EVOLUTION OF PHOSPHORUS CONCENTRATION IN SURFACE RUNOFF FROM PASTURES FERTILIZED WITH BROILER LITTER

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REFERENCE: Proceedings of the 1999 Georgia Water Resources Conference, held March 30-31, 1999, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Abstract. Previous research has shown that surface application of broiler litter to pastures can lead to elevated concentrations of dissolved reactive phosphorus (DRP) in surface runoff. It is not clear, however, for how long a after broiler litter application DRP concentrations in runoff remain high. This work was conducted to study the evolution of DRP concentration in surface runoff from pastures that received broiler litter in 1995 and 1996, and only inorganic fertilizer N in 1997 and 1998. The results showed that DRP concentrations in surface runoff remained high (> 2 mg P L^{-1}) while broiler litter was being applied. Once broiler litter applications stopped, DRP concentrations in runoff decreased below 1 mg P L^{-1} within 19 months. These results suggest that the risk of contaminating surface waters with DRP could be decreased by fertilizing pastures with broiler litter every two or three years, with the addition of only fertilizer N in those years when broiler litter is not applied.

INTRODUCTION

Extensive research with poultry (*Gallus gallus domesticus*) manure has shown that surface application of broiler litter (manure + bedding) to pastures may cause elevated concentrations of dissolved reactive P (DRP) in surface runoff (Edwards and Daniel, 1993; Shreve et al., 1995). These concentrations of DRP can be particularly high (>10 mg P L^{-1}) when runoff occurs soon after broiler litter application. The reason for these high concentrations is that surface applications deposit the litter on the soil surface, where it is likely to interact with surface runoff water. As time passes, the applied manure P is likely to be moved into the soil by the action of rain and animals. Consequently, DRP in runoff would be expected to decrease with time after an application. Most studies on surface runoff P have evaluated DRP concentrations in simulated runoff events occurring immediately after application. Limited data are available on the evolution of DRP with time after application, particularly under large plots that closely resemble field conditions. Such information is needed to design broiler litter management practices that minimize the potential for contamination of surface waters with phosphorus. The objective of this study was to evaluate the evolution of DRP with time in surface runoff from pastures that received broiler litter in 1995 and 1996 and only fertilizer N in 1997 and 1998.

METHODS

Six 0.75-ha, fescue [*Festuca arundinacea* Schreb.]-common bermudagrass [*Cynodon dactylon* (L.) Pers.] paddocks located at the Central Georgia Branch Station were used for this study. Soil series in the paddocks included Altavista (fine-loamy, mixed, thermic Aquic Hapludults), Cecil (fine, kaolinitic, thermic Typic Kanhapludults), Helena (fine, mixed, thermic Aquic Hapludults), and Sedgefield (fine, mixed, thermic, Aquic Hapludults). Earthen berms (0.6 m high, 1.5 m wide) were built around each paddock to route surface runoff to a 0.45-m, H-flume equipped with a sonic sensor (to measure flow) and a 0.6-m Coshocton wheel (to subsample surface runoff). At predetermined runoff volumes, samples were automatically collected from the Coshocton wheel pan and stored in an ISCO 3700FR Refrigerated sampler (ISCO Corporation, Lincoln, NE). The samples were kept refrigerated (4°C) until analyzed for dissolved reactive P by the molybdate blue method (Murphy and Riley, 1962). Precipitation and runoff volume data were recorded with CR10 dataloggers (Campbell Scientific, Inc., Logan, UT). The flow-

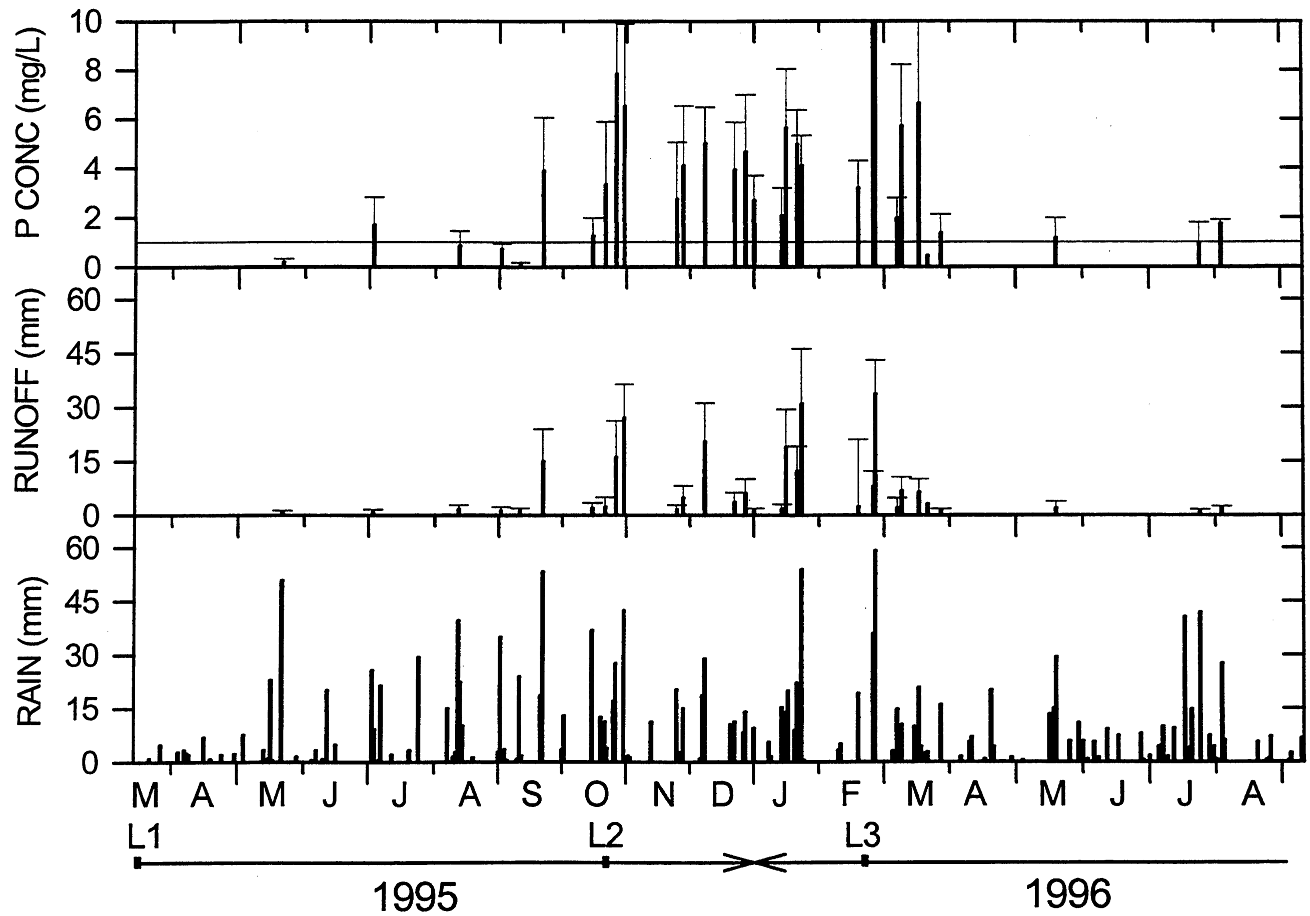

Fig. 1. Average (+ std dev) flow-weighted DRP concentration, runoff, and rain during 1995 and part of 1996 (L1, L2, and L3 indicate when the first, second, and third broiler litter application was made).

weighted DRP concentration for each runoff event in each paddock was calculated by dividing the total amount of P lost in runoff by the total volume of runoff.

During late fall and early winter 1994-95, all paddocks were managed under continuous stocking to establish baseline values for runoff DRP before broiler litter application. From March 1995 until March 1997, three of the paddocks were used for continuous stocking and three for rotational stocking. Both stocking methods used a put and take system that maintained 1340 to 1680 kg forage ha^{-1} on a dry matter basis. Broiler litter was applied in March and September/October of 1995 and 1996. The annual rates of application were 12700 kg ha^{-1} in 1995 and 14670 kg ha^{-1} in 1996 (dry matter basis), which provided 214 and 277 kg total P ha^{-1}, respectively. After the last broiler litter application (September 1996), the pastures received only fertilizer N (urea-ammonium nitrate solution) in March of 1997 (53 kg N ha^{-1}) and in March of 1998 (45 kg N ha^{-1}). The stocking method treatments were maintained through March of 1997; after that, all the paddocks were used for hay production.

RESULTS AND DISCUSSION

The mean flow-weighted DRP concentration during the baseline measurement period was 0.4 mg P L^{-1}. Most of this DRP was probably derived from manure deposited by grazing cattle since the soil was relatively low in P (13 mg P kg^{-1} by Mehlich I). When broiler litter applications started, DRP concentrations increased above the baseline value (Fig. 1). Since statistical analysis of the data showed that stocking method did not affect runoff volume or DRP concentration, the values presented in Fig. 1 correspond to the average of six paddocks for each

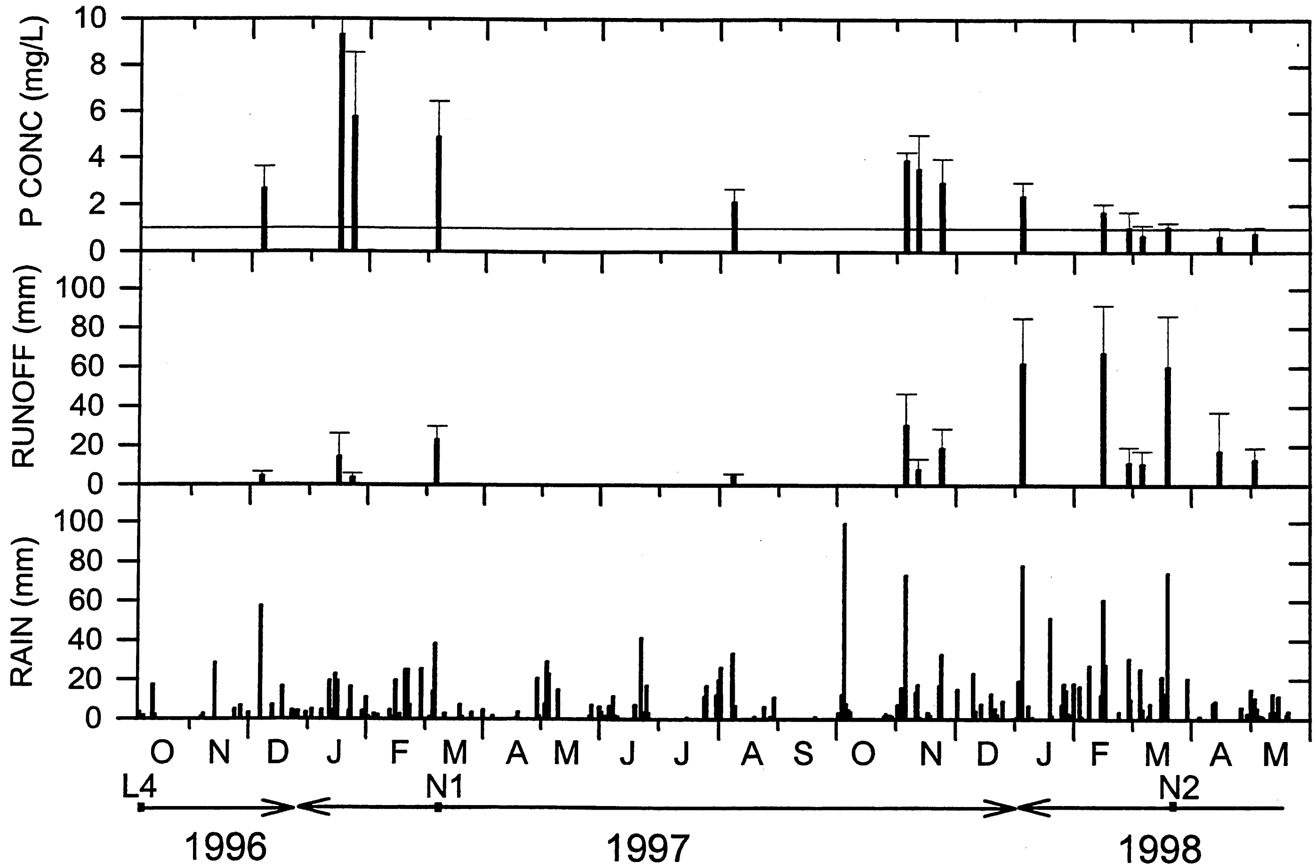

Fig. 2. Average (+ std dev) flow-weighted DRP concentration, runoff, and rain during part of 1996, 1997, and 1998 (L4 shows when the fourth application of broiler litter was made; N1 and N2 indicate when fertilizer N was added).

runoff event. Yearly flow-weighted concentrations of DRP and total P for the first two years of the study are presented on a separate paper in these Proceedings (Kuykendall et al., 1999).

During 1995 and 1996, the concentration of DRP in significant runoff events (> 2 mm) remained relatively high (> 2 mg P L^{-1}) between broiler litter applications (Fig. 1). Since the concentration of DRP in runoff before the first broiler litter application was 0.4 mg P L^{-1}, these results confirm previous work showing significant increases in DRP as a result of surface applications of broiler litter (Edwards and Daniel, 1993; Shreve et al., 1995).

From the last broiler litter application (L4 in Fig. 2) through December of 1997 (about 15 months), the concentration of DRP in runoff remained larger than 2 mg P L^{-1}. This may have been due in part to the lower-than-normal amount of rainfall received during that winter. The 50-yr average for January, February, and March is 364 mm for the area, whereas the amount received during that period in 1997 was 298 mm. A lower amount of rainfall would lead to lower runoff volumes, which in turn would lead to higher concentrations of DRP in runoff. After December of 1997 DRP concentrations decreased rapidly, in part due to the large amount of rainfall received during January, February, and March of 1998 (497 mm). Nineteen months after the fourth application, the average concentration of DRP in runoff was below 1 mg P L^{-1} (Fig. 2) for both large and small runoff events. A concentration of 1 mg P L^{-1} has been tentatively proposed as the maximum desirable concentration in surface runoff from agricultural fields (USEPA, 1986)

It should be pointed out that the soil test P (Mehlich I) in the upper 15 cm of soil increased from 13 to 80 mg P kg^{-1} as a result of broiler litter applications made in 1995 and 1996. Although 80 mg P kg^{-1} is considered very high for agronomic purposes (Plank, 1989), it does not appear to be high enough to cause high concentrations of DRP in runoff (> 1 mg P L^{-1}) once fresh broiler litter is no longer present on the soil surface. It should be kept in mind, however, that in this study the animals were removed from the pastures at the end of March of 1997, thereby removing their contribution to DRP. If the animals had remained on the pastures, DRP concentrations in runoff may have remained above 1 mg P L^{-1}. It should also be kept in mind that pastures which have received broiler litter for many years (> 15 yr) may have soil test P values that are high enough for significant desorption of P to occur during runoff events (Kingery et al., 1994; Sharpley et al., 1993). Under those conditions, the decrease in DRP obtained when litter applications are stopped may not occur as quickly as in this study. Nevertheless, the results of the present study suggest that when soil test P in these soils is not extremely high (<= 80 mg P kg^{-1}), DRP concentration in runoff may decrease below 1 mg P L^{-1} within 19 months after ceasing applications (if grazing animals are not present).

CONCLUSIONS

Our results indicate that the concentration of DRP in surface runoff is likely to remain high while broiler litter is being applied to pastures at the rates used in this study. When broiler litter applications are stopped, the concentration of DRP is expected to decrease with time, reaching concentrations below 1 mg P L^{-1} within 19 months under the conditions of this study. These results suggest that the risk of contaminating surface waters with DRP could be decreased by fertilizing pastures with broiler litter every two or three years, with the addition of only fertilizer N in those years when broiler litter is not applied.

ACKNOWLEDGMENTS

Thanks are extended to Vaughn Calvert, Joseph Garner, Ray Harwell, and Frank Newsome (from the Central Georgia Branch Station) for help with field operations, and to John Rema, Odeta Qafoku, Erica Sciara, Juli Leonard, Crandall Parlor, and Nicole Wilson for help with laboratory analyses. This work was supported in part by funds received from the USDA Natural Resources Conservation Service.

LITERATURE CITED

Edwards, D.R., and T.C. Daniel, 1993. Effects of poultry litter application rate and rainfall intensity on quality of runoff from fescuegrass plots. *J. Environ. Qual.* 22:361-365.

Kingery, W.L., C.W. Wood, D.P. Delaney, J.C. Williams, and G.L. Mullins, 1994. Impact of long-term land application of broiler litter on environmentally related soil properties. *J. Environ. Qual.* 23:139-147.

Kuykendall, H.A., M.L. Cabrera, C.S. Hoveland, M.A. McCann, and L.T. West, 1999. Effect of stocking method on surface runoff from pastures fertilized with broiler litter. These Proceedings.

Murphy, J., and J.P. Riley, 1962. A modified single solution method for the determination of phosphate in natural waters. *Anal. Chim. Acta* 27:31-36.

Plank, C.O., 1989. *Soil test handbook for Georgia.* University of Georgia Cooperative Extension Service, Athens, GA.

Sharpley, A.N., S.J. Smith, and W.R. Bain, 1993. Nitrogen and phosphorus fate from long-term poultry litter applications to Oklahoma soils. *Soil Sci. Soc. Am. J.* 57:1131-1137.

Shreve, B.R, P.A. Moore, Jr., T.C. Daniel, D.R. Edwards, and D.M. Miller, 1995. Reduction of phosphorus in runoff from field-applied poultry litter using chemical amendments. *J. Environ. Qual.* 24:106-111.

USEPA, 1986. Quality criteria for water. Office of water regulation and standards. EPA-440/5-86-001. May 1986.