Final Progress Report for Water Quality Project

On-Farm Demonstration of the Impact of Phosphorus Soil-Test Levels and Management on Phosphorus Loss with Surface Runoff

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Introduction

This report summarizes the field, laboratory, and outreach activities of the project. The work focused on demonstrating the impact of various field conditions on loss of dissolved, bioavailable, and total P with surface runoff from producers' fields based on a field rainfall simulation technique. Project objectives also included outreach activities targeted to producers, Iowa State University (ISU) Extension personnel, and nutrient management planners. These activities consisted on distributing project results and general information about risk of P loss from fields, use of the P index, and improved P management practices to minimize or improve water quality in Iowa. A total of 29 field demonstrations were conducted from spring 2004 to spring 2006. The soil and runoff chemical analyses of the last demonstrations continued until September 2006, while data analyses and outreach activities continued until March 2007.

Field Demonstrations

Activities in the project began in spring 2004, when work for the objectives began to be merged with the last stages of a related previous project that focused on a pilot implementation of the Iowa P index in cooperation with producers. The network of producers, nutrient management planners, and local agency personnel developed for the previous project was used to start developing the new project. Twenty-nine field rainfall simulation demonstrations were conducted from spring 2004 to spring 2006 at producers' fields having soybean or corn residues. In order to adjust the work to common field management practices and weather conditions, the spring demonstrations were conducted from late March to early May and the fall simulations were conducted from late September to early November. These two periods were of very intense field activities. Crop producers and animal feeding operators were contacted during a period one to three months prior to the field rainfall simulations. The project and its objectives as well as agronomic and environmental P issues and the Iowa P index were explained and discussed before and during these field activities to the producers and onlookers (such as neighbors, extension specialists, and crop consultants). During winter and summer of each year summary results of manure, soil, and runoff analysis were sent to each manure supplier and collaborating producers. A general summary with averages across fields also was sent to field extension agronomists or nutrient management planners that cooperated or were interested in the project.

In 2004, the rainfall simulation demonstrations were conducted at five fields in spring and three fields in the fall. The work focused on demonstrating P loss with runoff in spring and fall (between crop harvest and planting for the next season) without applying fertilizer or manure as determined mainly by soil cover, previous P applications, and current soil-test P levels.

Simulations were conducted in four to twelve areas of each field. The demonstrations were successful, but results and feedback from cooperators suggested a revision of the field methods to focus more on the effects of fertilizer and manure P application to the soil surface without incorporation into the soil. Since spring 2001, therefore, 21 additional field demonstrations were based on a different methodology to emphasize demonstration of P loss with runoff when various P sources were applied to the surface of undisturbed soil. The objective of this change was to better demonstrate and collect data about immediate and short-term P loss with surface runoff when fertilizer or manure P was applied without injection or immediate incorporation into the soil. A side positive result of the change was to provide potentially useful data to improve a portion of the Iowa P Index, because the P application factor in the current version does not differentiate among P sources. The P sources used at each field were fertilizer P (di-ammonium phosphate, DAP), poultry manure (from broiler, egg layers, or turkey feeding operations), liquid swine manure, and beef (feedlot) manure. A similar P rate of 100 lb total P_2O_5/acre was applied with all sources to all these fields. Each source was applied to three sets of plots at each field to assess and demonstrate the variability usually observed for soil-test and runoff P. These demonstrations were conducted in fields across central, eastern, southern, and western Iowa.

The methodology of the rainfall simulation was always the same. We applied simulated rain mostly to fields with soybean residues and to a few with corn residues. A heavy pick-up truck, a support smaller truck, and a trailer were used to carry the project personnel, galvanized steel runoff boxes, the rainfall simulator frame, a 1,000-gallon water tank, water pumps, hoses, and miscellaneous supplies to each field. The producers collaborated by identifying appropriate fields and field areas and by providing the water and manure sources, although sometimes water and manure from other sources were brought to a field. The rainfall simulation equipment and the techniques used were based on protocols suggested by the National Runoff P Project, of which Dr. Mallarino has been participating. The protocols were adapted to assessments of runoff P after applying fertilizer or manure. The rainfall was applied at an intensity of 3 inches/hour to get 30 minutes of continuous runoff. Runoff collection boxes (5 by 6.5 feet) were installed at representative sloping areas of each field without wheel tracks and were removed after the simulations were completed. A v-shaped flume with a canopy to exclude direct input of rainfall was installed with the edge level with the soil surface on the open end of each box located down the slope to collect runoff. A 2.5-inch diameter PVC pipe was connected to the flume end to route runoff to a plastic collecting vessel placed outside of the rainfall area and buried so that its surface was at a ground level. Soil samples were collected around the boxes and were analyzed for P by various methods and other soil properties. Runoff volume was measured in the field and samples were collected. A portion of the sample was filtered to measure dissolved reactive P. Soil and runoff samples were stored refrigerated to be analyzed during summer and winter months.

Field Characteristics and Soil and Runoff Analyses

Table 1 shows summarized information for 29 fields where the demonstrations were conducted. Seven fields had corn residue and 22 had soybean residue. Residue cover varied greatly across fields, and was estimated visually by the point-transect method. Soil, manure, and runoff chemical analyses for the last demonstrations (in spring 2006) continued until September 2006, while data analysis continued until the end of winter 2007. Soil samples were analyzed for P by three P tests supported by Iowa State University (Bray-1, Olsen, and Mehlich-3 with the standard colorimetric determination of extracted P), total P, organic matter, and pH. The results are summarized in Table 1. Soil-test P ranged from Very Low to Very High according to current ISU soil-test interpretations, soil organic matter ranged from 1.4 to 6.6%, and soil pH from 5.5 to 7.9. Two to three samples of each manure type used in all demonstrations conducted in 2005 and 2006 were collected before manure application to demonstrate the variability of manure nutrient content and the need for manure analysis (as opposed to relying on tabulated average values). The manure was analyzed for moisture, both total and soluble P, and total N contents by standard methods used in Iowa by many laboratories. Table 2 summarizes results of manure analyses, which show the common spread of moisture and P contents observed in Iowa. The filtered surface runoff samples were used to measure dissolved reactive P by the standard Murphy and Riley method. The unfiltered runoff samples were analyzed for bioavailable P by the iron-oxide impregnated paper test and total P by the alkaline digestion method. The dissolved reactive P runoff fraction is immediately available for algae growth in streams and lakes. The bioavailable P values result from a laboratory analysis that estimates P immediately available to algae plus the P available over a short period of time (weeks or a few months). A variable portion of the total P can become available to algae depending on many physical, chemical, and biological characteristics of water bodies.

Results of Field Demonstrations

Demonstrations of relationships between P concentration and loads in surface runoff when no P had been applied for at least four months prior to the runoff event showed that dissolved reactive, bioavailable, and total runoff P fractions increased with increasing soil P levels. This result was observed for all soil P testing methods used. There was much variability, however, due to history of P application (type and time since application especially for the relationship between runoff P and total soil P because of it was highly affected by large variation in flow volume and sediment loss. A known fact that was clearly confirmed and demonstrated was that the relationship between soil P and runoff P is highly affected by the period of time since the last P application. This result is summarized in Fig. 1, which shows that a certain soil P test value results in a much higher dissolved P in runoff for the most recent P applications. This result is explained by higher water-extractable soil P (not shown) with a recent P application for similar values of the routine soil P test method. Previous and ongoing research with more fields and a wide range of soil-test P values from fields sampled one year or more after applying P show linear relationships and little or no consistent effects of the time of P application.

Demonstrations of the effects of applying 100 lb P_2O_5/acre with various sources on runoff P within 24 hours of the application showed increased P loss compared with the check receiving no P in all fields. Results summarized in Fig. 2 show large differences in runoff P concentrations among the P sources even though the total P rate applied always was the same. The P concentration of all runoff P fractions always was highest for fertilizer, intermediate for liquid swine manure, and lowest for poultry and beef manures. Differences between poultry and beef manures were small, inconsistent, and varied among fields and seasons, but on average runoff P tended to be slightly higher for poultry manure. Interestingly, for the fall 2005 averages none of the runoff P fractions from the manured plots differed statistically from the control (runoff P from fertilizer was higher) but the ranking described before was maintained. Also, the runoff dissolved P concentration from plots receiving beef manure seldom differed statistically from the control plots.

The concentration of dissolved P in runoff expressed as a proportion of total runoff P was highest for fertilizer, was followed by swine manure, and then by poultry and beef manures (which did not differ consistently). The concentration of soluble P in manure was very poorly correlated with runoff dissolved P concentration or the percentage of dissolved P in the total runoff P both within and across manure types. The bioavailable runoff P fraction almost always was higher than the dissolved P fraction and less than the total P concentration. A few exceptions were for the P fertilizer applied to some fields, when the three P fractions were statistically similar mainly when there was very high residue cover and little soil loss. This result is reasonable because a large P rate was applied, rainfall occurred immediately after application, and almost all the P in the fertilizer is soluble in water.

The average results for P loads for the various P sources are shown in Fig. 3. In general P loads followed the trends described for runoff P concentrations, although results were more variable mainly because of high variation in runoff volume. Runoff P loss always was the highest for the fertilized plots. Differences in runoff P loads among the manure P sources were somewhat different from results observed for runoff P concentrations. Runoff P loss clearly was lowest for the beef manure plots and seldom differed with P loss from the control plots. Also, differences between swine manure and poultry manure were less consistent across fields and seasons, and on average were slightly higher for liquid swine manure. The amounts of dissolved and bioavailable P lost from the plots suggested potentially large P loss for runoff events immediately after surface application of fertilizer P without incorporation into the soil and in a lesser degree of liquid swine manure P. Iowa long-term precipitation data indicates a very low probability of runoff-causing rainfall events in the fall and a very high probability in spring. Therefore, results for spring likely represent better P losses that may occur for these P sources during the year under natural rainfall. However, results for bioavailable and total runoff P loss must be interpreted with caution and used only to compare P sources because rainfall simulations estimate poorly actual sediment and particulate P loss, especially transport beyond the edge of the fields to streams.

Other Educational and Outreach Activities

The project and its objectives, agronomic and environmental P issues, and the P index were explained and discussed before and during the field activities to the cooperators (producers, manure suppliers, and nutrient management planners) and onlookers such as neighbors, extension specialists, and crop consultants. In addition, presentations and workshops were conducted for small groups targeted to a small region or in open classic meetings developed in cooperation with other agencies and ongoing related projects targeting producers, crop consultants, custom manure applicators, and nutrient management planners. These agencies or projects included ISU Extension, producers’ associations, the IFLM program of IDALS, the Learning Farms Project, and several agribusinesses. The presentations and workshops began to be developed early in 2005 and shared project-related issues, preliminary results, general P environmental issues, reasons for increased risk of P loss with runoff, manure P management in high-testing soils, and results of a previous P index DNR-319 project that focused on pilot implementation of the P index. The small meetings and field days allowed for open discussions and exchange of ideas in an environment that encouraged as much participation as possible from the attendees.

In 2005, these activities included four workshop-style winter meetings conducted in Carroll, Clear Lake, Clearfield, and Storm Lake involving a total 129 attendees and presentations at four classic-style meetings (three in coordination with ISU Extension programs) attended by a total of about 500 people. The issues were discussed and shared at two spring field days developed in coordination with ISU Extension near Spencer (Clay County Growers Field Day) and at the Northeast Research and Demonstration Farm (these activities involved a total of about 300 attendees). In the fall, activities included a meeting with about 30 crop consultants in Marshalltown and a radio interview during the ISU Extension ICM conference. In winter 2006 the activities included presentations to crop consultants at an Ames meeting organized by Agriliance; farmers and consultants enrolled in the ISU Extension Soil Fertility Short Course; crop consultants at a meeting in Marshalltown; nutrient management planners, farmers, and agency personnel attending workshops of the Agriculture and the Environment Conference in Ames, and both producers and crop consultants at a tillage conference in Sheldon (these activities involved a total of about 550 attendees). From summer to late fall 2006 there were presentations at meeting or field days that included the Manure Nutrient Management Conference (in cooperation with Rembrandt Enterprises) in Sioux Center, the Manure Nutrient Management Short Course near Ames and Field Day near Nevada, the Conservation Systems and Manure Nutrient Management Field Day near Greenfield, the ISU Extension field-crop specialists In-Service Training in Ames; and the Iowa Egg Council Symposium in Ames (these activities involved a total of about 250 attendees). At the field days we also demonstrated the general field methods, rainfall simulation technique, and runoff collection procedures that were used in the demonstrations.

The project issues and preliminary results of the project also were explained and discussed with colleagues of other states. These activities included workshop discussions at the annual meeting and conference of the USDA/ARS - Land Grant Universities SERA-17-IEG (Minimizing P Losses from Agriculture) that took place on August 3-5, 2006, in Ithaca, New York; a poster presentation at the Annual Meeting of the American Society of Agronomy on November 14, 2006; and an invited talk to the Illinois CCA convention on December 15, 2006. Project funding was not used for these activities, but we mention them because they show that our work in Iowa also reached neighboring states. These activities included consultants, nutrient management planners, scientists, extension specialists, and/or NRCS technical personnel from neighboring states and other states that work with P environmental issues. There was interest in the project and our work because of the innovative way in which we collected useful scientific information while emphasizing demonstrations and outreach.

Another useful side product of the activities was that we introduced several P agronomic and environmental issues and procedures for both on-farm demonstration and outreach activities to two ISU graduate students and five undergraduate students who collaborated in different activities of the project over time.

Summary

This project developed field demonstrations and outreach activities focusing on effects of soil P level and fertilizer or manure application without incorporation into the soil on short-term P loss with surface runoff. The project demonstrated that surface runoff P increases with increasing soil-test P levels, and that the relationship is highly influenced by many field soil conditions and the time elapsed since the last P application. The project first assessed for Iowa and demonstrated that loss of dissolved, bioavailable, or total runoff P were highest for fertilized plots, was intermediate for liquid swine manure, and was lowest for poultry and beef manure. Runoff P for poultry and beef manure did not differ consistently, tended to be lower for beef manure, and often did not differ from the control receiving no P. These results must be interpreted with caution, especially in relation to the Iowa P Index and management recommendations, because they represent the maximum potential risk of P loss. Phosphorus loss will occur only when there is runoff-producing rainfall, and field rainfall simulations do not represent long-term losses and estimate poorly sediment and particulate P transport beyond the edge of the fields. However, these results did provide very useful insight about the potential effects of runoff immediately after P application without fertilizer or manure incorporation, which is considered in the P Index and in management guidelines.

The field demonstrations were very effective at achieving the project objectives because they included diverse producers and added the manure P management issue. The project involved not only crop and animal producers in whose fields we conducted the rainfall simulations but also manure suppliers. Also, other project outreach activities addressed the issues of manure sampling, manure P variability, and provided data needed to show how the P loss relates to soil-test P values and the P sources used. The project was successful at generating new knowledge, explaining processes, educating about P management practices; all activities that should help improve water quality in Iowa.

Table 1. Field locations and selected field and soil properties.

Field	Year	Season	County	Crop Residue	Cover	Slope	Soil Series	Initial Soil Test Results * Bray-1 P	Olsen P	Total P	OM	pH
					%	%	Series	------------ ppm	-----------		%	
1	2004	Spring	Story	Corn	6	6	Clarion	270	128	1063	2.3	7.3
2	2004	Spring	Marshall	Corn	25	6	Tama	111	60	785	2.0	6.1
3	2004	Spring	Floyd	Soyb	25	5	Kenyon	178	99	1232	4.1	6.8
4	2004	Spring	Buchanan	Corn	2.4	3	Kenyon	201	111	970	4.3	7.5
5	2004	Spring	Union	Soyb	80	3	Sharpsburg	7	4	261	4.0	6.8
6	2004	Fall	Tama	Soyb	44	6	Tama	171	122	870	2.1	6.7
7	2004	Fall	Buchanan	Corn	34	3	Kenyon	173	103	946	2.3	7.5
8	2004	Fall	Cherokee	Soyb	3	3	Galva	12	8	385	4.5	6.2
9	2005	Spring	Plymouth	Soyb	98	4	Ida	50	51	848	4.3	7.5
10	2005	Spring	Carroll	Soyb	41	5	Clarion	25	18	641	3.5	5.8
11	2005	Spring	Carroll	Soyb	73	11	Marshall	18	24	587	3.6	6.7
12	2005	Spring	Tama	Corn	10	4	Tama	150	113	890	4.8	6.4
13	2005	Spring	Delaware	Soyb	79	6	Kenyon	9	11	353	2.6	7.6
14	2005	Spring	Buchanan	Soyb	79	4	Kenyon	98	62	847	4.0	6.3
15	2005	Spring	Adams	Soyb	62	7	Adair	45	33	632	3.3	6.1
16	2005	Spring	Guthrie	Corn	24	3	Clarion	18	10	436	4.0	6.3
17	2005	Spring	Dallas	Corn	92	4	Clarion	20	12	401	3.6	6.3
18	2005	Fall	Franklin	Soyb	87	4	Clarion	125	68	621	3.4	7.0
19	2005	Fall	Wright	Soyb	98	4	Canisteo	16	9	626	6.6	7.9
20	2005	Fall	Story	Soyb	73	11	Clarion	8	5	273	2.1	7.3
21	2005	Fall	Dallas	Soyb	10	4	Clarion	6	4	279	2.1	7.1
22	2005	Fall	Taylor	Soyb	79	4	Nira	22	12	610	5.1	5.8
23	2005	Fall	Washington	Soyb	79	6	ladoga	18	11	425	3.1	5.5
24	2006	Spring	Story	Soyb	80	8	Clarion	25	15	343	2.3	7.0
25	2006	Spring	Buena Vista	Soyb	30	4	Clarion	39	24	530	3.6	5.8
26	2006	Spring	Wright	Soyb	90	6	Clarion	49	27	533	3.4	6.6
27	2006	Spring	Bremer	Soyb	96	5	Rockton	17	8	234	1.4	6.3
28	2006	Spring	Ringgold	Soyb	10	3	Clearfield	97	53	822	4.1	5.5
29	2006	Spring	Union	Soyb	98	6	Clearfield	6	5	539	3.5	6.4

* Averages for three to twelve small field areas where rainfall simulations were conducted (6-inch sampling depth, OM = organic matter).

Table 2. Results of the manure chemical analyses.*

	Poultry Manure			Liquid Swine Manure			Beef Manure		
	Phosphorus			Phosphorus			Phosphorus		
Field	Total	Soluble	Moisture	Total	Soluble	Moisture	Total	Soluble	Moisture
	-- lb P_2O_5/ton --		%	lb P_2O_5/1000 gal		%	-- lb P_2O_5/ton --		%
9	26	5	78	30	5	95	15	1	50
10	26	5	78	55	5	95	15	1	50
11	80	27	29	8	2	98	8	1	50
12	80	27	29	18	3	96	8	1	50
13	82	16	21	38	9	91	10	2	68
14	82	16	21	38	9	91	10	2	68
15	109	24	37	30	5	95	20	15	65
16	109	24	37	30	5	95	20	15	65
17	82	30	29	18	3	96	8	1	50
18	126	24	20	30	12	95	12	9	61
19	109	28	27	8	5	98	24	9	54
20	54	12	79	77	7	94	18	4	12
21	126	18	20	24	4	97	24	5	44
22	20	7	78	77	7	94	19	1	67
23	54	12	69	18	5	97	24	10	54
24	69	21	37	40	12	93	13	8	64
25	37	9	42	55	10	88	7	1	72
26	78	21	50	39	12	93	9	9	7
27	72	20	24	81	21	89	12	3	57
28	44	16	57	32	19	93	20	4	52
29	38	13	72	75	10	94	6	3	76

* No P fertilizer or manure was applied at Fields 1 through 8. Manure analysis is expressed on and as-is basis.

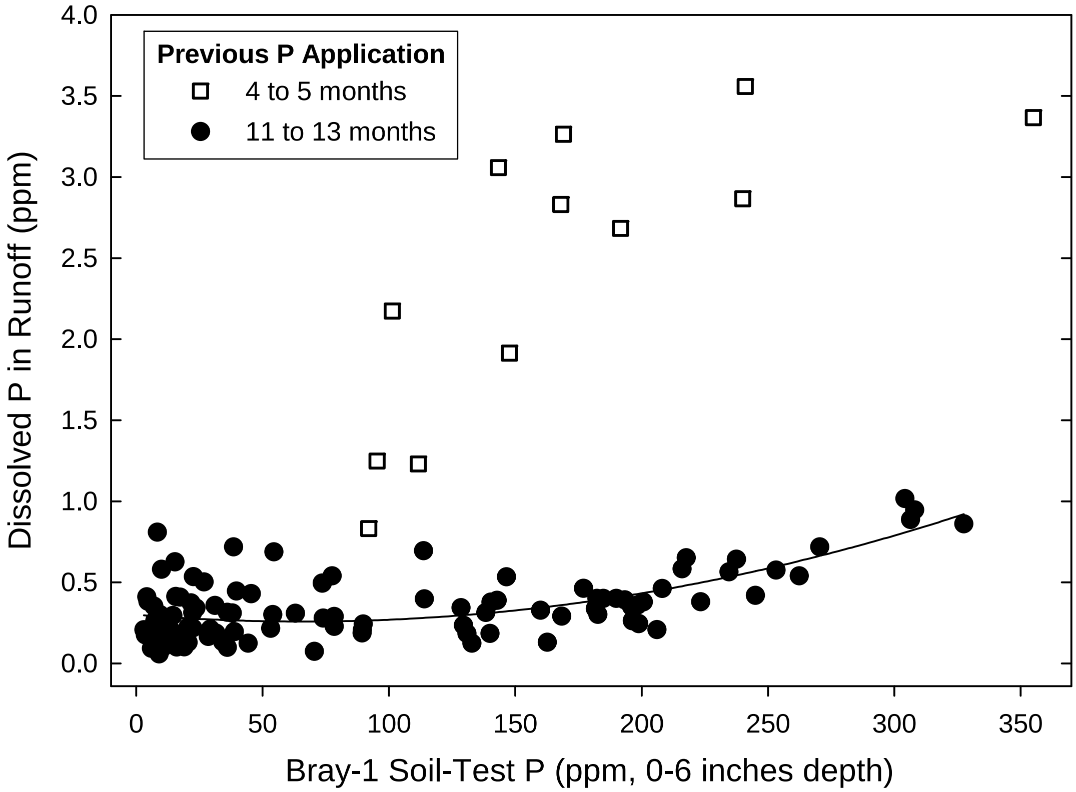

Fig. 1. Relationship between dissolved P in runoff and soil-test P for fields that had received no fertilizer or manure P application for several months prior to the rainfall simulations.

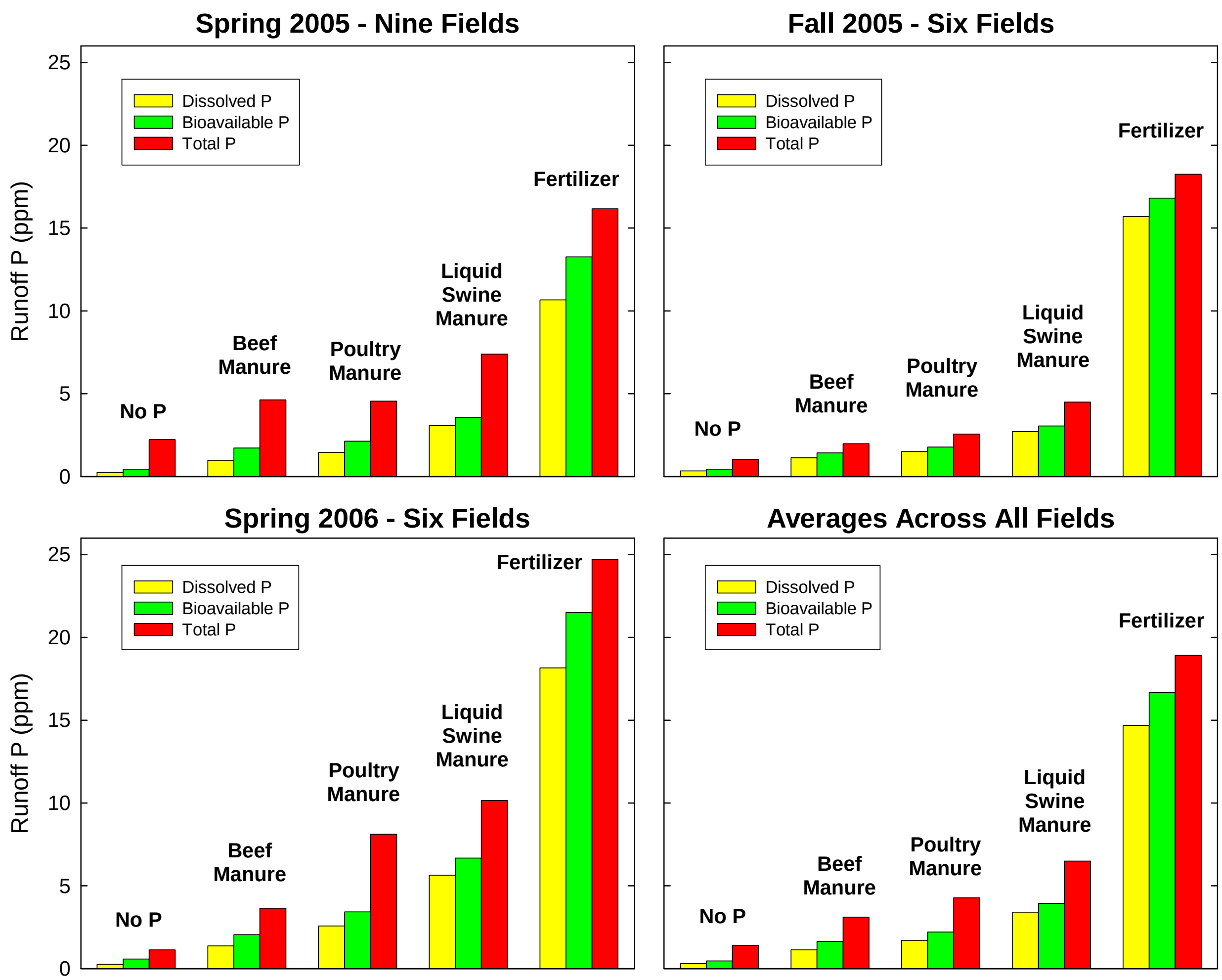

Fig. 2. Concentration of dissolved, bioavailable, and total P in surface runoff for rainfall events occurring within 24 hours of broadcasting 100 lb P_2O_5/acre using fertilizer and manure sources to untilled soils with soybean or corn residue.

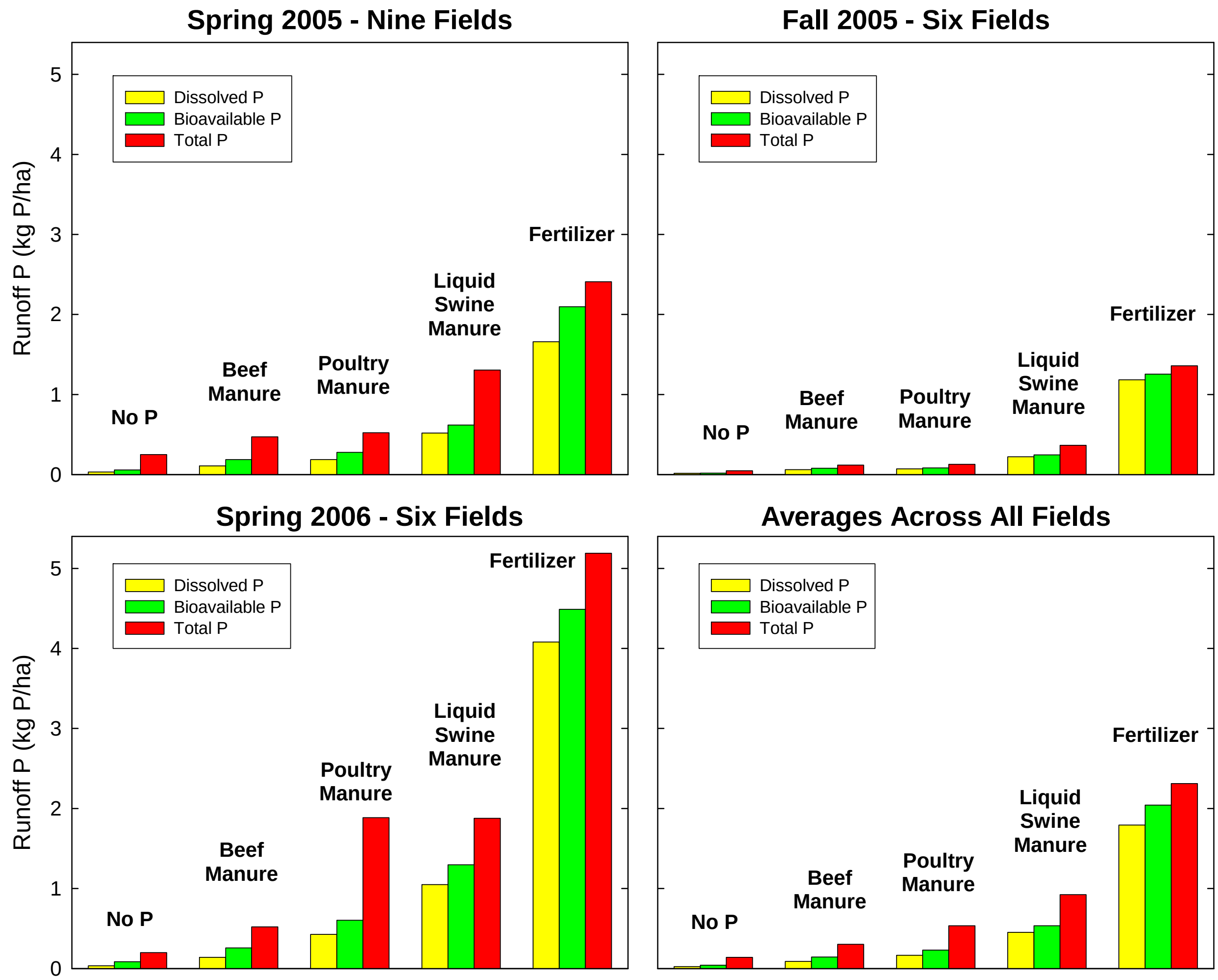

Fig. 3. Loads of dissolved, bioavailable, and total P in surface runoff for rainfall events occurring within 24 hours of broadcasting 100 lb P_2O_5/acre using fertilizer and manure sources to untilled soils with soybean or corn residue (1 kg P/ha equals 0.89 lb P/acre or 2.04 lb P_2O_5/acre).