Transforming Manure and Cedar Mulch from “Waste” to “Worth”

Karla Melgar

Agustin Olivo

Richard Koelsch

Larry Howard

Gary Lesoing
gary.lesoing@unl.edu

See next page for additional authors

Authors
Karla Melgar, Agustin Olivo, Richard Koelsch, Larry Howard, Gary Lesoing, Aaron Nygren, Randy Saner, Amy D. Timmerman, Troy Walz, Todd Whitney, and Amy Schmidt

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Summary with Implications

*In nearly every production environment, there are opportunities to capture profits if waste streams can be further processed or enhanced to create "value added" products. Animal feeding operations in Nebraska generate significant amounts of manure that are considered as a "waste" product. Additionally, Eastern red cedar (*Juniperus virginiana*) encroachment into grazing land has become an economic and ecological threat, reducing forage production, fragmenting wildlife habitats, and increasing the risk and severity of wild fires. Value-added uses for cedar woodchips are being sought by the Nebraska Forest Service and other agencies to promote tree management by landowners. Using manure and cedar mulch individually or in combination as soil amendments on agricultural crop land was proposed by farmers in the Middle Niobrara Natural Resource District to assess their impacts on soil health and crop productivity. On-farm research studies were initiated during 2019 at four locations across the state of Nebraska and two more sites were added in 2020. The goal is to document and demonstrate the effects of land applied manure and cedar mulch on agronomic, economic and soil health variables in corn fields under different agro-climatic conditions. Results from the 2019 cropping season indicate that pre-plant applications of beef manure can make significant contributions of nitrogen (N), phosphorus (P) and potassium (K) and K in crop fields without compromising yield, constituting a reliable resource to replace inorganic fertilizers. Depending on initial soil quality, manure also increased soil organic matter (SOM) concentration, pH, and electrical conductivity (EC). Surface applications of cedar mulch did not promote soil acidification or N immobilization, although it induced soil nitrate reduction in top soil layers when incorporated after crop harvest at one research site.*

Introduction

Recycling locally available livestock manure nutrients prior to importing commercial fertilizer is an essential component to improving water quality in areas of intensive livestock production. At the same time, environmental, ecological, economic and social threats posed by eastern red cedar tree proliferation are substantial and relevant throughout much of Nebraska. Individually or together, cedar mulch produced during tree management activities and manure from livestock operations could be beneficial to soil health and crop productivity when applied to agricultural cropland. Following small plot studies at two Nebraska Sandhills farms to measure soil health and crop productivity metrics over three cropping seasons under treatments with manure and mulch, a statewide study was initiated in spring 2019 to expand evaluation of these amendments to large-scale plots in corn fields throughout Nebraska.

Procedure

Research was initiated during spring 2019 on four on-farm research sites located near Saint Paul, Pierce, Ainsworth and Brule, Nebraska. Plots (40 ft. x 350 ft.) were established at these sites prior to the 2019 growing seasons to accommodate at least three different treatments (manure, manure+woody biomass, and control plots that received only inorganic fertilizer) with each treatment replicated four times. Buffers between plots measured 40 ft. Manure sources for these sites included beef feedlot manure at two sites and bedded beef barn manure or beef slurry manure at the other two sites. At the site near Brule, woody biomass was replaced by coal char from a Colorado sugar beet processing plant since wood chips were not readily available. Preplant nitrogen application was the same among all plots within a single site, whether supplied by manure, fertilizer, or a combination of both.

Initial soil chemical, physical and biological properties were determined with soil samples taken before the application of treatments. Subsequent samples were collected at the end of the 2019 cropping season and corn yield was determined for all research sites.

Results

Statistical analysis to assess treatment and experimental effects and interactions between treatments included a one-way or two-way analysis of variance. Least significant difference (LSD) was used to determine differences between treatments at the $\alpha=0.05$ level. Results indicate that single pre-plant manure applications can make significant contributions of macronutrients (N, P and K), constituting a reliable resource to replace inorganic fertilizers. With N balanced among all treatments within each site, no changes in crop yield were observed with manure applications. Depending on initial soil quality, manure also increased SOM, pH, and EC. Surface applications of woody biomass did result in soil acidification or N immobilization, although it induced soil nitrate reduction in top soil layers when incorporated after crop harvest at one research site. More research is being performed during 2020 and two more research sites, located near Julian and Overton, will be added for a first year of treatments.

Conclusions

While in-season application of beef manure remains incompatible with most cropping and manure management systems, utilizing beef manure to replace part or all of corn's pre-plant N needs appears feasible without negatively impacting yield. Most soil physical properties change quite slowly and may require multiple years of manure application to improve. This study will continue for at least two additional cropping seasons to allow assessment of long-term impacts on crop productivity and soil quality with additional annual treatment applications.

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Karla Melgar, graduate student, Biological Systems Engineering, University of Nebraska–Lincoln

Agustin Olivo, graduate student, Biological Systems Engineering, University of Nebraska–Lincoln

Richard Koelsch, professor, Biological Systems Engineering and Animal Science, University of Nebraska–Lincoln

Larry Howard, extension educator (retired), West Point

Troy Ingram, extension educator, St. Paul

Gary Lesoing, extension educator, Auburn

Aaron Nygren, extension educator, Schuyler

Randy Saner, extension educator, North Platte

Amy Timmerman, extension educator, O'Neill

Todd Whitney, extension educator, Holdrege

Amy Schmidt, associate professor, Biological Systems Engineering and Animal Science, University of Nebraska–Lincoln

Table 1. Average initial soil chemical properties for sites A, B, C and D.

	Depth (cm)	SOM (%)	CEC (me 100g $^{-1}$)	pH	EC (mmho cm^{-1})	NO_3^--N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Site A	**0-10**	3.03	14.5	6.15	0.14	11.5	26.5	374.8	7.2	1718.3	193.0	12.5
	10-20	2.05	15.8	6.23	0.12	6.3	9.0	852.8	5.6	2110.5	238.0	16.5
	20-51	-	-	-	-	3.6	-	-	-	-	-	-
	51-91	-	-	-	-	1.85	-	-	-	-	-	-
Site B	**0-10**	2.00	7.4	6.58	0.09	4.0	26.3	234.0	5.7	974.8	122.2	10.4
	10-20	1.33	6.5	6.48	0.07	3.2	29.3	155.6	6.1	896.7	105.9	9.8
	20-51	-	-	-	-	3.1	-	-	-	-	-	-
	51-91	-	-	-	-	2.4	-	-	-	-	-	-
Site C	**0-10**	1.39	5.7	5.98	0.05	1.7	13.8	203.1	3.9	496.1	57.1	7.2
	10-20	0.88	6.3	5.35	0.05	1.6	19.6	124.9	7.0	444.9	48.3	9.9
	20-51	-	-	-	-	2.4	-	-	-	-	-	-
	51-91	-	-	-	-	1.9	-	-	-	-	-	-
Site D	**0-10**	1.56	9.3	7.58	0.14	6.4	23.1	345.8	6.9	1226.1	224.8	92.9
	10-20	1.32	9.0	7.36	0.15	7.0	21.9	261.1	12.5	1250.9	208.8	76.8
	20-51	-	-	-	-	6.5	-	-	-	-	-	-
	51-91	-	-	-	-	4.2	-	-	-	-	-	-

Note: SOM=soil organic matter, CEC=cation exchange capacity, EC=electrical conductivity, NO_3-N=nitrate-nitrogen, P=phosphorous, K=potassium, SO_4-S = sulfate-sulfur, Ca=calcium, Mg=magnesium, Na=sodium.

Table 2. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site A.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm $^{-1}$)	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	2.21	6.09 $^{a b}$	12.28	-	-	-	270.9	8.0	1670.1	178.1 $^{a b}$	10.8
	CM	2.00	5.86 ^{b}	11.98	-	-	-	236.8	8.9	1545.5	173.5 ^{b}	10.6
	WB	2.19	5.99 ^{b}	12.83	-	-	-	278.9	7.1	1674.5	189.4 $^{a b}$	11.8
	CMWB	2.28	6.24 ^{a}	13.90	-	-	-	333.8	8.3	1950.9	217.4 a	12.3
Depth (cm)	**0-10**	2.64 ^{a}	6.04	12.28	-	-	-	330.1	8.6	1567.3 ^{a}	162.4 ^{a}	9.9 ^{a}
	CON	-	-	-	0.13	12.5 ^{b}	19.5 ^{b}	-	-	-	-	-
	CM	-	-	-	0.12	17.2 ^{a}	35.3 ^{a}	-	-	-	-	-
	WB	-	-	-	0.11	11.4 ^{b}	40.5 ^{b}	-	-	-	-	-
	CMWB	-	-	-	0.14	12.3 ^{b}	30.8 ^{b}	-	-	-	-	-
	10-20	1.70 ^{b}	6.04	13.21	-	-	-	230.1	7.6	1853.3 ^{b}	216.8 ^{b}	12.8 ^{b}
	CON	-	-	-	0.11	4.5	7.0	-	-	-	-	-
	CM	-	-	-	0.11	7.2	8.3	-	-	-	-	-
	WB	-	-	-	0.13	3.7	10.5	-	-	-	-	-
	CMWB	-	-	-	0.13	5.6	8.0	-	-	-	-	-
	trt	0.4045	0.0335	0.2089	-	-	-	0.1164	0.3714	0.1521	0.0403	0.4363
	depth	0.0122	1.0000	0.2268	-	-	-	0.0551	0.1429	<.0001	<.0001	0.0234
	0-10	-	-	-	0.5929	0.0027	0.0092	-	-	-	-	-
	10-20	-	-	-	0.3740	0.1106	0.9285	-	-	-	-	-
	trt*depth	0.2709	0.1641	0.1108	0.0482	0.0355	0.0155	0.1179	0.1937	0.3729	0.4289	0.1951

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 3. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site A.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec $^{-1/2}$)	Corn Yield (Mg ha $^{-1}$)
Treatment	CON	2.82	84.3	1.47	-	11.28
	CM	2.72	84.6	1.46	-	10.29
	WB	2.78	83.6	1.42	-	10.74
	CMWB	2.89	84.3	1.42	-	10.53
Depth (cm)	**0-10**	-	-	1.36 ^{a}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	10-20	-	-	1.52 ^{b}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	trt	0.9352	0.9469	0.1838	-	0.7331
	depth	-	-	0.0114	-	-
	0-10	-	-	-	-	-
	10-20	-	-	-	-	-
	trt*depth	-	-	0.6410	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 4. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site B.

	Factor	SOM (%)	pH	CEC (me $100g^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	1.10	-	-	-	-	37.1	-	9.0	715.8 ^{b}	-	7.1
	CS	1.36	-	-	-	-	47.4	-	10.5	934.9 ^{a}	-	8.1
	CSWB	1.26	-	-	-	-	35.4	-	8.7	864.9 ^{a}	-	7.5
Depth (cm)	**0-10**	1.58 ^{a}	-	-	-	-	43.5	-	8.9	824.3	-	7.7
	CON	-	5.68 ^{b}	7.58	0.14 ^{b}	11.1	-	147.8 ^{b}	-	-	89.0 ^{b}	-
	CS	-	5.98 ^{a}	8.45	0.28 ^{a}	19.6	-	254.8 ^{a}	-	-	122.8 ^{a}	-
	CSWB	-	6.13 ^{a}	8.70	0.17 ^{ab}	18.1	-	223.0 ^{a}	-	-	121.8 ^{a}	-
	10-20	0.90 ^{b}	-	-	-	-	36.4	-	9.9	852.8	-	7.5
	CON	-	6.10	6.63	0.13	7.1	-	129.5 ^{y}	-	-	85.5 ^{y}	-
	CS	-	6.15	7.98	0.13	15.0	-	198.0 ^{x}	-	-	120.3 ^{x}	-
	CSWB	-	6.18	7.35	0.18	8.5	-	154.5 ^{y}	-	-	102.8 ^{xy}	-
	trt	0.0886	-	-	-	-	0.2245	-	0.1068	0.0373	-	0.5457
	depth	0.0162	-	-	-	-	0.3383	-	0.1806	0.3603	-	0.8205
	0-10	-	0.0041	0.2332	0.0293	0.0557	-	0.0007	-	-	0.0102	-
	10-20	-	0.8109	0.1644	0.3272	0.0815	-	0.0150	-	-	0.0171	-
	trt*depth	0.2812	0.0398	0.0509	0.0244	0.0072	0.5363	0.0424	0.1068	0.0677	0.0453	0.1318

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CS= cattle slurry; CSWB=cattle slurry and woody biomass; CON=control.

Table 5. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site B.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm^{-3})	Sorptivity (cm $sec^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	2.22	27.0 ^{b}	1.53	0.13	15.56
	CS	2.45	43.6 ^{a}	1.52	0.17	15.13
	CSWB	2.35	45.9 ^{a}	1.52	0.19	14.94
Depth (cm)	**0-10**	-	-	1.46 ^{a}	-	-
	CON	-	-	-	-	-
	CS	-	-	-	-	-
	CSWB	-	-	-	-	-
	10-20	-	-	1.59 ^{b}	-	-
	CON	-	-	-	-	-
	CS	-	-	-	-	-
	CSWB	-	-	-	-	-
	trt	0.9139	0.0540	0.9345	0.1995	0.5622
	depth	-	-	0.0004	-	-
	0-10	-	-	-	-	-
	10-20	-	-	-	-	-
	trt*depth	-	-	0.1068	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CS= cattle slurry; CSWB=cattle slurry and woody biomass; CON=control.

Table 6. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site C.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm $^{-1}$)	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	-	-	7.04	-	-	-	121.4 ^{b}	7.0 ^{bc}	-	-	-
	CM	-		7.24	-	-	-	161.8 ^{a}	7.9 ^{ab}	-	-	-
	WB	-		6.53	-	-	-	124.6 ^{b}	6.6 ^{c}	-	-	-
	CMWB	-		7.44	-	-	-	159.6 ^{a}	8.7 ^{a}	-	-	-
Depth (cm)	**0-10**	-	-	6.74 ^{a}	-	-	-	165.3 ^{a}	6.7 ^{a}	-	-	-
	CON	1.58 ^{b}	5.73 ^{c}	-	0.10 ^{b}	7.2 ^{b}	12.8 ^{b}	-	-	678.0	78.5 ^{b}	7.8
	CM	1.83 ^{a}	6.20 ^{a}	-	0.13 ^{a}	11.9 ^{a}	47.3 ^{a}	-	-	749.5	119.3 ^{a}	7.3
	WB	1.60 ^{b}	5.83 ^{bc}	-	0.09 ^{b}	6.5 ^{b}	13.0 ^{b}	-	-	640.3	77.8 ^{b}	7.0
	CMWB	1.85 ^{a}	6.15 ^{ab}	-	0.13 ^{a}	10.7 ^{a}	56.8 ^{a}	-	-	724.3	116.8 ^{a}	7.5
	10-20	-	-	7.38 ^{b}	-	-	-	118.4 ^{b}	8.4 ^{b}	-	-	-
	CON	0.95	5.28	-	0.07	3.7	14.0	-	-	579.3	63.8	8.8
	CM	0.95	5.15	-	0.08	4.6	24.3	-	-	549.5	67.0	9.5
	WB	1.00	5.23	-	0.07	3.3	18.3	-	-	566.8	68.0	8.3
	CMWB	0.98	5.10	-	0.07	3.9	28.3	-	-	476.5	54.5	9.3
	trt	-	-	0.2935	-	-	-	0.0233	0.0068	-	-	-
	depth	-	-	0.2070	-	-	-	0.0088	0.0060	-	-	-
	0-10	0.0032	0.0253	-	0.0045	0.0004	<.0001	-	-	0.3244	0.0007	0.6500
	10-20	0.9052	0.6958	-	0.4006	0.7919	0.1683	-	-	0.3677	0.5461	0.2307
	trt*depth	0.0098	0.0009	0.3747	0.0541	0.0222	0.0010	0.0591	0.3450	0.0005	0.0004	0.0530

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 7. Average soil physical properties for the 0-20 cm soil layers and corn yield by treatments, for site C.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec $^{-1/2}$)	Corn Yield (Mg ha $^{-1}$)
Treatment	CON	1.46	26.0	1.54	0.12 ^{c}	14.09
	CM	1.49	27.7	1.47	0.15 ^{bc}	13.83
	WB	1.61	25.4	1.51	0.19 ^{ab}	13.09
	CMWB	1.52	29.5	1.50	0.21 ^{a}	13.91
Depth (cm)	**0-10**	-	-	1.40 ^{a}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	10-20	-	-	1.61 ^{b}	-	-
	CON	-	-	-	-	-
	CM	-	-	-	-	-
	WB	-	-	-	-	-
	CMWB	-	-	-	-	-
	trt	0.9847	0.9052	0.2555	0.0190	0.3362
	depth	-	-	0.0004	-	-
	0-5	-	-	-	-	-
	5-10	-	-	-	-	-
	trt*depth	-	-	0.2485	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMWB=cattle manure and woody biomass; CON=control; WB= woody biomass.

Table 8. Average soil chemical properties for the 0-20 cm soil layers by treatments, for site D.

	Factor	SOM (%)	pH	CEC (me 100g $^{-1}$)	EC (mmho cm^{-1})	NO_3-N (ppm)	P (ppm)	K (ppm)	SO_4-S (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)
Treatment	CON	-	-	-	-	-	-	383.1	-	-	-	-
	CM	-	-	-	-	-	-	494.9	-	-	-	-
	CC	-	-	-	-	-	-	384.6	-	-	-	-
	CMCC	-	-	-	-	-	-	453.1	-	-	-	-
Depth (cm)	**0-10**	-	-	-	-	-	-	472.3 [a]	-	-	-	-
	CON	1.40 [b]	7.65 [b c]	9.40	0.25	6.1 [b]	27.0 [b]	-	23.2 [c]	1262.8	216.0	53.5
	CM	1.78 [a]	7.48 [c]	10.58	0.28	19.5 [a]	158.8 [a]	-	40.8 [bc]	1317.5	269.8	70.3
	CC	1.65 [a]	7.83 [ab]	10.80	0.24	10.3 [b]	50.8 [b]	-	59.3 [ab]	1487.3	244.3	59.8
	CMCC	1.85 [a]	7.85 [a]	11.73	0.27	18.6 [a]	158.5 [a]	-	77.5 [a]	1554.8	283.5	61.0
	10-20	-	-	-	-	-	-	385.6 [b]	-	-	-	-
	CON	1.00	7.33 [xy]	8.75	0.22	4.6	17.5	-	45.4	1174.5	201.0	63.8
	CM	1.08	7.20 [y]	10.20	0.36	10.7	24.5	-	48.0	1349.3	237.8	85.8
	CC	0.93	7.15 [y]	8.55	0.29	4.3	20.75	-	45.1	1133.5	201.5	63.3
	CMCC	1.00	7.40 [x]	8.60	0.27	8.1	31.5	-	54.3	1116.0	201.0	66.8
	trt	-	-	-	-	-	-	0.1287	-	-	-	-
	depth	-	-	-	-	-	-	0.0201	-	-	-	-
	0-10	0.0082	0.0018	0.2042	0.0563	<.0001	<.0001	-	0.0004	0.1165	0.1062	0.5098
	10-20	0.6348	0.0442	0.3372	0.7836	0.1075	0.9435	-	0.7918	0.2777	0.4341	0.1812
	trt*depth	0.0015	0.0436	0.0024	0.0525	0.0263	0.0094	0.1818	0.0136	0.0009	0.0080	0.0415

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-10 cm soil layer, and "x", "y" and "z" for the 10-20 cm layer. CM= cattle manure; CMCC=cattle manure and coal char; CON=control; CC= coal char.

Table 9. Average soil physical properties for the 0-10 cm soil layers and corn yield by treatments, for site D.

	Factor	Mean Weight Diameter (mm)	Water-Stable Macroaggregates (%)	Bulk Density (g cm $^{-3}$)	Sorptivity (cm sec$^{-1/2}$)	Corn Yield (Mg ha^{-1})
Treatment	CON	0.58	19.42	-	0.09	12.50 [a]
	CM	0.85	24.98	-	0.10	13.52 [a]
	CC	0.70	22.19	-	0.09	10.43 [b]
	CMCC	0.52	19.14	-	0.09	13.10 [a]
Depth (cm)	**0-5**	-	-	-	-	-
	CON	-	-	1.66 [c]	-	-
	CM	-	-	1.61 [bc]	-	-
	CC	-	-	1.54 [ab]	-	-
	CMCC	-	-	1.50 [a]	-	-
	5-10	-	-	-	-	-
	CON	-	-	1.79	-	-
	CM	-	-	1.78	-	-
	CC	-	-	1.80	-	-
	CMCC	-	-	1.84	-	-
	trt	0.2038	0.4013	-	0.9157	0.0311
	depth	-	-	-	-	-
	0-5	-	-	0.0020	-	-
	5-10	-	-	0.4574	-	-
	trt*depth	-	-	0.0003	-	-

Note: When significant trt*depth interaction was found, p values for differences between treatments, and treatment means were reported for each of the soil layers. If no trt*depth interaction was detected, main effects for each of the treatment factors were included in the table. Means in the same column and factor with equal letters do not significantly differ from each other at the 0.05 level (LSD). When reporting the impact of treatments for each soil layer, letters "a", "b", "c" and "d" were used to indicate differences in the 0-5 cm soil layer, and "x", "y" and "z" for the 5-10 cm layer. CM= cattle manure; CMCC=cattle manure and coal char; CON=control; CC= coal char.