THE EFFECT OF TILLAGE AND LIME RATE ON SOIL ACIDITY AND GRAIN YIELDS OF A CORN-SOYBEAN ROTATION

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Abstract

Modern tillage systems, such as reduced tillage and no-tillage systems, provide shallow incorporation of surface applied materials at best. Because of concern of over-liming the surface few inches of agricultural soils, producers either reduce lime rates (and apply more often) or perform some sort of soil inversion to mix the lime deeper into the soil profile. The objectives of this field study were to evaluate the effects of tillage, lime rate and time of limestone application on corn and soybean growth, and assess the changes in soil acidity in an initially acidic soil. Treatments consisted of a no lime check, two no-tillage systems with either a half-rate lime application every two years or an annual application of 400 lb pelleted lime per acre, a continuous annual chisel tillage system with a full rate of lime applied every four years, and two inversion systems utilizing a rotary tiller where the full rate of lime was mixed into the soil followed by either continuous chisel tillage or continuous no-tillage. Lime rate was based on initial soil pH and on the quality of limestone available in the area. It ranged from 2.0 ton per acre at Brownstown to 4.0 ton per acre at Dixon Springs and Carbondale. Soil samples were collected annually in increments of 2 inches to a 12 inch depth for determination of soil pH. The inversion of the soil the initial year resulted in reduced corn grain due to reduced moisture conservation compared to the no-tillage systems at Dixon Springs. The continuous chisel system increased soil pH in the upper 4-6 inches and had grain yields comparable to the no-tillage system. The no-tillage system had only a slight increase in pH in the surface 2 inches of soil, although there are indications that lime moved to the 6-8 inch depth, possibly through macro-pores or earthworm channels. The inversion treatments seemed to mix the lime more thoroughly in the upper 4-6 inches, but that was only about one-half to two-thirds of the depth that the implement ran. The pelleted lime had little effect on soil acidity. It does not appear that the acidity is reducing yields at this point. This study will continue for several more years.

Background

Tilling highly erodible soils in southern Illinois leads to increased erosion and disturbs the natural physical and biological processes that lead to increased productivity of long-term no-tillage systems. Yet, there is a perceived problem with the stratification of nutrients and lime over a long period of no-tillage. This stratification occurs because of the placement of nutrients and lime on the soil surface under no-till systems with very little incorporation into the soil profile. The tilling of these highly erodible soils causes erosion of the soil and subsequent movement into lakes and water channels. This added pollution may outweigh any and all detrimental effects of nutrient stratification.

The effects of adding liming materials to no-tillage systems in southern Illinois are very difficult to predict because of a limited knowledge of the extent of lime movement down an acid soil profile over time with the periodic application of liming materials to the surface. It is still unclear as to whether the periodic inversion of the soil is needed to improve root growth and nutrient uptake within the top layers of soil. The lack of mixing in no-till and the limited inversion in chisel tillage systems leads to stratification of immobile nutrients including lime. Tillage and periodic lime application effects on nutrient uptake and crop response under these conditions need further evaluation.

The objectives of this study were to 1) assess pH changes in the soil profile as affected by tillage system and frequency, lime rate and timing of limestone application, and 2) determine if periodic tillage to reduce stratification and mix fertilizers and lime throughout the top layers in a no-till system is beneficial to producers.

Methods and Materials

A field study was established in 1999 at the Dixon Springs Agricultural Center on a Grantsburg silt loam soil (fine-silty, mixed, mesic Oxyaquic Fragiudalfs) which had been in continuous no-till production for the previous five years without lime application. The pH at the start of the study ranged between 5.2-5.4 in this field. In 2000, the study was expanded to sites at the Southern Illinois University Carbondale Research Farm and the University of Illinois Brownstown Agronomy Research Center (see Table 1 below). The Carbondale experiment is on an Alford silt loam soil (fine-silty, mixed, mesic, Ultic Hapludalfs) whereas the Brownstown study is on a Cisne silt loam soil (fine, smectitic, mesic Vertic Albaqualfs)

Treatments consisted of continuous chisel tillage versus continuous no-till, each with and without a periodic inversion of lime at the time of lime application. An agricultural grade limestone obtained locally was applied at each location. This limestone rate varied by location depending upon the pH of the soil and the quality of limestone at the local quarry. In addition to the four treatments above, a no lime check treatment and a continuous no-till plus pelleted lime treatment were added. The rate of pelleted lime was 400 lb acre^{-1} and was applied annually prior to crop establishment. Plot size was 20 feet x 30 feet and consisted of eight rows of either corn or soybean with 30 inches between rows. Corn and soybean were grown at each location with fields rotated between the crops each year.

Table 1. Soil pH, lime needs, and lime quality for each location.

	Dixon Springs	Carbondale	Brownstown
Initial Soil pH	5.3	5.0	5.8
Lime Needed	4.0 ton acre^{-1}	4.0 ton acre^{-1}	2.0 ton acre^{-1}
Lime CCE	91%	98%	92%
Passing 60 Mesh	24%	44%	26%

A rotary tiller was used to represent periodic inversion with the hope of uniformly distributing the liming material throughout the plow layer. This would serve as a best case scenario for lime incorporation. The continuous no-till treatment received one half the rate of limestone of the other treatments but at twice the frequency of application, thus providing the same rate of lime application as the other treatments.

Soil samples were collected in the spring every year in 2 inch increments to a 12 inch depth to determine lime and nutrient movement over time. After four years (2003) we will re-assess limestone needs and determine if changes in our protocols are needed.

Results and Discussion

The no lime plots had very small pH changes over time at the 3 locations. Applying limestone to the continuous chisel treatment increased pH in the surface 6 inches at Dixon Springs and Carbondale but only 4 inches at Brownstown (see Figures 1-6). This represents only one-half to two-thirds the depth that the tillage implement ran. Applying limestone to no-till plots (at half-rate) increased the pH mostly in the surface 2 inches at each location as expected. This was due to the relatively insoluble nature of limestone and not being incorporated by tillage. However at two locations there appeared to be significant increases in pH to a depth of 8 inches under the no-till system. This may be associated with lime movement through macro-pores and perhaps earthworm channels under these established no-till systems. Using a rotary tiller to incorporate the limestone proved to be less successful than hoped. In most cases, the use of the rotary tiller produced the largest increase in pH in the surface 2 inches of soil. The increase in pH by sampling depth with the rotary tiller was similar to the continuous chisel treatment. It appeared that the soil moisture at time of tillage affected the depth at which the tiller ran (it was very dry at Brownstown which severely limited the running depth) and that tillage did not completely mix the limestone to the depth of tillage. In most cases the tiller ran from 6-8 inches. The annual application of pelleted lime increased the pH in the surface 0-2 inches only slightly.

Even with relatively acidic soils at the three locations, the no lime check treatments still produced grain yields comparable to the "best" treatments for 6 out of the 8 site-years studied thus far (Table 2). Tillage effects on yield seemed to vary by location and year (in the case of Dixon Springs) and tended to be affected by rainfall. At Dixon Springs, dry weather in 1999 seemed to favor no-till over other tillage systems, whereas in 2000 the tilled treatments produced higher soybean yields than no-tillage.

This study is slated to continue for several more years with half-rate lime treatments being applied every two years with the continuous no-till plots and full rates of lime applied every four years with the other tillage treatments, except for the pelleted lime treatment (which is a yearly treatment) and the check (no lime) treatment.

Table 2. Grain yields (bu $acre^{-1}$) of corn and soybeans by location.

Treatment	Dixon Springs				Carbondale		Brownstown	
	1999		2000		2000		2000	
	Corn	Soybean	Corn	Soybean	Corn	Soybean	Corn	Soybean
No lime check	118	33.0	139	39.0	178	52.1	101	62.0
Continuous Chisel	111	36.7	130	43.1	174	48.3	95	61.6
Continuous No-till	117	34.2	132	39.4	168	52.2	112	58.4
Rotary tilled/ Cont. Chisel	88	34.9	120	43.2	186	52.7	99	62.8
Rotary tilled/ Cont. No-till	107	33.9	129	46.5	158	50.1	89	64.4
Cont. No-till Pelleted Lime	110	34.4	137	38.8	178	56.0	80	56.7
LSD	*22*	*NS*	*NS*	*6.7*	*15*	*3.4*	*NS*	*6.0*

Acknowledgments

The authors wish to acknowledge project funding from the Illinois Soil Testing Association and the Illinois Council on Food and Agricultural Research (C-FAR).

Figure 1. Tillage effects on soil pH changes after corn, Dixon Springs, 2001.

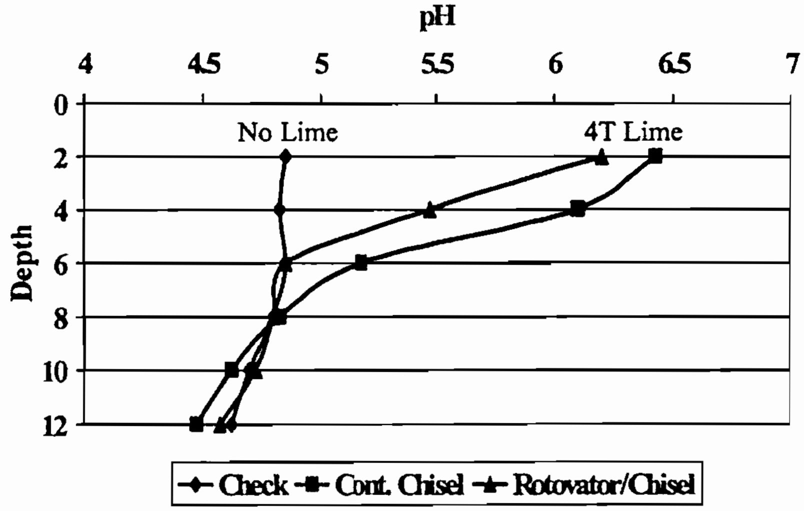


Figure 2. No-tillage effects on soil pH changes after corn, Dixon Springs, 2001.

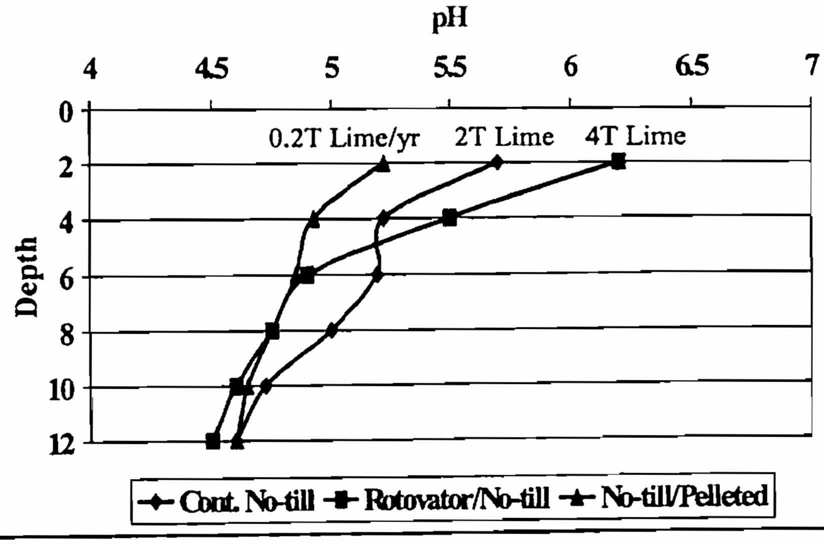


Figure 3. Tillage effects on soil pH changes after corn, Carbondale, 2001.

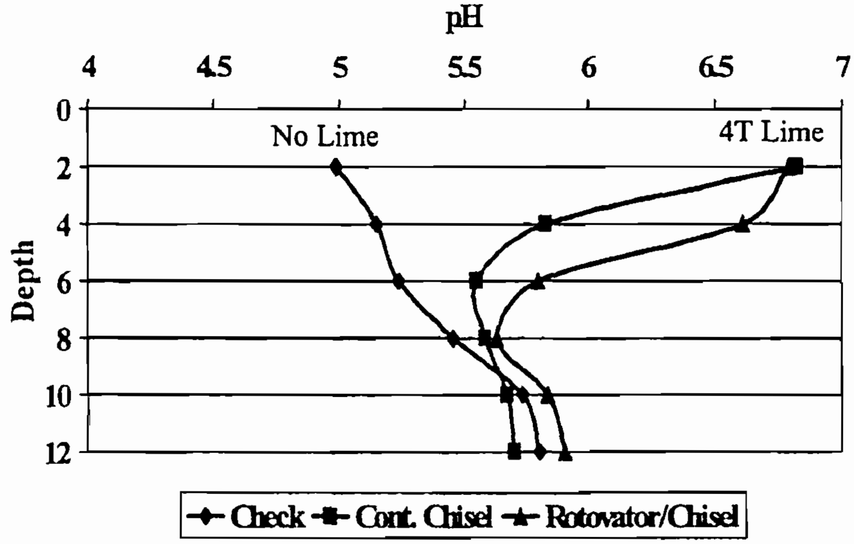


Figure 4. No-tillage effects on soil pH changes after corn, Carbondale, 2001.

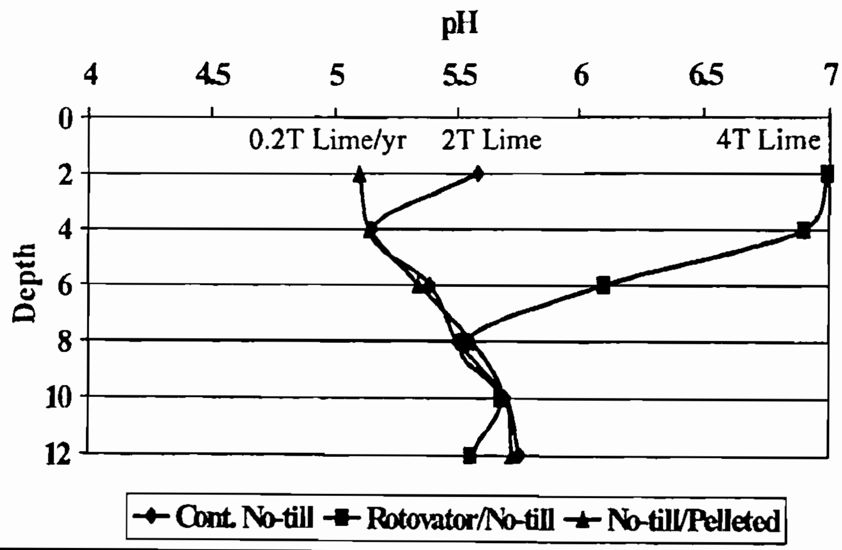


Figure 5. Tillage effects on soil pH changes after corn, Brownstown, 2001.

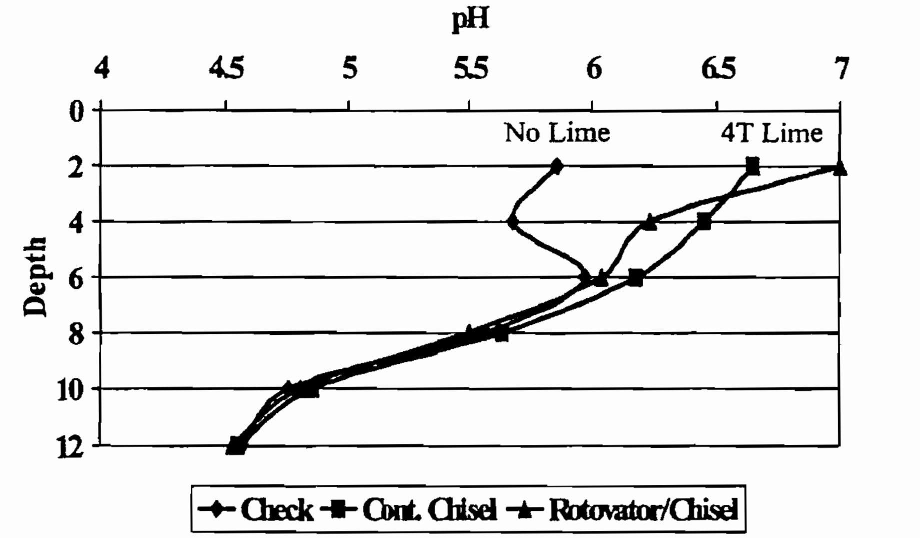
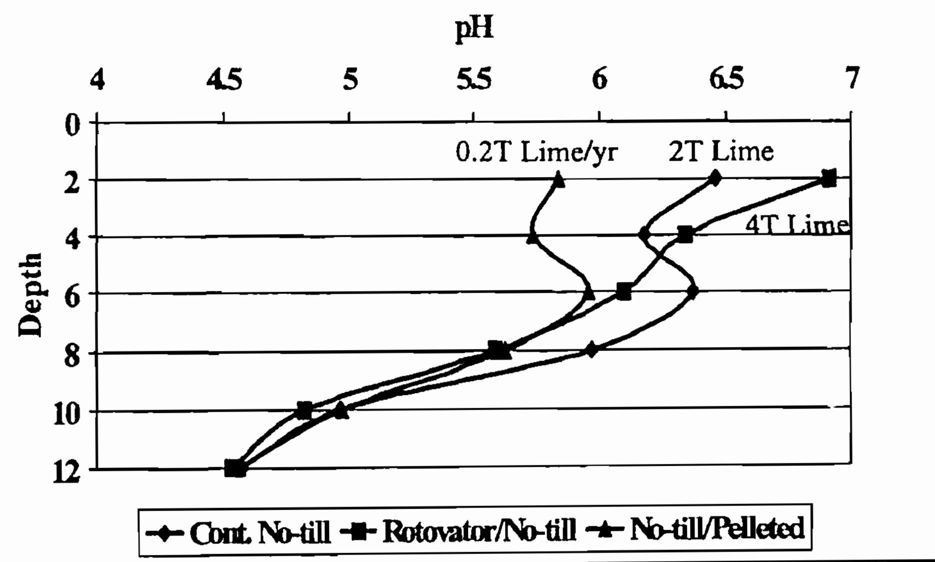


Figure 6. No-tillage effects on soil pH changes after corn, Brownstown, 2001.



PROCEEDINGS OF THE

THIRTY-FIRST NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 17

November 14-15, 2001
Holiday Inn University Park
Des Moines, IA

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Published by:
Potash & Phosphate Institute
772 – 22nd Avenue South
Brookings, SD 57006
605/692-6280