Published April 14, 2014

Accepted for publication 14 September 2006. Published 15 December 2006.

Crop Response to Poultry Litter and Deep Tillage Following Land Leveling in a Clay Soil

K. R. Brye, Department of Crop, Soil, and Environmental Sciences, 115 Plant Science Building, University of Arkansas, Fayetteville 72701

Corresponding author: K. R. Brye. kbrye@uark.edu

Brye, K. R. 2006. Crop response to poultry litter and deep tillage following land leveling in a clay soil. Online. Crop Management doi:10.1094/CM-2006-1215-01-RS.

Abstract

Land leveling results in severe soil disturbance. Several agronomic practices have been recommended (i.e., poultry litter application) or suggested (i.e., deep tillage) to help restore soil tilth following land leveling. The objective of this study was to determine the effects of poultry litter application and deep tillage on crop response in the first two growing seasons following land leveling of a clay soil in Mississippi Co., AR. Though land leveling in a clay soil significantly altered the magnitude, variability, and spatial distribution of many soil physical, chemical, and biological properties, crop response to poultry litter application and deep tillage was minimal. With the exception of greater soybean yield in plots that did not receive deep tillage compared to those that were deep tilled in the first year after land leveling, neither the application of 1 ton/acre of fresh poultry litter nor deep tillage in both years following leveling resulted in a rice yield response in the second year after leveling. Results indicate that land leveling a clay soil may not cause sufficient surface compaction to allow for a significant positive crop response to deep-tillage. Results also indicate that 1 ton/acre of fresh poultry litter may be insufficient to produce a short-term, positive crop response on clay soils.

Introduction

Land leveling is a government-subsidized, water-conservation practice common in the rice (*Oryza sativa* L.)-producing regions of the Mississippi River Delta in the mid-southern United States. In states such as Arkansas, Mississippi, and Louisiana, land leveling is conducted to create a slight, but uniform, slope gradient to facilitate an even distribution of irrigation water. Nearly 50% of all United States rice is produced in eastern Arkansas alone (1), where approximately 41% of the rice production occurs on soils with a clay or clay loam surface texture (22). It is estimated that between 69,000 and 81,500 acres of cropland are land leveled annually in Arkansas (23). Land leveling has been shown to improve soil and water conservation, uniformity of crop growth, and yield (21), but land leveling also results in severe soil disturbance (6) that has several major disadvantages.

Land leveling can cause a decline in soil fertility coupled with reduced crop productivity (8). Nitrogen and phosphorus deficiencies can limit crop growth following land leveling (9,15,16,21). Subsoil exposure can significantly alter soil surface pH, cause decreased organic carbon, and exposure of sodic horizons (13).

Inorganic fertilizers and/or organic soil amendments, such as poultry litter, can help restore post-leveling productivity to some degree (11,12), but are not always successful (12). Walker et al. (19) reported rice yields were between 6 and 45% lower in cut compared to filled areas on recently leveled clay soils in Mississippi and attributed some of the yield decline to decreased soil-test P. It has been recently reported that land leveling activities immediately alter the magnitude, variability, and spatial distributions of soil physical and fertility-related chemical properties on silt-loam (3,4) and clay soils (2,7) in the rice-producing region of eastern Arkansas. It has also been recently documented that land leveling activities cause increased soil surface bulk density (i.e., compaction) on silt-loam (3) and clay soils (6) in eastern Arkansas.

The use of 1 ton/acre of fresh poultry litter is the recommended practice following land leveling on silt-loam soils in Arkansas to help restore lost productivity (17). However, less is known about the potential benefits of poultry litter applications on clay soils following land leveling. Similarly, Brye et al. (7) suggested that deep tillage may help alleviate soil surface compaction and potential negative effects on early season crop growth, such as low plant population and poor stand development. Therefore, the objective of this study was to evaluate the effects of poultry litter and deep tillage on crop response following land leveling on a clay soil. It was hypothesized that, in the presence of sufficient N, crop growth (i.e., plant height and leaf area index) and seed yield would be positively affected by poultry litter and deep tillage.

Site Description and Experimental Design

In Spring 2004, a 4.9-ha (12-acre) field at the Northeast Research and Extension Center in Keiser, AR (35°40'N, 90°4'W), previously cropped to soybean, was chosen as the study site. The field consisted of Sharkey clay soil (very-fine, smectitic, thermic Chromic Epiaquert), a very deep, poorly and very poorly drained, very slowly permeable soil that formed in clayey alluvium (10,18). The Sharkey clay, typically located on flood plains and low terraces of the Mississippi River, is commonly used for rice production in Arkansas and Louisiana and is a component of Major Land Resource Area 131A (18). The field was slightly sloped (< 2%), such that irrigation water flowed from east to west, and contained < 15-cm (6-inch) tall, north-south-oriented raised beds spaced every 12 m (40 ft) throughout the field.

Prior to land leveling, two 50-m (197-ft) wide by 100-m (395-ft) long study areas were established parallel to one another separated by a 25-m (98-ft) buffer. Each study area was divided into ten 10-m (39.5-ft) wide by 50-m (197-ft) long plots. One study area was used to evaluate the use of poultry litter, while the other study area was used to evaluate deep tillage. Poultry-litter and deep-tillage treatments were randomized within each study area, resulting in a completely random experimental design with five treatment replications [i.e., where poultry litter was used (PL) or deep tillage was performed (DT)] and five untreated replications [i.e., where no litter was added (NPL) or no deep tillage was performed (NDT)] in each study area.

Field Management

The field was land leveled over a 3-day period in mid-April 2004. Following initial land leveling activities, the entire field was disked and land-planed numerous times to reduce soil clod size to an approximate diameter of < 2 cm (0.8 inch) for proper seed-bed preparation. Land leveling altered the surface drainage from the original east-to-west orientation to a south-to-north orientation.

In June, fresh poultry litter was spread manually on the soil surface at a rate of 1 ton/acre (247 lb fresh litter per plot) (17) to the plots receiving litter in the poultry-litter study. Poultry litter was not incorporated prior to planting. The deep-tillage treatment was implemented by chisel plowing to a depth of 3 inches and disked several times to re-prepare a reasonably smooth seed bed. Moist soil conditions prevented tillage to any greater depth.

Frequent rainfall immediately following land leveling delayed the planting of rice long enough to exclude any expectation of a reasonable yield. Therefore, a glyphosate-resistant soybean cultivar was drill seeded in 7.5-inch rows throughout both study areas in mid-June. After emergence, approximately 1 week after planting, 100 lb/acre of triple-super phosphate was manually applied with a hand spreader to both study areas. No K or N was applied to the soybean crop. Soybeans were furrow-irrigated approximately three times on an as-needed basis throughout the growing season. Two 1.5-m (5-ft) wide by 50-m (197-ft) long areas in each plot of both studies were harvested with a combine on October 27, 2004. Both studies were left fallow over winter.

In April 2005, the second growing season after land leveling, deep-tillage plots were chisel plowed again to a depth of approximately 7 inches. Two passes across both study areas were made with a soil conditioner and then both studies were land planned twice to prepare a proper seed bed. ‘Wells’ rice was drill

-seeded on 27 April in 7.5-inch rows and at a rate of 100 lb/acre. Prior to emergence, fresh poultry litter (238 lb fresh litter/plot) was spread manually on the soil surface to the selected plots in the poultry-litter study. Fresh poultry litter was applied in 2005 to equal the dry litter rate applied in 2004. At the 5-leaf rice stage, an application of 167 lb/acre of N as urea was spread manually across both study areas. Soil-test results indicated no P or K were needed for optimal rice production. Flooding was done within 24 h of urea application. A plot combine was used to harvest a single ~ 2.33-ft by 197-ft area from each plot on 16 September 2005.

Soil and Plant Measurements, Sampling, and Analyses

Before and immediately after land leveling, soil bulk density was measured at five pre-determined sampling points per plot throughout the deep-tillage study to evaluate the degree of compaction caused by land leveling. At each sampling point, a single 4.8-cm (1.9-inch) diameter soil core was collected from the top 10 cm (4 inches) using a slide hammer. The sampling chamber was beveled to the outside to minimize compaction upon sampling. Soil samples were weighed, dried at 70°C for 48 h, and re-weighed for bulk density determination.

Crop response to poultry litter and deep tillage was determined by measurement of plant height and population, leaf area index (LAI), and seed yield. Plant heights were measured at five pre-determined points per plot of each study 49 days after planting (DAP) in 2004 and 43 and 97 DAP in 2005. Plant populations were measured 49 DAP for the soybean crop in 2004 by counting the number of plants in a 1-m row section straddling each of the five pre-determined sampling points used to measure plant height. Rice LAI was measured non-destructively 97 DAP with a Li-Cor LAI-2000 (Li-Cor Inc., Lincoln, NE) plant canopy analyzer (20). Soybean grain weights from the two harvest areas in each plot (10-ft by 197-ft total harvest area) were averaged for determining plot yield. Soybean and rice grain samples were dried and adjusted to 13 and 12% moisture, respectively.

Land leveling effects on soil bulk density and poultry litter and deep tillage effects on crop responses were evaluated separately with one-way analyses of variance using Minitab (Minitab 13.31, Minitab Inc., State College, PA).

Immediate Effects of Land Leveling

Land leveling resulted in an average surface elevation change of -0.43 ft (i.e., an overall cut), ranging from +0.12 (i.e., a fill) to -0.95 ft, across the poultry-litter study area (7). Similarly, land leveling resulted in an average surface elevation change of -0.26 ft, ranging from +0.19 to -0.72 ft, across the deep-tillage study area.

Poultry Litter Effects

Immediately after land leveling in 2004, soil pH averaged 6.3 [standard error (SE) = 0.02], electrical conductivity averaged 0.277 (SE = 0.01) dS/m, and Mehlich-3 extractable P and K averaged 45.6 (SE = 2.2) and 413 (SE = 5.3) kg per ha, respectively, in the top 10 cm (4 inches) of the poultry-litter study area (2). Since soil fertility levels as shown by the soil test results were high and since P was applied to the entire study area, little soybean response was expected from the application of poultry litter. Poultry litter is generally recommended following land leveling for rice to help restore soil properties other than those directly related to soil fertility (i.e., N, P, and K) (17).

Neither soybean height 49 DAP nor yield were affected by poultry litter application in 2004, the first growing season following land leveling (Table 1). Soybean yield averaged 56.6 bu/acre across the entire study area, which was substantially greater than the whole-field average soybean yield (~33 bu/acre) in the year prior to land leveling (Sam Atchley, *personal communication*, 2005). This result indicates that land leveling improved the yield potential of the field, perhaps due to the improved ability to manage water.

Table 1. Summary of the effects of poultry litter [poultry litter (PL) vs. no poultry litter (NPL)] on plant height, plant population, leaf area index (LAI), and yield in the two cropping seasons following land leveling. Treatment means and least significant differences (LSD) are reported.

Year-crop	Plant property	PL	NPL	LSD
2004-Soybean	Plant height (49 DAP, cm)	48.3	48.5	NS
	Plant population (49 DAP, plants/m)	7.0	9.7**	1.6
	Seed yield (bu/acre)	56.1	57.1	NS
2005-Rice	Plant height (43 DAP, cm)	21.6	19.6*	1.9
	Plant height (97 DAP, cm)	103	100	NS
	LAI (97 DAP, m^2/m^2)	4.61	4.21	NS
	Seed yield (bu/acre)	171	162	NS

NS = not significant.
* Significant at the 5% level ($P < 0.05$).
** Significant at the 1% level ($P < 0.01$).

Soybean population 49 DAP was significantly greater ($P = 0.002$) in the control plots that did not receive poultry litter (9.7 plants/m) than in the poultry litter-amended plots (7.0 plants/m) (Table 1). This indicates that the use of poultry litter may have had a negative early-season effect on soybean stand establishment potentially due to short-term toxicity of one or several litter-contained nutrients, although no visual symptoms were evident.

In 2005, the second growing season following land leveling, rice height and LAI at 97 DAP and yield were not affected by the application of poultry litter (Table 2). Rice yield averaged 167 bu/acre across the entire study area. However, rice height 43 DAP was significantly greater ($P = 0.035$) in the poultry-litter-amended plots (21.6 cm) than in the control plots (19.6 cm) (Table 1). In contrast to soybean growth in 2004, the significant response in the height of the rice indicated that poultry litter had a positive effect on early-season rice growth. The exact reasons for the positive response are yet unknown, but may have been related to a slight N response since litter was applied approximately one month before the entire study area received an application of N at 167 lb/acre as urea.

Table 2. Summary of the effects of deep tillage [deep tillage (DT) vs. no deep tillage (NDT)] on plant height, plant population, leaf area index (LAI), and yield in the two cropping seasons following land leveling. Treatment means and least significant differences (LSD) are reported.

Year-crop	Plant property	DT	NDT	LSD
2004-Soybean	Plant height (49 DAP, cm)	46.7	46.8	NS
	Plant population (49 DAP, plants/m)	9.0	9.4	NS
	Seed yield (bu/acre)	55.9	59.7*	2.3
2005-Rice	Plant height (43 DAP, cm)	23.0	22.4	NS
	Plant height (97 DAP, cm)	104	105	NS
	LAI (97 DAP, m^2/m^2)	4.44	4.73	NS
	Seed yield (bu/acre)	168	176	NS

NS = not significant.
* Significant at the 5 % level ($P < 0.05$).

Deep Tillage Effects

Land leveling caused a significant increase ($P < 0.001$) in soil bulk density throughout the deep-tillage study area. Soil bulk density in the top 10 cm (4 inches) increased significantly ($P < 0.001$) from 1.18 (SE = 0.01) g/cm^3 before to 1.44 (SE = 0.02) g/cm^3 after leveling. This indicated that the soil surface into which the soybean crop was to be planted was somewhat compacted, which in turn could have negatively affected early-season stand development.

In contrast to expectations, neither soybean population nor height 49 DAP were affected by deep tillage (Table 2). However, soybean yield was significantly greater (P = 0.016) in the control plots which were not deep tilled (59.7 bu/acre) compared to the yield in the deep-tilled plots (55.9 bu/acre) (Table 2). This observation may have occurred as a result of poorer soil-to-seed contact at planting in the tilled plots where the soil surface was somewhat rougher and more cloddy compared to the soil conditions in the controls plots. Similar to the results in the poultry-litter study, the average soybean yield throughout the entire deep-tillage study area (57.8 bu/acre) was substantially greater than the whole-field average soybean yield (~33 bu/acre) in the year prior to land leveling (Sam Atchley, *personal communication*, 2005). The increased yield potential was again likely due to improved water management.

In the second growing season following land leveling, there was no rice response to deep tillage. Rice yield averaged 172 bu/acre throughout the deep-tillage study area. The likely explanation for the general lack of a deep-tillage effect in the clay soil in this study is that the soil surface was not compacted enough to result in a positive crop response to deep tillage. Though land leveling caused an immediate increase in whole-field mean bulk density (7), meaning the soil surface was somewhat more compacted immediately after leveling than before, the standard field practice on clayey soils that have been recently disturbed, whether from land leveling, previous post-harvest tillage, or previous harvest where ruts may have been formed and remain in the field, is to disk the surface numerous times to prepare a relatively smooth, uniform seed bed. Disking following land leveling and following harvest of each crop tends to unify the soil surface such that potential near-surface compaction problems are minimized. Therefore, in addition to the clayey nature of the soil which tends to resist change and the field manipulations that are necessary to prepare the seed bed prior to planting, crop rotation (i.e., rice following soybean) likely had little influence on near-surface soil bulk density that may have affected the subsequent crop.

Practical Implications

Though the potential effectiveness of poultry litter and deep tillage were not explicitly investigated, a recent study demonstrated that crop response was negatively affected by relatively shallow-cut land leveling activities in a silt-loam soil (8). More importantly, in the same study, Brye et al. (5) reported that post-leveling crop response and productivity could not be predicted solely from assessment of post-leveling soil physical, chemical, and biological properties.

Similar to effects in a silt-loam soil (3,4), land leveling significantly altered the magnitude, variability, and spatial distribution of many soil physical, biological (7), and chemical properties (2) in the Sharkey clay soil of this study. However, crop response to land leveling in a clay soil appears to differ from that documented in a silt-loam soil. It has been suggested that the potential productivity decline after land leveling activities is less in alluvial Vertisols of the Mississippi River Delta region of eastern Arkansas, such as the Sharkey clay, due to similar topsoil and subsoil characteristics compared to other rice soils where topsoil and subsoil characteristics may differ more drastically (14).

The results of this study indicate that either soil physical and chemical properties were not altered enough by land leveling to cause a positive poultry litter response or that the 1 ton/acre litter rate was insufficient to provide measurable benefit to soybean and/or rice in the first two years following land leveling in this clay soil. Due to the generally deep, alluvial nature of the soil parent material, 1 ton/acre rate of fresh poultry litter may be insufficient to produce a short-term, positive crop response on clay soils because the newly exposed subsoil is sufficiently fertile to support near-optimal crop growth (2). Furthermore, it appears that, despite significantly greater soil surface bulk density following land leveling, soil compaction as a result of land leveling has to be much more severe than that observed in this study to warrant deep tillage as a compaction remedy.

Acknowledgments

This research was funded by the Arkansas Rice Research and Promotion Board. Field assistance provided by Mandy Pirani, Matt Cordell, Tarra Verkler, Mike Duren, and other station personnel is gratefully acknowledged.

Literature Cited

1. Agricultural Statistics Board (ASB). 2004. Acreage. Online. National Agricultural Statistics Service (NASS), USDA, Washington, DC.
2. Brye, K. R. 2006. Soil biochemical properties as affected by land leveling in a clayey Aquert. Soil Sci. Soc. Am. J. 70:1129-1139.
3. Brye, K. R., Slaton, N. A., Savin, M. C., Norman, R. J., and Miller, D. M. 2003. Short-term effects of land leveling on soil physical properties and microbial biomass. Soil Sci. Soc. Am. J. 67:1405-1417.
4. Brye, K. R., Slaton, N. A., Mozaffari, M., Savin, M. C., Norman, R. J., and Miller D. M. 2004. Short-term effects of land leveling on soil chemical properties and their relationships with microbial biomass. Soil Sci. Soc. Am. J. 68:924-934.
5. Brye, K. R., Slaton, N. A., and Chen, P. 2004. Can crop productivity be predicted by soil characterization after land leveling? Online. Crop Management doi:10.1094/CM-2004-0908-01-RS.
6. Brye, K. R., Slaton, N. A., and Norman, R. J. 2005. Penetration resistance as affected by shallow-cut land leveling and cropping. Soil Till. Res. 81:1-13.
7. Brye, K. R., Slaton, N. A., and Norman, R. J. 2006. Soil physical and biological properties as affected by land leveling in a clayey Aquert. Soil Sci. Soc. Am. J. 70:631-642.
8. Brye, K. R., Chen, P., Purcell, L. C., Mozaffari, M., and Norman, R. J. 2004. First-year soybean growth and production as affected by soil properties following land leveling. Plant Soil 263:323-334.
9. Eck, H. V. 1987. Characteristics of exposed subsoil - at exposure and 23 years later. Agron. J. 79:1067-1073.
10. Ferguson, D. V., and Gray, J. L. 1971. Soil survey of Mississippi county, Arkansas. Soil Conservation Service, USDA, Washington DC.
11. Miller, D. M., Wells, B. R., and Norman, R. J. 1991. Fertilization of rice on graded soils using organic materials. Pages 55-57 in: Arkansas Soil Fertility Studies 1990. Res Ser. 411. Ark. Agric. Exp. Stn., Fayetteville, AR.
12. Miller, D. M., Wells, B. R., Norman, R. J., and Alvisyahrin, T. 1990. Fertilization of rice on leveled soils. Pages 45-48 in: Arkansas Soil Fertility Studies 1989. Res. Ser. 398. Ark. Agric. Exp. Stn., Fayetteville, AR.
13. Miller, D. M. 1990. Variability of soil chemical properties and rice growth following land leveling. Ark. Farm Res. 39:4.
14. Norman, R. J., Wilson, C. E., and Slaton, N. A. 2003. Soil fertilization and mineral nutrition in U.S. mechanized rice culture. Pages in: 331-411. in: Rice: Origin, History, Technology, and Production. C. W. Smith, ed. John Wiley & Sons, Inc. New York, NY.
15. Robbins, C. W., Mackey, B. E., and Freeborn L. L. 1997. Improving exposed subsoils with fertilizers and crop rotations. Soil Sci. Soc. Am. J. 61:1221-1225.
16. Robbins, C. W., Westermann, D. T., and Freeborn, L. L. 1999. Phosphorus forms and extractability from three sources in a recently exposed calcareous subsoil. Soil Sci. Soc. Am. J. 63:1717-1724.
17. Slaton, N. A., ed. 2001. Rice production handbook. Univ. of AR, Coop. Ext. Serv. MP192, Little Rock, AR.
18. NRCS. 2006. Official soil series descriptions. Natural Resources Conserv. Serv. (NRCS), USDA. Washington, DC.
19. Walker, T. W., Kingery, W. L., Street, J. E., Cox, M. S., Oldham, J. L., Gerard, P. D., and Han, F. X. 2003. Rice yield and soil chemical properties as affected by precision land leveling in alluvial soils. Agron. J. 95:1483-1488.
20. Wells, J. M., and Norman J. M. 1991. Instrument for indirect measurement of canopy architecture. Agron. J. 83:818-825.
21. Whitney, R. S., Gardner, R., and Robertson D. W. 1950. The effectiveness of manure and commercial fertilizer in restoring the productivity of subsoils exposed by leveling. Agron. J. 42:239-245.
22. Wilson, C. E., and Branson, J. W. 2004. Trends in Arkansas rice production. Pages 15-21 in:: B.R. Wells Rice Research Studies 2003. Univ. of Ark., Div Agric., Ark. Agric. Exper. Stat., Res. Ser. 517, Fayetteville, AR.
23. Young, K. B., Goodwin, H. L., and Wailes, E. J. 2004. Economics of poultry litter use on cut rice fields. Pages 420-425 in: B.R. Wells Rice Research Studies 2003. Univ. of Ark., Div. Agric., Ark. Agric. Exper. Stat., Res. Ser. 517, Fayetteville, AR.