Dairy Heifer Manure Management, Dietary Phosphorus, and Soil Test P Effects on Runoff Phosphorus

William E. Jokela,* Wayne K. Coblentz, and Patrick C. Hoffman

Manure application to cropland can contribute to runoff losses of P and eutrophication of surface waters. We conducted a series of three rainfall simulation experiments to assess the effects of dairy heifer dietary P, manure application method, application rate, and soil test P on runoff P losses from two successive simulated rainfall events. Bedded manure (18–21% solids) from dairy heifers fed diets with or without supplemental P was applied on a silt loam soil packed into 1-by-0.2-m sheet metal pans. Manure was either surface-applied or incorporated (Experiment 1) or surface-applied at two rates (Experiment 2) to supply 26 to 63 kg P ha⁻¹. Experiment 3 evaluated runoff P from four similar nonmanured soils with average Bray P₁-extractable P levels of 11, 29, 51, and 75 mg kg⁻¹. We measured runoff quantity, total P (TP), dissolved reactive P (DRP), and total and volatile solids in runoff collected for 30 min after runoff initiation from two simulated rain events (70 mm h⁻¹) 3 or 4 d apart. Manure incorporation reduced TP and DRP concentrations and load by 85 to 90% compared with surface application. Doubling the manure rate increased runoff DRP and TP concentrations an average of 36%. In the same experiment, P diet supplementation increased water-extractable P in manure by 100% and increased runoff DRP concentration threefold. Concentrations of solids, TP, and DRP in runoff from Rain 2 were 25 to 75% lower than from Rain 1 in Experiments 1 and 2. Runoff DRP from nonmanured soils increased quadratically with increasing soil test P. These results show that large reductions in P runoff losses can be achieved by incorporation of manure, avoiding unnecessary diet P supplementation, limiting manure application rate, and managing soils to prevent excessive soil test P levels.

P HOSPHORUS in surface runoff from cropland can cause increased eutrophication that negatively impacts lake and stream water quality (Carpenter et al., 1998). Although multiple sources contribute to P in surface waters, agriculture, particularly livestock agriculture, is considered a major nonpoint source (U.S. Geological Survey, 1999). Manure produced on dairy and other livestock farms is a valuable nutrient resource for crops, but manure application to cropland can significantly increase runoff P losses, both from direct P release from surface-applied manure and from increased soil P that results from application of manure at rates that exceed crop P needs (Kleinman et al., 2002; Smith et al., 2001).

Various practices are recommended to reduce runoff P losses from soils that receive manure. Application method, specifically placement of manure, is a management practice that affects runoff P loss. Incorporation of manure by tillage or injection has consistently resulted in reductions of dissolved P in runoff compared with surface application (Bundy et al., 2001; Daverede et al., 2004; Eghball and Gilley, 1999; Mueller et al., 1984; Withers et al., 2001). However, total P loss has sometimes increased because of increases in runoff sediment concentrations associated with the tillage operation (Bundy et al., 2001; Eghball and Gilley, 1999).

Another common recommendation is to apply manure at rates based on soil tests or, at least, not exceeding crop P removal (Sharpley et al., 1996) because runoff P losses have generally increased with increasing manure application rates (Eghball and Gilley, 1999; Kleinman and Sharpley, 2003; Volf et al., 2007). For example, runoff concentration of dissolved P was greater from beef cattle manure applied at N-based rates than at lower P-based rates (Eghball and Gilley, 1999; Miller et al., 2011).

Application of excessive rates of manure or fertilizer P can elevate soil P levels well above those needed to supply P for crop production, resulting in increased runoff concentrations of dissolved P (Sims et al., 2000). Previous research with rain-simulation-generated runoff on field plots showed a direct relationship between extractable soil P levels and concentration of dissolved P in runoff, but the nature of that relationship varies with the soil test extractant, soil type, crop, and other factors.

Abbreviations: DRP, dissolved reactive phosphorus; HPD, high phosphorus (P-supplemented) diet; LPD, low phosphorus (nonsupplemented) diet; TP, total phosphorus; WEP, water-extractable phosphorus.

W.E. Jokela and W.K. Coblentz, USDA–ARS, Environmentally Integrated Dairy Management Research Unit, Dairy Forage Research Center, 2615 Yellowston Dr., Marshfield, WI; P.C. Hoffman, Dep. of Dairy Science, Univ. of Wisconsin, 2611 Yellowston Dr., Marshfield, WI. Assigned to Associate Editor Barbara Cade-Menun.

Copyright © 2012 by the American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America. All rights reserved. No part of this periodical may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any information storage and retrieval system, without permission in writing from the publisher.

J. Environ. Qual. doi:10.2134/jeq2012.0046
Received 30 Jan. 2012.
*Corresponding author (bill.jokela@ars.usda.gov).
© ASA, CSSA, SSSA
5585 Guilford Rd., Madison, WI 53711 USA