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The trays are subdivided with hardboard dividers into four main compartments that may be subdivided further (Fig. 3). The main dividers are flush with the top of each tray to give internal support to the hardware-cloth bottoms down to the stack support in the base. Twelve 2.9-cm holes per tray were drilled near the top of the main dividers to facilitate air movement throughout the stack. To maintain turbulance in the stack 5.1-cm-wide duct tape was affixed to the hardware cloth under the main dividers, and 2.5-cm-wide duct tape was affixed around the edges of the tray bottoms.

The cap, 61.0 × 61.0 × 15.2 cm, also of sandwich construction, had a plywood top with a 19.7-cm-diam exhaust port. Exhaust air was vented to the outside to maintain ambient room air at a relatively constant temperature.

The four dryer units were operated in 1979 and 1980 at 35, 40, 45, or 50 C. Ambient air was relatively constant at 22 ± 1 C. Ambient relative humidity was monitored with a hydrothermograph in 1980 and was found to be 45 ± 5%. No determinations of relative humidity were made in 1979. Four stackable trays and eight stackable trays per unit were used in 1979 and 1980 respectively. Airflows of 1.3 and 18.4 liters/sec/m^2 were used in 1979 and 1980, respectively, depending on the stack height, to obtain greater uniformity throughout the stack.

In 1979, 10 ears were placed in each main section of the trays, with a total of 40 ears per tray. Subdividers were used in 1980 (Fig. 3), and six ears were placed in each subdivision in the bottom five trays, with a total of 48 ears per tray. The upper three trays were loaded with 80 ears per tray.

Table 1 shows the measured temperatures in the dryers in 1979 and 1980 at the bottom, just below the first tray of corn, and at the top, in the exhaust port. Over both years, a temperature drop of 0.4 to 4.2 C occurred from the bottom to the top depending on the drying temperature. Because a drop of 1 C or less has been noted when the dryers have been operated at all temperatures without corn, evaporative cooling probably accounts for the temperature drop. Inasmuch as all seed in a thin-layer drying system is, in theory, exposed to air of uniform temperature and humidity, the evaporative cooling noted here would indicate a small departure from the thin-layer concept.

In spite of the increased height of the stack, which allowed more ears to be dried in 1980, the 2 years are quite comparable in temperature differential from bottom to top and in variability as indicated by the standard deviations. Increased airflow in 1980 evidently helped prevent excessive cooling. Measured mean temperatures in both years were within 0.3 C of the desired temperatures.

The dryers are quite flexible. They are capable of drying shell corn or bulk soybeans [*Glycine max* (L.) Merrill] as well as ear corn. By connecting the exhaust ports of two adjacent stacks, these units could also be used to recycle exhaust air in a two-pass arrangement through the second stack. Convenient unstacking of the drying trays facilitates rapid addition or removal of samples and transfer of samples from one drying environment to another. These units not only serve to supply seed that have been dried under defined conditions for physiological studies, but can also be used to screen germplasm for tolerance to high drying temperatures. Although quality estimates from seed dried with use of the system described here would not necessarily reflect the mean performance that could be expected from a seed lot dried in a large commercial dryer, they could be used as indices of the relative tolerances of different seed parents to high drying temperatures. Since producers of hybrid seed corn in the North American Corn Belt are often hard pressed to complete their harvest and drying operations before the onset of inclement weather such information should be helpful to them in maximizing dryer efficiency while minimizing potential damage.

EFFECT OF N FERTILIZER AND CORN RESIDUE MANAGEMENT ON ORGANIC MATTER IN MINNESOTA MOLLISOLS[1]

P. R. Bloom, W. M. Schuh, G. L. Malzer, W. W. Nelson, and S. D. Evans[2]

ABSTRACT

Two long-term continuous corn (*Zea mays* L.) experiments were used to determine the effect of the rate of stover return on soil organic matter in high organic matter mollisols (O.C. > 2.4%). One experiment was an N rate experiment which had been cropped for 19 years. The other was a stover-fertility management study which had been cropped for 13 years in which there were two stover management treatments: total removal and plowdown, both at high and low fertility. In the N rate experiment a 3-ton ha^{-1}yr^{-1} difference in stover yield between the low and high N rates resulted in a 4.5% less organic carbon content for the lower N rate after 19 years. All of the treatments in the stover management study had no significant changes in organic matter content after 13 years except for the low fertility-stover removal treatment which had 15% less organic carbon. It was concluded that for precise estimates of treatment effects on organic carbon loss in mollisols, longer treatment times are needed.

Additional index words: **Organic carbon, *Zea mays* L., Residue removal.**

Soil fertility practices and residue management both have an impact on the long-term effects of cropping on soil organic matter. The direction and magnitude of the rate of change in organic matter content with a change in management is a function of the rate of return of aboveground residues (Barber, 1979; Larson et al., 1972; Snowden and Atkinson, 1968) and the quantity of root biomass and root exudates produced (Barber, 1979).

Under continuous corn (*Zea mays* L.), removal of the stover plus grain has been shown to have a deleterious effect on organic matter content of mollisols in Indiana (Barber, 1979) and Iowa (Larson et al., 1972). Nitrogen fertility also effects soil organic carbon stability. The results of long-term continuous corn

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[2] Assistant professor of soil science, graduate student, assoc. prof. of soil science, professor of soil science and superintendent of Southwest Exp. Station, professor of soil science at the West Central Exp. Station, respectively. University of Minnesota St. Paul, MN 55108.

Table 1. Effects of ammonium nitrate and urea on soil organic carbon after 19 years of continuous corn at Lamberton.

Nitrogen kg ha⁻¹	Number of replications	Residue plowed down kg ha⁻¹ yr⁻¹	Organic carbon, %
0	9	4,880	2.63
45	32	6,750	2.74
90	24	7,720	2.70
180	12	7,930	2.75
Significance (0.05) HSD.			NS

Table 2. Effect of fertility and silage removal on soil organic carbon after 13 years of continuous corn at Morris.

Treatment	Residue plow down kg ha⁻¹ yr⁻¹	Organic carbon Initial %	Final %	% change†
A, silage low fertility	0	2.63	2.25	−15
B, silage high fertility	0	2.47	2.37	−3.6
C, grain low fertility	6,410	2.58	2.58	−0.2
D, grain high fertility	6,820	2.44	2.49	+2.9
Significance (0.05) HSD		NS	NS	12.7

† [(Initial carbon − Final carbon)/Initial carbon] 100.

experiments in Indiana (Barber, 1979) and Iowa (Moldenhauer et al., 1967) suggest that lower N fertility results in lower organic carbon contents. The cooler climate of Minnesota might be expected to slow the process of carbon loss (Jenny, 1941).

The objective of this study was to determine the effects of residue and fertility management on organic matter in very high organic matter mollisols (O.C. > 2.4%) under the cool sub-humid climate of the northern Great Plains. This has special relevance considering the current interest in utilization of corn stover for energy.

MATERIALS AND METHODS

Experimental Sites Two continuous corn experiments in western Minnesota were utilized for this study. One experiment which had been cropped for 19 seasons, was an N management study located at the Southwest Experiment Station near Lamberton. The treatments, each replicated four times, were 0, 45, 90, and 180 kg N $ha^{-1}yr^{-1}$ applied as urea or ammonium nitrate. All plots received and additional 16 kg N $ha^{-1}yr^{-1}$ with the applications of starter fertilizer. Details of the experiment have been described by Nelson and McGregor (1973). The soil was predominantely a Nicollet clay loam (Aquic Hapludoll) with small area of Webster clay loam (Typic Aquoll) at one end of the experiment. The other experimental site, located at the West Central Experiment Station near Morris, had been cropped for 13 seasons. This experiment was established to study the influence of silage removal vs. plow down of stover on yield and soil properties under conditions of both high and low fertility. The low fertility treatment was 87, 54, and 54 kg $ha^{-1}yr^{-1}$ of N, P_2O_5, and K_2O, respectively. The high fertility treatment was 166, 108, and 108 kg $ha^{-1}yr^{-1}$ of N, P_2O_5, and K_2O, respectively. The N was applied as ammonium nitrate. The design was 4 × 4 Latin square using 15 × 15 m plots. The experiment extended over 3 soil series; Hamerly clay loam (Aeric Calciaquoll), McIntosh, silt loam (Aeric Calciaquoll), and Winger silty clay loam (Typic Calciaquoll).

At Lamberton, the stover was incorporated utilizing a moldboard plow after the grain was harvested with a combine. At Morris, the stover was chopped prior to moldboard plowing.

Soil Sampling At the Lamberton experiment, four samples were taken from the plow layer (0 to 20 cm depth, 6 cores per sample) in each of the plots after 19 cropping seasons. At the Morris experiment, one sample (0 to 20 cm) was taken from each plot at the beginning of the experiment and after 13 cropping seasons. The samples were air-dried, ground, and sieved to pass 2 mm.

Laboratory Methods Organic carbon was determined by the Walkley-Black method (Allison, 1965). Total N was determined by semimicro-Kjeldahl (Bremner, 1965).

RESULTS AND DISCUSSIONS

The Effects of Fertility and Residue Management on Organic Matter

The quantity of stover plowed down at each site (Tables 1 and 2) was calculated from yield data. At Morris where both dry matter and grain yields were available, assuming 80% shelling rate, the calculated stover yield was 53% of total dry matter. For the Lamberton experiment, only grain data were available and stover yields were calculated based on the same percentage as at Morris.

Lamberton. There was a small but nonsignificant difference (P = 0.05) in the organic carbon of the zero N plots compared to the N fertilized plots (Table 1). The experimental plots, however, contained considerably less soil organic carbon than an adjacent sod aircraft runway which had 3.36% organic carbon. There was no significant treatment effect on organic N content or C/N ratio. The mean organic N was 0.208 ± 0.015% and the mean C/N ratio was 13.09 ± 0.33.

Comparing the zero N treatment with 180 kg N $ha^{-1}yr^{-1}$ treatment (Table 1) shows that 3,000 kg $ha^{-1}yr^{-1}$ difference in residue resulted in a 4.5% (nonsignificant) less organic carbon content in the zero N treatment after 19 years. A similar effect of N rate on organic carbon was observed for continuous corn in a silty clay loam Typic Hapludoll in southwest Iowa (Moldenhauer et al., 1967). Two plots were compared after a 12-year period. During the last 9 years of this period one plot was fertilized with 179 kg N $ha^{-1}yr^{-1}$ while the other received no N. During the first 3 years no N was applied to either plot. In 12 years organic carbon in the high N plot decreased from 1.84 to 1.74% (5.4% loss of O.C.) and the zero N plot decreased from 1.80 to 1.65% (8.9% loss of O.C.). The high N plot averaged 5,400 kg $ha^{-1}yr^{-1}$ of stover while the low N plot average 3,900 kg $ha^{-1}yr^{-1}$ of stover. In another study of the effects of residue return, at the same site, Larson et al., 1972 found that a 3,000 kg $ha^{-1}yr^{-1}$ decrease in stover residue resulted in a 5% less organic carbon content after 11 years of continuous corn. Larson et al. (1972) also observed an increase in N content and C/N ratio with increasing residue.

The effect of N fertilization after 12 years of continuous corn was also measured on a silt loam Aquic Argiudol in Indiana (Barber, 1979). Nitrogen treatments of 0, 67, and 200 kg N $ha^{-1}yr^{-1}$ yielded stover (calculated from grain yields) of 2,500, 5,500, and 8,800 kg $ha^{-1}yr^{-1}$, respectively. The stover was plowed down and after 12 years the organic carbon levels were 1.57, 1.65, and 1.68%, respectively. The 6,300 kg $ha^{-1}yr^{-1}$ difference in stover residue between the zero N and the 200 kg N $ha^{-1}yr^{-1}$ treatments resulted in only a 7.1% difference in organic carbon.

Larson et al. (1972) obtained a linear relationship between carbon loss and stover residue applied. The relationship obtained however, predicts greater differences between treatments than that observed in the present study or observed by Moldenhauer et al. (1967) and Barber (1979). In the Larson et al. (1969) study, the stover was chopped before incorporation and ammonium nitrate was added to give the stover the same C/N ratio as alfalfa (*Medicago sativa* L.).

Morris. The statistics on the organic matter data from Morris were done with the omission, of one column of the Latin square. The omitted column was for plots along a roadway that had a high initial carbon content (as high as 3.9%). The high carbon contents were likely due to the previous history of the site. Even with the omission of the highest carbon plots the initial carbon contents varied from 2.05 to 3.23%.

A plot by plot comparison of the initial and final carbon values (Table 2) shows that there was a significant decrease in organic carbon in treatment A, and small nonsignificant changes in treatments B, C, and D. The lack of decrease in organic carbon in treatments C and D is expected from the observation of Larson et al. (1972) that 6 tons $ha^{-1}yr^{-1}$ is the quantity of residue sufficient to maintain organic carbon at a constant level. With stover removal at high NPK, however, Larson et al. (1972) observed a 12% drop in carbon after 11 years. This is similar to the data of Barber (1979) showing that under high NPK, stover removal compared to return of stover, results in a 10% decrease in organic carbon after 11 years on a soil with 1.5% organic carbon. Despite the higher carbon content of the Morris soils, compared to the soils studied by Barber (1979) and Larson et al. (1972), the removal of silage under high fertility, treatment B, resulted in only a 3.6% decrease in carbon.

The difference in organic carbon decrease between treatments A and B suggests that fertility level may be important in determining the quantity of carbon contributed to the soils by the roots. Barber (1979) calculated that the root exudates and biomass contribute more to the maintenance of soil carbon than does the stover. The observed NPK effect may be a reflection of what Ohlrogge (1962) calls the "N-P effect" on root proliferation in the plow layer.

CONCLUSIONS

Nitrogen fertility does have an effect on the levels of soil organic carbon under continuous corn cultivation. The data from Lamberton taken together with the results of Moldenhauer et al. (1967) and Barber (1979) demonstrate that when the stover residue is plowed down, lower N levels result in greater carbon losses. The rate of carbon loss, however, was less than predicted by the correlation, found by Larson et al. (1972), between the stover returned and the change in organic carbon. Larson et al. (1972), however, adjusted the C/N ratio of the chopped stover to that of alfalfa. (*medicago sativa* L.).

The effect of fertility on organic matter is due both to its effect on stover yield and the contribution of roots to soil organic matter in the plow layer. The effect of fertility on the contribution of roots was demonstrated by the much greater loss of carbon at Morris when stover was removed under low fertility than under high fertility. The data suggest that the negative effects of stover removal can be greatly mitigated by maintenance of high levels of fertility.

The rate of change in soil organic matter under continuous corn cultivation in the high organic matter mollisols in Minnesota is very slow. The treatment effects observed appear to have similar or slower rates than those observed in Iowa (Moldenhauer et al., 1967) and Indiana (Barber, 1979). Precise estimates of the effect of fertility on organic matter in mollisols under continuous corn will require longer term experimentation.

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