SOIL TREATMENT WITH FERRIHYDRITE TO CONTROL RUNOFF, EROSION, AND PHOSPHORUS MOVEMENT

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ABSTRACT: Erosion and off-site movement of agrichemicals can result in impaired surface waters. Ferrihydrite, a Fe-oxide waste product of water treatment plants, is being tested at the North Mississippi Branch Experiment Station as a soil amendment to reduce runoff, erosion, and off-site movement of phosphorus. A field study was initiated in 2001 that involved ferrihydrite application to 18 runoff plots managed as conventional-tillage soybean with winter wheat cover. Additionally, a laboratory study was conducted on soil samples from the plots to determine the impacts of ferrihydrite on phosphorus removal from solution by adsorption to the sediment and release back into solution by desorption. The field study will continue for a couple of years and results will be reported in the future. The laboratory study documented that ferrihydrite application increases adsorption and decreases desorption for this soil.

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BACKGROUND: Numerous erosion control practices have been investigated on upland soils over the past 40 years by scientists of the NSL and the Mississippi Agricultural and Forestry Experiment Station (MAFES) at the North Mississippi Branch Station of MAFES at Holly Springs. Research at Holly Springs has resulted in improved soil erosion control practices. However, the use of soil amendments to control erosion has, until recently, received less attention than such practices as conservation tillage, cover crops, and grass hedges.

Soil amendments can improve aggregate formation and soil structural stability, which can result in decreased runoff and decreased erosion (restricts particle detachment). One such soil amendment is ferrihydrite, which is a waste product filtered from groundwater supplies by water treatment plants in the Southern Mississippi River Valley region. Although Fe-oxides, such as ferrihydrite, comprise a small percent of the soil mass, increases in Fe-oxide contents have been shown to improve soil aggregation and aggregate stability. This can potentially result in a decrease in runoff and erosion that will decrease the off-site transport of sediment-bond agrichemicals. Off-site movement of highly reactive chemicals, such as Phosphorus (P), can predominately be by sediment movement. Once this sediment enters surface waters, the chemicals can be released from the sediment. In contrasts to other soil amendments, ferrihydrite may not only provide a reduction in off-site movement of phosphorus by reducing runoff and erosion, it may also directly reduce field losses by increasing the adsorption (removal from solution by sediment) and reducing the desorption (release from the sediment back into the water column) capacity.

No study to date has documented the use of ferrihydrite as a soil amendment under field-scale conditions nor have the impacts of adsorption-desorption been quantified. A new field study was initiated in 2001 at the North Mississippi Branch Experiment Station to determine the effectiveness of ferrihydrite at reducing runoff and erosion. The experimental design will be presented but results will be reported in later years. A complimentary study was also initiated to determine the impacts of ferrihydrite application on phosphorus adsorption-desorption properties that control the offsite impacts on water quality.

MATERIALS AND METHODS: Field Study: The field study will utilize 18 runoff plots (35 ft x 12 ft) at the North Mississippi Branch of MAFES at Holly Springs. Plot management consists of conventionally tilled soybean with a winter-wheat cover crop. The 18 runoff plots are being utilized as a split plot design with a completely randomized main unit and 3 treatment levels in the subunit. Treatments involve ferrihydrite applied at rates of 0, 3, and 5 t/ac, replicated three times. Nine plots will receive ferrihydrite plus an organic matter amendment (dairy manure) at a rate of 2.5 t/ac to evaluate the effect of ferrihydrite on aggregate stability at elevated organic C contents. Prior to applying the treatments, baseline soil samples were collected from each plot and characterized for extractable Fe, nutrient contents, pH, organic C, particle size distribution, aggregate stability, water dispersible clay, and crust strength. Each plot has a 5% slope with a runoff collection and monitoring system. Runoff and rainfall have been continuously monitored since just prior to soybean planting on 6/14/2001. Runoff hydrographs will be computed along with rainfall kinetic energy, and erosion index by storm event. Three discrete sampling ISCO samplers were installed into the flume section of one replication of each ferrihydrite treatment to collect runoff samples with the hydrograph. Additionally, a composite sample is being obtained from all plots following all significant runoff events. Sediment from the composite and ISCO samples are being characterized for size distributions, organic C, extractable Fe, pH, and adsorbed nutrients.

Lab Study: The phosphorus adsorption-desorption capacity was determined using the batch method. Soil samples were taken from the surface (0-1 in) of each of the 18 runoff plots and combined for a composite sample. Ferrihydrite was mixed into air-dried soil at 3 and 5 t/A rates. A control (0 t/A) subsample had the equivalent amount of water added. All treatments were air-dried and samples were separated into >0.08 and <0.08 in size materials.

Triplicate 0.18 oz samples of each treatment and size class were placed in 0.11 pt polypropylene tubes. Solutions (0.05 pt) of known initial P concentrations were added. Initial P concentrations were 0, 5, 10, 20, 50, and 100 ppm. These soil suspensions were shaken for 15 min every 2 h until the end of the experiment. After 2, 4, 6, 8, 12, 24, 48, 96, 192, 720, and 1440 h of reaction time, suspensions were centrifuged and 0.001 pt sample extracted for P analysis.

Following the last adsorption step, P desorption was carried out using successive extractions-dilutions. Soil suspensions were centrifuged and a 0.001 pt sample extracted as before but this time the remaining water was poured out leaving only the sediment. Diluting solution (0.05 pt with no P) was added back into the tube and samples resuspended and then returned to the shaker. Ten successive daily extractions were followed by 10 extractions with a 5 day equilibration time interval.

RESULTS AND DISCUSSION: Phosphorus adsorption was found to be extremely rapid for all treatments with P concentrations after just 2 hours being substantially lower than the concentrations applied. The application of ferrihydrite consistently resulted in lower P concentrations (Table 1) due to increased P adsorption. P adsorption was greater for the aggregates than the < 0.08 in material that consisted of small aggregates and individual particles.

P concentrations during the desorption stage were initially much lower for the ferrihydrite treated soil. At the final time steps, however, concentrations were slightly higher for the treated material. The rapid release of P from the nontreated material resulted in all the applied P being desorbed while the ferrihydrite treated material still had P on the sediment to slowly release. P desorption was lower for the > 2 mm aggregates.

Ferrihydrite application clearly increased the P adsorption and decreased P desorption. These findings show that ferrihydrite has great potential as a soil amendment to reduce P loads by reducing soluble P concentrations in runoff water and reducing P release from sediment.

Table 1. Phosphorus concentrations (ppm) in solution at selected adsorption (a) times (2a, 24a, 1440a) following application of 5, 10, 20, 50, and 100 ppm of P and at selected desorption (d) times (24d, 840d, and 1440d).

	Non-Aggregates (< 0.08 in)					Aggregates (> 0.08 in)				
Time	0 t/ac Ferrihydrite					0 t/ac Ferrihydrite				
hour	5	10	20	50	100	5	10	20	50	100
2a	0.90	2.77	5.37	27.37	70.73	0.64	1.79	4.56	23.01	63.85
24a	0.26	0.96	3.92	12.29	54.81	0.31	0.88	2.55	11.23	52.75
1440a	0.35	0.62	1.41	4.01	21.04	0.06	0.20	0.54	2.10	10.94
24d	0.66	0.86	1.43	5.27	7.85	0.05	0.13	0.40	1.81	5.50
840d	0.48	0.45	0.54	1.01	1.63	0.00	0.01	0.03	0.18	0.34
1440d	0.00	0.00	0.00	0.09	0.26	0.00	0.00	0.00	0.05	0.17
Time	5 t/ac Ferrihydrite					5 t/ac Ferrihydrite				
hour	5	10	20	50	100	5	10	20	50	100
2a	0.27	0.88	2.60	17.23	64.39	0.28	0.72	1.61	16.24	63.93
24a	0.03	0.25	1.31	6.29	43.65	0.19	0.31	0.77	5.89	33.79
1440a	0.10	0.13	0.43	2.76	14.75	0.04	0.05	0.12	0.89	5.05
24d	0.08	0.12	0.30	1.17	3.87	0.05	0.06	0.12	0.85	4.21
840d	0.23	0.05	0.43	0.21	1.32	0.00	0.01	0.03	0.18	0.50
1440d	0.00	0.00	0.01	0.13	0.41	0.00	0.00	0.00	0.13	0.22

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