LIQUID SWINE MANURE NITROGEN AVAILABILITY

John Sawyer, Professor, Department of Agronomy, Iowa State University

Introduction

Swine manure has been used as a crop nutrient source for many years in Iowa corn production systems. Swine production practices have evolved over time to where it is common for manure to be collected in under-building pits or outside tanks, stored as a liquid (anaerobic conditions), and then mixed for land application. Along with advances in feed rations, these swine production systems result in liquid swine manure that is low in solids, low in organic-N, and high in ammonium-N. Liquid swine manure used in twenty-five recent on-farm trials averaged 84% of total-N as ammonium-N, with many facilities having manure with ammonium-N over 90% of total-N. This high ammonium fraction results in swine manure that does not behave, for N availability to crops, as manure from a bedded system with high organic matter content. Recognition of this from crop production research conducted the last ten-fifteen years at Iowa State University (ISU) and other state universities, and knowledge of the high ammonium-N content, resulted in recommendations in Iowa that liquid swine manure total-N should be considered 100% crop available in the year of application. The current ISU Extension publication (*Using Manure Nutrients for Crop Production,* PMR 1003; Sawyer and Mallarino, 2008) suggests that for liquid swine manure use 90-100% for first year N availability, with no second year availability. The range is provided to account for variation in the proportion of total-N as ammonium-N, sampling, and analysis. The concern from producers, advisers, and manure management planners is that the suggested manure-N availability is too high, that it may limit manure-N application rates, and therefore may limit corn yield.

An important aspect related to this issue is the difference between the concepts of nutrient availability and actual nutrient supply, which applies to all nutrient sources. Manure nutrient availability refers to the manure nutrients being in a form or converted to a form that plants can take up. Ammonium-N in manure already is in a crop available form, as is the case of ammonium-N in inorganic fertilizers. With time in the soil, the organic-N compounds in liquid swine manure (the small fraction of total N) will be mineralized (the organic N is converted by microorganisms to inorganic ammonium). Also with time in the soil, ammonium-N (the large fraction of total N in liquid swine manure) is converted (nitrified by microorganisms) to nitrate. Of course manure N availability cannot be greater than 100%.

When soils are warm and moist, these conversions occur rapidly. Hence, liquid swine manure reacts in soil much like an ammonium containing fertilizer. For instance, the earlier in the fall liquid swine manure is applied, the greater the conversion of organic-N and ammonium-N to nitrate and the greater potential for loss with wet soil conditions the next spring due to denitrification and/or leaching. This can occur even with late fall or early spring applications. This is part of the nutrient supply issue for any N source. Nitrogen may have been applied to the soil with swine manure application, but the actual N supply for crop uptake is dependent on potential losses, which are influenced by many factors including time of application. Therefore, the availability of N in liquid swine manure is high, but the supply could be high or low depending on environmental conditions. This is the confusion and why producers claim low availability of the manure N, when in fact it is poor or low supply due to application time before corn N uptake and loss from the soil. Add in uncertainty about actual manure N analysis, application rate, and application distribution (other components of manure nutrient supply), and a low supply can be more frequent and severe than for N fertilizers. Of course if producers use the suggested high crop manure N availability and apply an assumed agronomic total N rate but there are supply problems, then the corn crop will either suffer from low N supply or additional N will need to be applied. Good liquid swine manure N management, just like good fertilizer N management, can help offset potential supply problems.

Research

Recent research has been conducted in Iowa, the Midwest, and other geographic areas that gives insight into the crop N availability of liquid swine manure. In field research, N supply issues are also sometimes documented. Following is a brief summary of research on liquid swine manure N availability. A list of references is provided at the end. A considerable number of studies have been conducted the last ten-fifteen years where the equivalence of liquid swine manure N can be compared to fertilizer N. Comparisons are based on accumulation of nitrate in soil, corn yield, or tile-flow nitrate loss.

Laboratory Incubation

Laboratory incubations allow for controlling environmental factors that cannot be controlled in the field and that can complicate interpretation of field studies. Laboratory incubation of liquid swine manure (50% of manure total-N as ammonium-N) with soil at 72ºF by Loria and Sawyer (2005) found rapid ammonium-N decrease to near soil background levels by fourteen days after application and a concurrent increase in nitrate-N during that time period. There was additional slow nitrate-N increase until the end of incubation at 112 days. The nitrate formed from applied fertilizer was near 100% of that applied, while with swine manure the nitrate-N accumulated was approximately 80% of the total manure-N applied. Further nitrate production could have continued with longer incubation. Laboratory incubation (77ºF) of liquid swine pit manure by Burger and Venterea (2008) found approximately 65% of total applied N was converted to nitrate-N after 180 days of incubation. The manure had 68% of total-N as ammonium-N. There was little net N mineralization by 180 days for any of the manure sources studied (liquid dairy, solid dairy, liquid swine, and turkey). Chae and Tabatabai (1986) dried fresh swine manure before incubating it with four soils for twenty-six weeks. The manure organic-N mineralized was 39% on average, with two soils at 49 and 52%. Even with drying, the organic-N component of the fresh swine manure was easily mineralized indicating high potential to produce crop available inorganic N. These incubation studies show that the organic fraction of liquid swine manure is highly mineralizable, which in addition to the high ammonium-N content, would make the total N highly crop available. For example, using the 84% average ammonium-N fraction of liquid swine manure found in recent field studies, and assuming 50% of the organic-N fraction is mineralized in the first crop year, then the total N availability would be 92%.

Field Studies

A number of field studies have been conducted where liquid swine manure was applied as an N source for corn production. Some studies were at water quality sites where impact on corn production and nitrate leaching were both measured (Helmers and Lawlor, 2005; Kanwar et al., 2006). Other studies were conducted on experiment farms (Killorn, 1998; Randall et al., 1999; Brenneman et al., 2002, 2004; Kwaw-Mensah and Al-Kaisi, 2006; Loria et al., 2007; Chantigny et al., 2008) or producer fields (Randall et al., 1999; Killorn et al., 2008; Sawyer et al., 2003, 2004, 2005). Comparisons of corn yield with liquid swine manure N and fertilizer N consistently indicated that the swine manure-N can produce equivalent corn yield at the same total-N applied, and thus indicated that liquid swine manure under field conditions is 100% crop available. As one example, three years of study across three tillage systems (no-tillage, strip-tillage, and chisel plow) by Kwaw-Mensah and Al-Kaisi (2006) found a maximum yield response at 163 lb total-N/acre (186 bu/acre) for liquid swine manure and 157 lb N/acre (178 bu/acre) for fertilizer N. Research measuring tile flow nitrate-N losses show similar comparative results, that is, about the same nitrate-N concentration or load with similar fertilizer and manure total-N rates.

Application of liquid swine manure in the fall has not resulted in greater N availability and sometimes resulted in less N supply, likely due to the low organic N content and no need for an extended time for mineralization before crop uptake. In some instances the field studies show that N losses occur, with reduced manure N supply and lower corn yield (not due to low manure-N availability but instead reduced N supply). A good example of this is in the study by Loria et al. (2007), where in one year the equivalence of late fall applied liquid swine manure N to fertilizer applied in the spring was 100% (with normal spring rainfall), but was much reduced (44 and 60%) in two other years with wetter than normal spring conditions. This was also noted at some producer field sites where fertilizer N was applied at multiple rates in addition to two rates of liquid swine manure (Sawyer et al., 2003, 2004, 2005); that is, with normal to dry spring rainfall conditions manure N equivalence was 100% but in wet spring conditions the N supply was reduced. Research with continuous corn summarized by Randall (2008) also indicated N loss and N supply issues with fall applied liquid swine manure in three of four years when there were prolonged wet springtime conditions. In some studies spring application of liquid swine manure has improved N supply compared to fall application, but not when fall applied manure performed well or when there were wet spring conditions following spring manure application. Research with sidedress applied liquid swine manure to corn by Chantigny et al. (2008) in Quebec (Canada) found 100% equivalence to sidedressed fertilizer N. The swine manure had an average 67% of total-N as ammonium-N. Even with application in-season at the four-to six-leaf corn growth stage the liquid swine manure crop available N was equivalent to fertilizer N.

Summary

Due to the N composition normally found in anaerobically stored liquid swine manure, the crop N availability should be high. That would be mainly due to the high proportion of total-N as ammonium-N, and also the low concentration of organic-N and easily decomposable organic compounds (and no bedding). High crop availability is what has been found in incubation and field research. Of particular concern to producers should be the agronomic issues related to this N composition, specifically rapid conversion to nitrate and potential losses of nitrate with wet soil conditions. Additional concerns deal with issues not specific to high crop N availability, such as variability in manure nutrient analysis, manure application rate and distribution, and nitrate-N losses. These are supply issues, which are important risks but not due to error in suggested crop N availability. Nitrogen supply problems due to variability in nutrient

content and difficulty at controlling the application rate can be magnified for manure compared with fertilizer. Using appropriately high manure-N availability in conjunction with application rates to closely match corn agronomic N needs does put corn production more at risk from supply issues. Attempting to overcome supply risks through use of low crop N availability is neither economically feasible nor environmentally sustainable, however, since N over-application from liquid swine manure is just as important as with fertilizer. Therefore, use of good manure nutrient management practices and awareness of conditions that may limit N supply are important to ensure success of liquid swine manure as an N source for corn production.

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