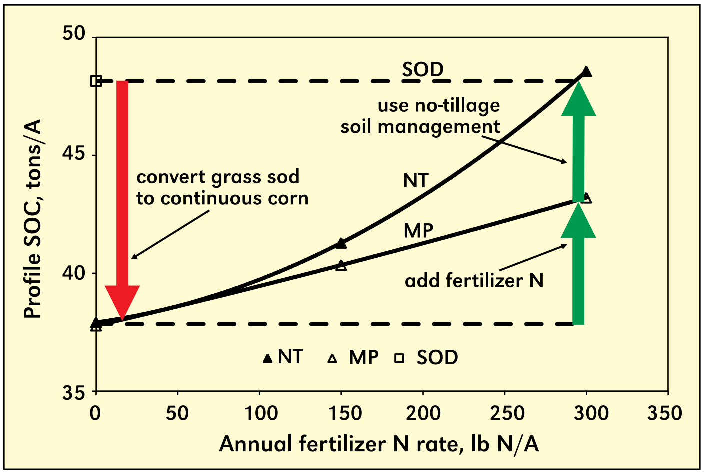


**Figure 5.** The impact of fertilizer N on total profile SOC levels found after 39 years of cropping to continuous corn with a winter cereal cover crop.

in the upper 12 in. of soil. Fertilizer N rate influenced profile SOC to a depth of 20 to 24 in., probably because of greater root growth with N fertilization **(Figure 4)**. The surface 4 to 8 in. of soil exhibited the greatest SOC response to fertilizer N rate. The unfertilized sod exhibited the greatest SOC, primarily because of the large amount (16 tons/A) found in the surface 4 in. of soil.

## Interpretation/Conclusion

**Figure 5** summarizes our findings. Profile SOC was as low as 38 tons/A, where corn has been grown without N fertilization, and regardless of tillage system. Profile SOC was as high as 48 tons/A, under the unfertilized grass sod and also where NT corn was grown with an agronomically excessive annual N fertilization rate of 300 lb N/A/year. Without N fertilizer, conversion of grass sod to continuous corn, with a winter cereal cover crop, has resulted in about 20% less SOC. At 150 lb N/A/year, the corn soils contain about 15% less SOC than the sod. Plow tillage has an increasing impact on SOC with greater fertilizer N rate, resulting in 10% less SOC at 300 lb N/A/year.

The agronomic evidence indicates that fertilizer N is needed for adequate yield and that the need for supplemental N nutrition has become greater with time and tillage. The greater need for added N is due to reduced soil N release from the SOM reservoir, itself diminished by both time and tillage.

There was no evidence that fertilizer N caused SOM loss. With NT and a winter cereal cover crop, 150 lb N/A/year appears to sustain corn yield, but it appears that more fertilizer N will be needed to sustain MP corn yield. Tillage-caused losses of SOM are outpacing N derived gains, at 150 lb N/A/year. The loss of SOC was more associated with agroecosystem change, than with tillage. The gain/maintenance of SOC was most associated with N fertilization, which presumably increased crop and winter cover crop dry matter formation, and with no-tillage, which conserves that carbon-laden material.

Well-informed soil management should cause, as much as is practical, SOM to be maintained/replaced. Soil management science should acknowledge, rather than confuse/confound, the roles of different practices, acting over different time frames. The oxidative practices (drainage, tillage, and fallow), the reductive practices (photosynthesis, immobilization, and denitrification), and the mass transfer practices (additions of compost, manure, etc.; removal of grain, stover, etc.) all contribute to the SOM we have today.

On this soil, crop productivity and C sequestration are intimately linked agroecosystem services – services fostered by management practices appropriate to this soil – no-tillage and fertilizer N application. BC

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## References

Khan, S.A., R.L. Mulvaney, T.R. Ellsworth, and C.W. Boast. 2007. Journal of Environmental Quality. 36:1821-1832.

# 10th International Conference on Precision Agriculture Set for July 18-21 in Denver


The 10th International Conference on Precision Agriculture (ICPA) is set for July 18-21, 2010, in Denver, Colorado. Dr. Rajiv Khosla of Colorado State University will serve as Conference Chairperson for the event. Dr. Harold Reetz of IPNI/FAR serves on the Organizing Committee, along with Dr. Dwayne Westfall of Colorado State University and Mr. Quentin Rund of PAQ Interactive.

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