REDUCING RUNOFF VOLUME AND CONCENTRATIONS OF PHOSPHOROUS AND ATRAZINE WITH GYPSUM AMENDMENT

L. Darrell Norton
National Soil Erosion Research Laboratory
USDA-ARS, Purdue University

ABSTRACT

Erosion control can be achieved by reducing runoff volume using soil amendments that improve infiltration and prevent particle detachment and transport. Effective soil erosion control can be achieved by a number of means, however, water quality may still be impaired by removal of soluble nutrients and pesticides. We hypothesized that addition of an electrolyte source (gypsum) to the soil/air/water interface not only could achieve erosion control, but could also reduce the concentration of soluble reactive phosphorous (SRP) and atrazine (ATz). We tested this hypothesis in a two year rainfall simulator study on field plots untreated and treated with recycled drywall gypsum (surface applied at 1 MT/ha) following addition of ATz containing herbicides. We applied rainfall to replicated plots with 5% slope at a target rate of 64 mm/hr until steady state runoff was achieved and runoff samples were collected in intervals of 5 minutes to measure sediment, SRP and ATz losses. A control, gypsum and a poultry litter treatment were all trimmed of corn grown in a no-tillage system prior to rainfall. We found that addition of gypsum not only reduced runoff volume and sediment loss but also reduced the concentration of SRP especially in the poultry litter treatment and ATz. Total losses of both SRP and ATz were reduced by a combination of reduced runoff volumes and concentrations. Addition of gypsum to critical areas in fields treated with soluble ATz or poultry litter appears to be a viable management strategy to reduce off-site water quality concerns.

INTRODUCTION

Phosphorus (P) is one of the more problematic plant nutrients causing offsite eutrophication which upsets ecosystem balance in downstream areas. Areas affected by eutrophication include the mouth of the Mississippi River, where a “hypoxyia” zone occurs, the Florida Everglades and the Great Lakes. Although there is no drinking water standard established for P, it is still a concern for runoff from agricultural land especially where fertilizers and/or manures have been applied. Such water quality problems as eutrophication, resulting from application of commercial fertilizers or manures have been well documented (USEPA, 2000; USEPA, 1999) yet it continues to be a problem in agriculture because it serves as a non-point source of pollution which is difficult to control. As time between fertilizer or manure application and the first runoff event increases, the potential for release of P to surface runoff declines (Smith et al., 2007). However, producers cannot control weather conditions, and sometimes runoff events occur soon after application of fertilizers. Furthermore, recent research has shown that application of commercial fertilizers may be more detrimental to P loading and water quality than animal manures (e.g. DeLaune et al., 2004). Competitive P sorption isotherms for soil have shown that the various forms of P (i.e., orthophosphate, inositol hexaphosphate, glucose-6-phosphate) that are present in manures compete for sorption sites, and that soil P can be released to runoff water following application (Berg and Joern, 2006).

Pesticides from agricultural areas have also been a major concern for drinking waters. Atrazine (ATz-6-chloro-*N*-ethyl-*N'*-(1-methylethyl)-1,3,5-triazine-2,4-diamine) is a pre-emergent herbicide used to control annual broad leaf weeds in corn, sorghum, sugarcane, and other crops, and is among the most widely used herbicides in the US (NASS, 1995). Atrazine is heavily used the US Midwest corn belt and it easily removed by runoff when it runoff occurs near the time of application. It does have an EPA established maximum contaminant level (MCL) in drinking water of 3 ppb (USEPA, 2003) which is often exceeded in many Midwest surface water bodies used for drinking water (USEPA, 2005).

No-tillage has been promoted as the preferred environmentally friendly method for soil and water conservation for more than 20 years by the USDA-Natural Resources Conservation Service and other organizations. The development of modern weed control systems using systemic post-emergent herbicide and pre-emergent chemicals together made practicing no-tillage more successful. The development of glyphosate resistant crops has greatly increased the popularity of no-tillage in the US and other countries. However, in no-tillage most of the chemicals are either surface or near surface applied in soluble forms which are not incorporated which can easily moved when runoff and erosion do occur. This is particularly problematic for water quality concerns and no-tillage has been shown to have considerable losses of pesticides even though runoff volume was significantly reduced because of the increased concentrations in runoff water (Sauer and Daniel, 1987).

Soil amendments including gypsum and gypsum like materials (Norton, 1995) have been shown to have the potential to reduce erosion by improving infiltration and reducing surface sealing (Wallace-Cochrane, et al., 2005). Bauer et al., (2005) demonstrated the usefulness low cost gypsum and a waste paper material as soil amendments in reducing soil test P levels while Norton and Mamedov (2006) demonstrated that a surface application of gypsum reduced runoff and erosion but also the concentrations of soluble reactive P (SRP) in runoff from high soil test P fields.

In order to make US agriculture more sustainable with respect to environmental concerns of the public new approaches to reducing both nutrient and pesticide loadings to surface waters must be found. The objective of this study was to evaluate a proven approach to control soil erosion for its ability to attenuate P and ATz losses from no-tillage agriculture.

MATERIALS AND METHODS

We conducted a two year field rainfall simulator study on a Blount soil (fine-loamy, mixed, mesic Typic Hapludalf) that had been in long-term no-tillage agriculture for over 20 years. The site was located in DeKalb County, IN near the village of Waterloo. We compared either conventional tilled (CT) or no-tillage control (NC) to: precision tillage (PT), no-tillage with 1MT/ha surface applied recycled wall-board gypsum (GP), 1 MT/ha surface applied dry poultry manure (M), 1MT/ha GP plus 1MT/ha (MG) using rainfall simulation. Other fertilizer and pesticide additions were the same across all plots. These included a fall broadcast application of 1kg/ha glyphosate (Gly) followed by spring broadcast application of 1kg/ha ATz and 1kg/ha Gly. Fertilize applications were based on periodic soil tests and included broadcast application of P and K in the fall and spring injections of liquid nitrogen in a band at planting with side dressed anhydrous ammonia approximately 4 weeks following emergence.

The GP was recycled wall board gypsum (~70% $CaSO_4$ x $2H_20$) from a manufactured housing recycled waste wall-board facility in Bremen, IN. Soil loss and runoff samples were collected at 5-minute intervals following initiation of runoff until four samples of steady state runoff were collected. Rainfall rate was a constant intensity target rate of 50 mm/hr using de-ionized water applied with a programmable simulator equipped with 80-100 Vee-jet nozzles (Norton, 2007). Actual rainfall amount was measured with gauges. Soil loss was measured gravimetrically from a 1-liter sediment sample taken and runoff rate was calculated based on the mass and time to collect. Smaller nutrient and pesticide samples were collected immediately following the runoff sample, one filtered and frozen until analyzed colorimetrically using a Kone-Lab auto-analyzer for soluble reactive P (SRP), ammonia nitrogen (AN) and nitrate nitrogen (NN). The other non filtered sample was immediately frozen and thawed prior to digestion by Kjeldahl procedure and N and P measured by the Kone-Lab for total Kjeldahl nitrogen (TKN) and total phosphorous (TP). The pesticides were measured on the filtered sample by solid phase micro-extraction and gas chromotography for ATz and by HPLC for Gly. Data were statistically analyzed using SAS Proc GLM and the steady state means compared using Tukey's Studentized Range Test at P=0.05.

RESULTS AND DISCUSSION

Runoff and Erosion

Steady state runoff and soil loss had considerable difference in both years, however, the order of the differences varied because treatments varied. In 2005, the conventional tilled (CT) treatment had intermediate water discharge but the greatest soil loss due to the greater sediment concentrations (Table 1). It was followed in soil loss by precision tillage (PT) which has a zone approximately 10 cm wide that has the residue removed, is tilled at planting and liquid fertilizer applied, and partially recovered with residue, which had high runoff rate. The least soil loss rate but highest runoff rate was with the no-tillage with gypsum (NG) treatment due to the low sediment concentration. The poultry litter (NM) treatment had the least runoff and low soil loss which was not significantly different from either the NG or the no-till with manure and gypsum (MG).

In 2006, runoff rates were very similar for all treatments with the NG being the greatest but not different than the NM. For soil loss, the no-tillage control (NC) had the least and lowest sediment concentration but they were not significantly different than the two gypsum treatments (MG and NG). The NG and NM runoff rates were greater than all the other treatments. The PT had an intermediate soil loss rate probably due to the disturbance, but it was not as high as the NM treatment which caused a very high sediment concentration when applied without gypsum. Possibly the surface addition of he low density manure due the surface caused movement of the manure particles selectively when gypsum was not applied. It is unclear why this large difference for this treatment from the results of 2005.

Nutrients and Pesticides

Phosphate had previously been shown by Brauer et al., 2005 to have less in P in runoff with gypsum application. This was found to be true for both years in the case of no-tillage, however, not for the case of manure application. In both years, the loss of P was greatest with the NM but the MG treatment was intermediate and greater than PT and NG in both years. This is probably due to the manure moving with the runoff water as observed with the soil loss. The NG was least in 2005 and different from all other treatments except the PT. In 2006, only the NM had a significantly greater P loss compared to all other treatments.

Total P (TP) which includes both soluble and that held with the sediment had considerable differences in both years. The CT treatment was significantly greater than all other treatments in 2005 because of the high sediment concentration. The next highest was the MG followed by the PT and NM and the least with NG. These differences largely follow the sediment concentration differences. The NG treatment had the least TP loss of any of the treatments for both years. Differences in 2006 showed that the NM had the greatest TP loss, no differences between the PT and MG and no differences between the NC and NG. Since TP is mainly controlled by P attached to particles no difference beyond the effect of reducing sediment concentration would be expected with the gypsum treatment.

The treatments had interested results for both years. In 2005, Ammonia (Am) was not different among treatments because of high variability, but in 2006 considerable significant differences were observed. In 2006, the two manure treatments (NM and MG) produced the greatest soluble Am loss. Although the gypsum treatment was less than without, no significant difference was observed. The PT and NG treatments were the least and significantly less than the other treatments indicating gypsum has no effect of Am loss.

Nitrate exhibited considerable loss differences in 2005 but no treatment differences in 2006. For 2005, the greatest loss was the NG treatment and the least was the CT. This indicates that also the gypsum treatment has not effect on nitrate loss and that tillage or mixing of soluble nitrate from the surface of no-till will significantly lower its threat to runoff. None of the nitrate levels found in the runoff approached the drinking water standard of 15 mg/L of nitrate-N. The highest level measure was 16.8 mg/L from the NG but this is only one third of the allowable limit.

Total Kjeldahl nitrogen (TKN) which includes soluble and soil bound N behaved similarly to TP. In 2005 it was greatest in the CT and least in both years in NG. The greatest loss in 2006 was with the NM treatment because of the high sediment concentration. It is interesting that by tillage the nitrate N loss was less but TKN was almost twice as great as even the NM treatment.

Glyphosate (Gly) is a very common agriculture chemical that is heavily used in conservation tillage but is considered of low risk because of its low toxicity compared to other pesticides. In this study, no treatments came close to loosing Gly near the levels approaching the drinking water MCL of 700 ppb. Although the levels are considerably lower than the present concern, there were a few treatment differences in Gly losses. In 2005 the conventional tillage (CT) system had the greatest loss compared to all other treatments (Table 1) which were similar. In 2006, the greatest level was found in the NM treatment and as with the soil loss the reason is unclear. However, all the levels except for the NM were below that measured in 2005 probably because the study was conducted approximately one week later following product application.

Atrazine (Atz) is a major low cost effective herbicide that is widely used in agriculture. Like other triazines, the MCL in drinking water are very low (3 ppb). The data in this study represent essentially what happens at a point scale in a watershed. It is data collected from those areas of the overall field that produce surface runoff. In this study, we found that none of our treatments could reduce Atz levels to the drinking water standard. The greatest Atz loss was for our CT treatment and the least for the PT treatment in 2005. Dur to large variability there were no differences among treatments in 2006 but all were greater than the MCL ranging from 15.9 to 27.7 for the NC. Although our gypsum treatments MG and NG had less than the control in both years the results were only significant in 2005. We thought that the manure treatment by reduce the amount of Atz moving since it is highly absorbed to organic matter, however, we did not find any significant differences with manure addition.

CONCLUSIONS

Since these are steady state concentrations and do not represent total loadings from the various treatments, the results should not be extrapolated to entire management systems used in a watershed. For example the main differences in the treatments were the amount of water loss in total (data not presented here) which includes the time to runoff, peak runoff, and precipitation intensity and duration in nature. These differences were considerable among the management practices and can represent considerable differences when related on a per unit area which produces runoff. These data represent a worst case, point scale, process where we had hoped to lower threat to drinking water concentrations by our treatments. We have shown that Atz is a risk of its movement in all management systems when surface applied and runoff occurs and Gly is not mainly because of the differences in MCL. The soluble forms of nutrients that cause hypoxia have been reduced by our gypsum treatment and care should be taken when applying manure even with gypsum co-applied when there is a threat of runoff.

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Table 1. Steady state values and significant differences are shown for the years 2005 and 2006.

Treatment	Sed Conc	Soil loss	Runoff	Glyphosate	Atrazine	Ammonia	Phosphate	Nitrate	TKN	TP
2005	g/L	g/m2/min	g/s	ppb	ppb	mg/L	mg/L	mg/L	mg/L	
CT	6.79 a	6.00 a	88.13 ab	69.3 a	30.2 a	1.03 a	0.49 b	3.14 c	21.15 a	4.63 a
PT	5.23 a	5.62 ab	103.67 a	17.0 b	10.4 c	1.21 a	0.12 c	7.95 bc	13.63 b	2.07 c
MG	9.03 b	3.19 bc	89.32 ab	12.1 b	12.6 bc	2.11 a	0.76 b	10.05 b	10.69 bc	3.40 b
NM	2.83 b	2.37 c	78.57 b	10.0 b	27.6 ab	1.22 a	1.13 a	8.48 bc	14.07 b	1.93 c
NG	2.09 b	2.20 c	108.45 a	13.5 b	14.9 abc	1.84 a	0.05 c	16.82 a	8.99 c	0.94 d

2006

NC	3.07 c	2.30 c	74.86 b	8.7 ab	27.7 a	0.19 bc	0.21 b	1.61 a	6.65 b	1.66 c
PT	7.78 b	5.94 b	76.50 b	8.2 ab	22.8 a	0.14 c	0.07 b	0.94 a	7.14 b	2.81 bc
MG	4.76 bc	3.50 c	76.90 b	7.0 b	15.9 a	0.67 ab	0.56 b	1.19 a	8.58 ab	4.03 b
NM	11.07 a	8.85 a	79.02 ab	15.2 a	16.5 a	0.70 a	1.17 a	1.68 a	13.55 a	7.15 a
NG	3.28 c	2.89 c	89.88 a	6.2 b	21.8 a	0.15 c	0.08 b	1.83 a	4.80 b	1.60 bc

Columns with like letters are not significantly using Tukey's Studentized Range Test at P=0.05.

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