

## DAIRY HEIFER DIETS, MANURE MANAGEMENT, AND RUNOFF PHOSPHORUS.

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Livestock manure is considered a waste product from the perspective of the animal operation, but it can be an important resource for crop production by providing valuable nutrients and enhancing soil quality. However, manure application to cropland can also have adverse environmental effects, in particular ammonia and greenhouse gas emissions and impairment of surface and ground water quality. The benefits of manure can be enhanced and the potential environmental risks minimized by employing improved manure and soil management practices (Sharpley et al., 1994; Jokela et al., 2004). In this article we discuss the results of integrated research to evaluate several of these “best management practices” for their effect on runoff P losses: a) prompt incorporation of manure, aimed at controlling N losses by ammonia volatilization and protecting manure from runoff losses of P and N, b) application of manure at rates that do not exceed crop nutrient need (typically N or P, depending on crop needs and soil P test level), c) avoiding build-up of soil test P to excessive levels can contribute to runoff P losses even if manure and fertilizer are not applied, and d) eliminating unnecessary P supplementation of dairy diets, a practice that can have economic benefits and can help balance whole-farm P budget, thereby helping prevent soil P build-up.

Studies in Wisconsin and elsewhere have shown that dietary P levels fed to lactating dairy cattle can be reduced substantially without negatively affecting animal health or production, with a resultant decrease in manure P (Wu et al., 2000; Morse et al., 1992). More recent research in Wisconsin has shown that P supplementation for dairy heifers does not result in growth, reproductive, or lactation benefits (Bjelland et al., 2011). Other research has shown that application of manure from lactating cows fed diets over-supplemented with P led to increased losses of dissolved and total P in runoff (Ebeling et al., 2002; Hanrahan et al., 2009). We found no similar studies for heifer manure.

We conducted a series of three rainfall simulation experiments to assess the effects of dairy heifer dietary P, manure incorporation, manure application rate, and soil test P (in various combinations) on runoff P losses from successive rains.

### Materials and Methods

Manure used in these experiments was from dairy heifers (average weight=1000 lb) at the UW Marshfield Agricultural Research Station. Pens of dairy heifers containing eight heifers per pen bedded with sawdust were offered diets with (0.38% P) or without (0.32% P) supplemental P. This resulted in manure with 18 to 21% dry matter and differing P levels. Manure from heifers fed non-supplemented diets had 16 to 20% lower total P and 35 to 50% lower water-extractable P than manure from heifers fed diets supplemented with P.

To evaluate runoff effects, soil from the surface layer of a Withee silt loam was put in 40 x 8-inch sheet metal pans to a 2-inch depth and packed to approximate the bulk density of a field

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soil (about 1.2 g/cm<sup>3</sup>). Pans with soil (10 or 12 for each run) were placed under a rainfall simulator (Joerns, Inc., West Lafayette, IN; Humphrey et al., 2002) at a slope of 5%. Rain generated through a single nozzle 10 feet above the pans provided a uniform rain intensity of 2.75 inches per hour. Runoff was collected from each pan for 30 minutes after the start of runoff (2 to 6 minutes in most cases). This is a rainfall of relatively high intensity, equivalent to a storm with an approximate recurrence interval of 10 years in Wisconsin (Huff and Angel, 1992). Two successive rain/runoff events were generated in each experiment, the first about 24 hours after manure application and the second three or four days later. We measured runoff volume, total and dissolved P, and total and volatile solids from both runoff events. We also calculated runoff loads of solids and P (concentration x runoff volume), but only concentrations are reported here. Treatments had little or no effect on runoff volumes, so treatment effects on loads of P and solids were similar to those on concentrations.

In Experiment 1, manure was applied at a rate equivalent to 20 tons per acre from heifers fed either non-supplemented or P-supplemented diets, which supplied P at rates of 88 or 112 lb P<sub>2</sub>O<sub>5</sub>/acre. Each manure type was applied either on the surface or incorporated by mixing manure with the soil and was compared to a no-manure control. In Experiment 2, manure produced from each of the two dietary P levels was surface-applied at two rates (equivalent to 15 and 30 tons/acre), which supplied a range of 75 to 180 lb P<sub>2</sub>O<sub>5</sub> per acre for different manure P-level and application-rate combinations. Experiment 3 consisted of soils from the surface horizon of a Withee silt loam without manure with Bray P1-extractable P levels of 11, 29, 51, and 75 ppm.

## Results and Discussion

The concentration of total solids in runoff was lower (about 50%) from surface-applied manure than from incorporated manure in both runoff events (Experiment 1; data not shown), reflecting a mulching effect of surface manure that protected the mineral soil from erosion. However, the concentration of volatile solids, which is a measure of the organic, primarily manure-derived, solids, was about three times greater from surface-applied than from incorporated manure in runoff from both rains. Incorporation of manure reduced total and dissolved P concentration and load by 85 to 90% compared to surface application (Fig. 1). As a result, P concentrations from incorporated manure treatments were not different from those with no manure applied (except total P in Rain 1). So, despite the reduction in erosion of total solids by the surface manure, the P-rich manure left on the surface dominated effects on runoff P because runoff interacts primarily with the immediate surface layer of the soil. Doubling the rate of surface-applied manure increased runoff dissolved and total P concentrations an average of 35% (Experiment 2; Fig. 2), which is a function of more manure P being available for release to runoff from the higher application rate.

Phosphorus diet supplementation resulted in twice the concentrations of dissolved and total P in runoff from surface-applied manure in Experiment 2 (Fig. 2) and smaller but significant increases of dissolved P in Experiment 1. Alternatively, eliminating supplemental P from the diet, which has been shown to have no adverse effect on dairy heifer performance (Bjelland et al., 2011), lowered runoff P concentration by approximately 50%. Thus, avoiding over-supplementation of P in dairy heifer diets can have both environmental and economic benefits.

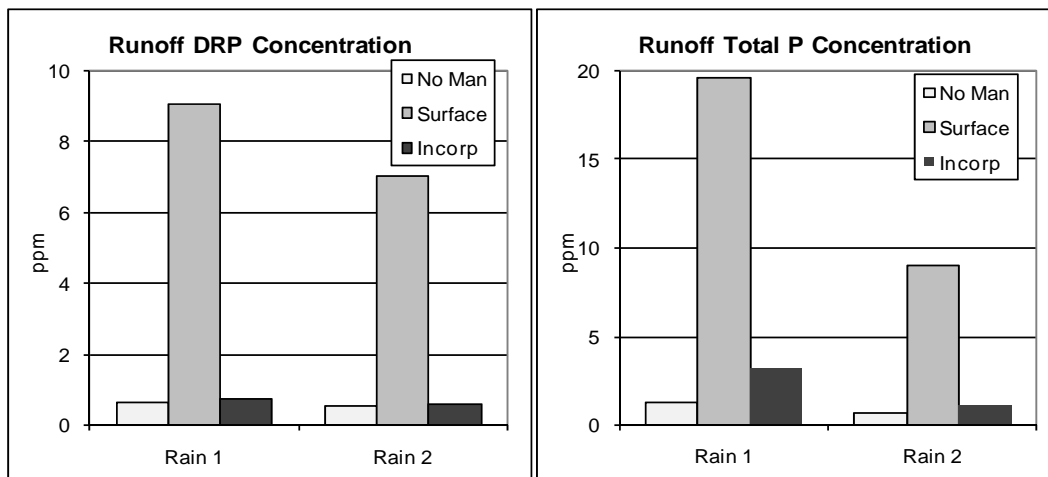


Figure 1. Dissolved reactive P (DRP) and total P concentrations for Rains 1 and 2, Experiment 1. P concentrations for manure treatments were averaged across dietary P levels.

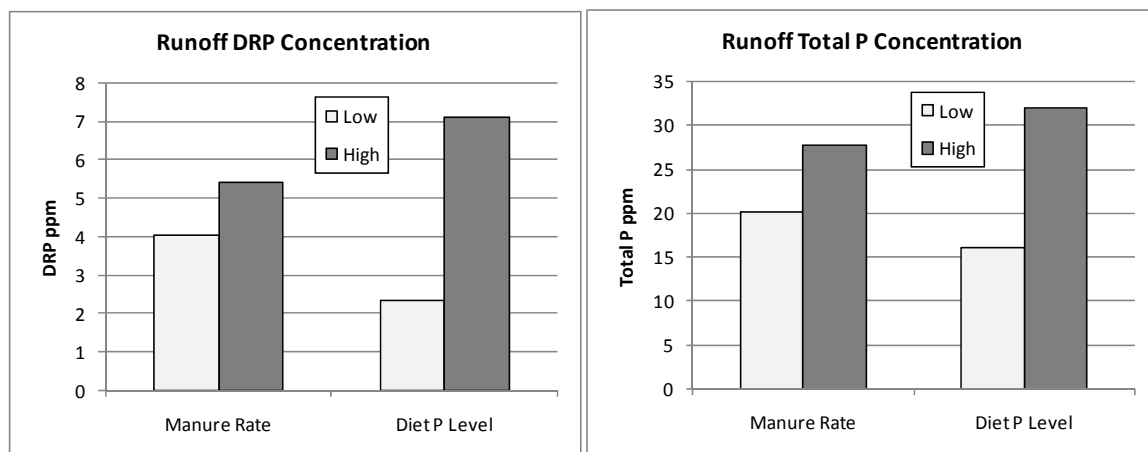


Figure 2. Dissolved reactive P (DRP) and total P in runoff from Rain 1, Experiment 2. P concentrations for each manure rate were averaged across dietary P levels, and those for each dietary P level were averaged across manure rates.

Evaluation of the effect of soil test P without manure application (Experiment 3) showed that runoff dissolved P increased with increasing soil test P, particularly at excessive (above optimum) levels (Fig. 3). Note that soils testing in the optimum range (16 to 23 ppm for alfalfa and corn silage on a Withee soil; Laboski et al., 2006) resulted in quite low concentrations of dissolved P in runoff, but that P concentrations increased rapidly at excessive (> 30 ppm) or higher levels. While manure, especially when surface applied, has a much greater effect on runoff P than high soil test P, avoiding buildup of soil test P to excessive levels is also important. Applying higher manure rates than needed, as in the high rate in Experiment 2, not only contributes directly to increasing runoff P, but also increases soil test P to levels that will continue to contribute to P loading even if manure is no longer being applied.

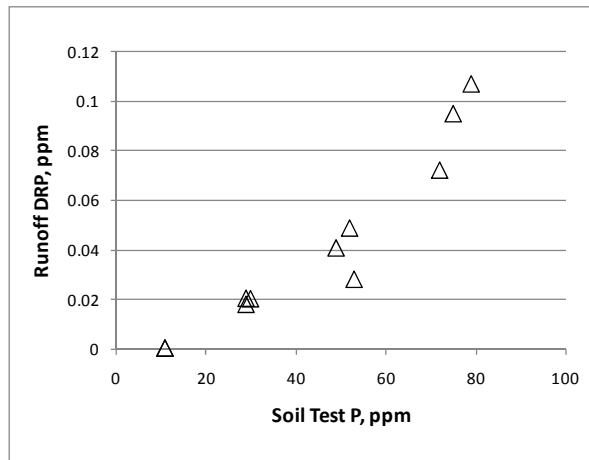


Figure 3. Runoff dissolved reactive P (DRP) concentration vs. soil test P for Rain 1, Exp. 3.

All three experiments involved two rain/runoff events, an initial one and a second one three or four days later. In most cases, concentrations of solids and total and dissolved P in runoff from the second event were 25 to 75% lower than from the first one, as illustrated by P data from Experiment 1 (Fig. 1). This suggests that the first runoff-producing rain event soon after manure application has the potential to produce the greatest P runoff, but the degree will depend on the weather and resulting soil and manure conditions in the intervening period.

Results from this research demonstrate that large reductions in P runoff losses can be achieved by incorporation of manure, avoiding unnecessary dietary P supplementation, limiting manure application rate, and managing soils to prevent excessive soil test P.

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