Manure Management in No-Till & Pasture Systems

Rory Maguire & Josh McGrath
January 2009

MID-ATLANTIC Water Program

SUMMARY

No-till is a best management practice (BMP) that has several benefits to water quality as well as to crop production systems. However, when manure applications are made to no-till or pasture systems, surface application is the traditional method as incorporation by tillage is not possible. As surface application leads to losses of ammonia through volatilization and increases losses of nitrogen (N) and phosphorus (P) in runoff, recent efforts have focused on injection of manure in no-till and pasture systems. As this is a relatively new area of research, this review of the literature was conducted to evaluate the “state of the science” and look for needs or areas where our knowledge of these new technologies is lacking. From an environmental perspective, injection systems that placed all of the manure below the soil surface performed well consistently, reducing nutrients lost in runoff and/or ammonia volatilization relative to surface application of manure, aerators and tillage. Where ammonia volatilization was decreased, this translated into increased crop yield due to greater plant available N from the manure application. This increased capture of valuable manure N could off-set the increased costs associated with manure injection relative to surface applications, but there are no economic assessments of this to date. In some situations, aerators reduced ammonia volatilization and/or nutrients in runoff, but these effects were inconsistent across studies. Tillage decreased ammonia volatilization, but lost the benefits associated with no-till, such as decreased soil and sediment erosion in runoff. Overall, manure injection holds promise as a new technology that can help improve manure management for improved water quality. However, as this is a new area of research, more studies are needed to evaluate which technologies are most appropriate in different agricultural situations.

Types of Tools Evaluated

There are a variety of tools available that are compatible with no-till and they can be placed into a few categories (Meisinger and Jokela, 2000). Disc injectors cut a slit in the ground, inject the manure and then close the injection slit causing a minimum of soil disturbance. Chisel injectors cause slightly more soil disturbance, dragging a vertical chisel through the soil and injecting manure behind it. Often there is a sweep at the base of the chisel that helps spread the manure horizontally in the soil (Meisinger and Jokela, 2000). Finally there are aerators, which punch holes into the ground and are meant to help increase manure liquid and rainfall infiltration (Franklin et al., 2006). However, by changing the angle of the arms on some aerators, they can be used to till instead of simply aerating. There is not an easy answer to which implements are compatible with no-till, although some consider an implement that disturbs the soil in less than one third of the implement width to be a good guide.

EFFECTS OF MANURE APPLICATION METHOD ON KEY FACTORS

Sediment Losses in Runoff

Little et al. (2005) reported that cultivation increase sediment losses in one rainfall simulation relative to a surface manure application with no tillage, despite a lower runoff volume. If further rainfalls had been conducted, the sediment in runoff from the tilled soils would have further increased due to crust formation and surface sealing (Panuska et al., 2008). For poultry litter injected in 8 inch deep slits, Pote et al. (2003) measured consistently lower suspended solids concentrations and loads in runoff where litter had been injected relative to where it had been surface applied, although the differences were not significant. For soil aeration, Shah et al. (2004) measured significantly greater sediment concentrations from manured and aerated soils than those that received a surface manure application with no aeration. Due to the lack of substantial numbers of publications reporting sediment losses in runoff for different manure injection techniques, more research is needed. However, these few studies suggest that manure injection may decrease sediment losses while tillage or sometimes aeration may increase sediment losses in runoff.

Phosphorus Losses in Runoff

Allen and Mallarino (2008) surface applied swine manure and incorporated by disking 10 to 15 cm into the soil, and compared to surface application without incorporation. In runoff generated after 24 hours, dissolved reactive P (DRP) and total P concentrations were greater from the unincorporated than the incorporated. However, Allen and Mallarino (2008) found these differences decreased dramatically for the second rainfall event conducted after 15 days. For a rainfall event six months after the treatments were applied, DRP losses from the two treatments were almost identical (Allen and Mallarino, 2008). Total P losses in the runoff event after six months were significantly greater for the incorporated than the unincorporated, probably due to crust formation and surface sealing increasing sediment losses.

Franklin et al. (2007) reported that aeration increased DRP and total P losses from a poorly drained soil, while aeration decreased DRP and total P losses from a well drained soil, compared to a surface application of manure with no aeration. While in a separate study, Franklin et al. (2006) found that aeration had no effect on DRP loads in runoff following broiler litter applications. Other researchers have measured inconsistent or no effect of aerating manured soils versus surface applying manure on DRP and total P losses in runoff (Shah et al., 2004). However, there are many types of aeration device that aerate using different techniques, such as slicing or punching a hole, or removing a soil core.

Daverede et al. (2004) injected or surface applied swine manure and reported that injection of manure resulted in a 93% decrease in DRP and a 94% reduction in the total P concentration in runoff. Burcham et al. (2008) used a disk injector for dairy manure and reported a 71% decrease in DRP event relative to a surface application in one runoff event soon after manure application. There were no significant differences in total P in runoff between surface applied and injected manure, probably due to similar sediment concentrations for both treatments (Burcham et al, 2008). Injecting poultry litter has also been shown to decrease DRP and total P in runoff relative to surface applications (Pote et al., 2003). For the studies available, injection of manure has consistently decreased DRP and often total P in runoff and no studies have shown manure injection to increase P in runoff relative to surface applications. This suggests that manure injection is a very promising technology for decreasing P in runoff.

Nitrogen Losses in Runoff

Incorporating manure by tillage may decrease N losses in runoff initially, but over several rainfall events tillage can lead to increased soil erosion (Little et al., 2005; Panuska et al., 2008). After applying dairy manure to soils with and without aeration, Shah et al. (2004) found no differences in nitrate in runoff, while results for total N were inconsistent over 6 rainfall events. Franklin et al. (2006) also found that aeration had no significant effect on N losses in runoff from manured soils.

Using a disk injector and dairy manure, Burcham et al. (2008) reported a 67% decrease in soluble N in one runoff event relative to a surface application. There were no significant differences in total N in runoff between surface application and injection, probably due to similar sediment concentrations for both treatments (Burcham et al, 2008). Pote et al. (2003) measured runoff from litter amended soils and injecting the poultry litter decreased N concentrations and loads in runoff by >80%. Therefore, from the limited number of studies available, manure injection seems like a promising technology for decreasing N losses in runoff.

Nitrogen Losses in Ammonia Volatilization

More studies have looked at the effect of manure application technique on ammonia volatilization than on nutrient losses in runoff. Many studies have shown that surface applying manures leads to great ammonia losses, while tillage can substantially reduce these losses if done close to the time of manure application (Sommer and Hutchings, 2001). Injecting manure is an effective method of reducing ammonia volatilization in most situations, as long as the rate of manure applied can be contained in the injection slit, as slit closing is essential (Sommers and Hutchings, 2001). There are some exceptions, such as where soil is compacted or wet and the injection slit is not closed as the injector can't function correctly (Sommer and Hutchings, 2001). Moseley et al. (1998) also reported on the importance of not only manure injection, but injector design. They tested two manure injectors and reported that one reduced ammonia emissions by up to 80% compared to the other, due to improved manure incorporation into the soil.

As for nutrient runoff losses, studies have reported inconsistent effects of combining soil aeration with manure applications. Bittman et al. (2005) banded dairy slurry behind an aerator and measured ammonia volatilization that was reduced 46 to 48% compared to a surface manure application with no aeration. Gordon et al. (2000) also showed that soil aeration before or after dairy manure application had little effect on ammonia volatilization, while meteorological conditions had a substantial effect.

Odor

Odor issues are becoming more common due to urbanization of agricultural areas, although measurements are difficult. Hanna et al. (2000) measured significantly greater odor for surface applied manures than injected manures. Moseley et al. (1998) also reported that injecting manure could decrease odor compared to surface applications, depending on type of injector.

Nitrogen Uptake, Yields and Rooting Issues

In situations where manure has been injected, no problems with crop yields have been reported. Where a practice such as injection decreases ammonia volatilization, yields increase due to greater plant available N. Groot et al. (2007) either surface applied or injected manure into pasture and reported greater yields where manure was injected. Groot et al. (2007) also reported greater N recovery from injected manure than surface applied, probably due to lower losses via ammonium volatilization. Ball-Coelho et al. (2006) also surface applied or injected swine manure and measured greater N recovery for injected (59%) than surface applied (41%) manure.

In forages, Gordon et al. (2000) found that combining soil aeration with surface manure applications decreased yields compared to manure applications without soil aeration. Shah et al. (2004) applied manure and also found that yields where soils had been aerated were only 81% of those without aeration. Bittman et al. (2005) reported that soil aeration and manure sometimes increasing yield and sometimes decreasing yield relative to a surface manure application. These inconsistent effects may have been due to different weather conditions, soil moisture and time of year when aeration was conducted (Bittman et al. 2005).

References

Allen, B.L., and A.P. Mallarino. 2008. Effect of liquid swine manure rate, incorporation, and timing of rainfall on phosphorus loss with surface runoff. J. Environ. Qual. 37:125-137.

Ball-Coelho, B.R., R.C. Roy, and A.J. Bruin. 2006. Nitrogen recovery and partitioning with different rates and methods of sidedressed manure. Soil Sci. Soc Am. J. 70:464-473.

Bittman, S., L.J.P. van Vliet, C.G. Kowalenko. S. McGinn, D.E. Hunt and F. Bounaix. 2005. Surface-banding liquid manure over aeration slots: A new low-disturbance method for reducing ammonia emissions and improving yield of perennial grasses. Agron. J. 97:1304-1313.

Burcham, M., R.O. Maguire, M. Alley, W. Thomason, and B. Jones. 2008. Injecting dairy manure to decrease nitrogen and phosphorous in runoff. SERA17 Annual Conference, Grasonville, MD.

Daverede, I.C., A.N. Kravchenko, R.G. Hoeft, E.D. Nafziger, D.G. Bullock, J.J. Warren, and L.C. Gonzini. 2004. Phosphorus runoff from incorporated and surface applied liquid swine manure and phosphorus fertilizer. J. Environ. Qual. 33:1535-1544.

Franklin D.H., M.L. Cabrera, and V.H. Calvert. 2006. Fertilizer source and soil aeration effects on runoff volume and quality. Soil Sci. Soc. Am. J. 70:84-89.

Franklin D.H., M.L. Cabrera, L.T. West, V.H. Calvert and J.A. Rema. 2007. Aerating Grasslands: Effects of Runoff and Phosphorous losses from applied broiler manure. J. Environ. Qual. 36:208-215.

Gordon, R., G. Patterson, T. Harz, V. Rodd and J. MacLeod. 2000. Soil aeration for dairy manure spreading on forage: Effect on ammonia volatilization and yield. Can. J. Soil Sci. 80: 319-326.

Groot, J.C.J., J.D. Van Der Ploeg, F.P.M. Verhoeven, and E.A. Lantinga. 2007. Interpretation of results from on-farm experiments: manure-nitrogen recovery on grassland as affected by manure quality and application technique. 1. An agronomic analysis. Netherlands J. Agric. Sci. 54:235-254.

Hanna, H.M., D.S. Bundy, J.C. Lorimor, S.K. Mickelson, S.W. Melvin, and D.C. Erbach. 2000. Manure incorporation equipment effects on odor, residue cover, and crop yield. App. Eng. Agric. 16:621-627.

Little, J.L., D.R. Bennett, and J.J. Miller. 2005. Nutrient and sediment losses under simulated rainfall following manure incorporation and different methods. J. Environ. Qual. 34:1883-1895.

Meisinger, J.J. and W.E. Jokela. 2000. Ammonia volatization from dairy and poultry manure. p.334-354. In Proc. Managing Nutrients and Pathogens from Animal Agriculture, Camp Hill, PA. 28-30 Mar. 2000. NRAES, Ithaca, NY.

Moseley, P.J., T.H. Misselbrook, B.F. Pain, R. Earl, R.J. Godwin. 1998. The effect of injector tine design on odor and ammonia emissions following injection of bio-solids into arable cropping. J. Agric. Eng. Res. 71:385-394.

Panuska, J.C., K.G. Karthikeyan, and P.S. Miller. 2008. Impact of surface roughness and crusting on particle size distribution of edge-of-field sediments. Geoderma. 145:315–324.

Pote, DH., W.L. Kingerly, G.E. Aiken, F.X. Han, P.A. Moore, and K. Buddington. 2003. Water-quality effects of incorporating poultry litter into perrenial grassland soils. J. Environ. Qual. 32:2392-2398.

Shah, S.B., J.L. Miller, and T.J. Basden. 2004. Mechanical aeration and liquid dairy manure application impacts on grassland runoff water quality and yield. Trans. ASAE. 47:777-788.

Sommer, S.G., and N.J. Hutchings. 2001. Ammonia emission from field applied manure and its reduction. Euro. J. Agron. 15:1-15.

AUTHORS

Rory Maguire
Department of Crop and Soil Environmental Sciences
Virginia Tech
Blacksburg, VA 24061

Josh McGrath
Environmental Science & Technology
University of Maryland
College Park, MD 20742

This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 2004-51130-03110.