HIGH GYPSUM APPLICATION RATES IMPACTS ON IOWA SOIL PROPERTIES, DISSOLVED PHOSPHORUS LOSS, AND CROP YIELD

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ABSTRACT

Gypsum (calcium sulfate) is a common sulfur (S) source for crops and rates in the northcentral region seldom are greater than 250 lb/acre. It is known that even higher gypsum rates do not raise soil pH. Research in eastern and southeast states showed that in some conditions high gypsum rates can improve other chemical or physical properties and can reduce dissolved phosphorus (P) loss from fields. However, there is little research available on the potential benefits of high gypsum rates in prairie-developed soils of Iowa and neighboring states. This article summarizes results of two studies conducted from 2016 to 2020 in Iowa. A 3-year study conducted at two sites with corn-soybean rotations managed with no-tillage evaluated single or annual gypsum rates of 0, 250, 500, 1000, 2000, and 4000 lb/acre on several soil chemical properties and aggregate stability, crop tissue nutrient concentrations, and grain yield. The other study assessed gypsum effects on dissolved and total P loss with surface runoff by conducting two one-year trials using rainfall simulations in two different years and no-till fields with soybean residue. In the first trial of this runoff study, soil-test P was very low, treatments were granulated or finely ground gypsum each broadcast once in the fall at rates of 0, 500, 1000, or 2000 lb/acre with or without broadcast P fertilizer and three time periods from the materials application to a first runoff event (within 2 days, after 15 days, or natural snowmelt runoff from first snowfall until early spring) all from different plots. In the second trial of the runoff study the soil had very high soil-test P and treatments were similar except that only granulated gypsum was used.

Results from the 3-year study with corn-soybean rotations showed that gypsum increased yield one year at one site (soybean) with no rate differences and increased S content of crop vegetative plant tissue but had no consistent effects on other macro-, secondary, or micro-nutrients. Gypsum rates of 250 lb/acre or higher increased topsoil (6 inches) sulfate-S, rates greater than 1000 lb/acre also increased S in the 6 to 12-inch depth, and reduced topsoil water-extractable P only one year at both sites. The two highest annual rates increased topsoil calcium (Ca) concentration and saturation but decreased magnesium (Mg) concentration. Single or annual gypsum rates of 2000 lb/acre or higher improved soil aggregate stability only at the site where grain yield was not affected. The runoff trials showed that no gypsum source or rate affected dissolved P loss with runoff.

Overall, we conclude that gypsum application at rates higher than needed to supply S for crops did not increase yield further, increased topsoil Ca but reduced Mg, did not reduce dissolved P loss from fields, and improved soil aggregate stability at one site where yield was not affected. Benefits from applying high gypsum rates may be more likely in soils with poorer physical and chemical properties.

INTRODUCTION

Gypsum (calcium sulfate) has been used for decades to supply sulfur (S) to crops in Iowa and other states. Gypsum also has been used in states with poorer soils (weathered, sandy, or extremely acid) to supply calcium (Ca) to crops and improve both cation balance and soil physical properties and also to alleviate excess sodium (Na) levels in saline or strongly alkaline soils. Since the early 2000s, research in several states began studying the potential value of soil amendments such as alum (aluminum sulfate) and gypsum at high rates to reduce dissolved phosphorus (P) loss from fields through surface runoff or subsurface tile drainage. In response to these new developments, numerous farmers, soil conservationists, and nutrient management planners of Iowa and northcentral region have been asking questions about the value of these amendments, especially with no-till management. However, there is little research available on the potential benefits of these amendments, especially gypsum, in prairie-developed soils of Iowa and neighboring states.

Previous Iowa studies have focused on effects of alum and gypsum on dissolved P loss with surface runoff when mixed with manure and effects of gypsum application on P loss with subsurface tile drainage. Mallarino and Haq (2012) conducted research at three Iowa fields collecting surface runoff from rainfall simulations and natural snowmelt runoff when finely ground alum (aluminum sulfate) or gypsum were mixed with poultry (egg layers) manure. Results showed that across all rainfall and snowmelt runoff events, alum and gypsum decreased dissolved reactive P by 65 to 88 and 17 to 58%, respectively, compared with manure applied alone. A 4-year study conducted by Dougherty et al. (2020) in northeast Iowa evaluated the effect of 2000 lb/acre of gypsum on P loss with subsurface tile drainage from a field testing very high in P and managed with continuous corn, tillage, and N-based liquid swine manure. Gypsum application did not affect P loss with tile drainage.

Therefore, two new complementary studies were implemented from 2016 to 2020 to study the potential benefits of high gypsum rates in Iowa. One study focused on evaluating impacts of gypsum on dissolved and sediment-bound P loss with surface runoff. The other study focused on assessing gypsum impacts on several soil chemical properties, soil aggregate stability, crop tissue nutrient concentrations, and grain yield.

SUMMARY OF PROCEDURES

For the study of gypsum effects on crop and soil properties, two 3-year field trials with similar treatments for corn-soybean rotations managed with no-tillage were conducted at two Iowa State University research farms. One was in central Iowa (Boone County) at a field with Clarion loam soil (Typic Hapludolls) and the other in the northeast Iowa research farm (NERF) at a field with Floyd loam soil (Aquic Hapludolls). Soil tests (6-inch depth) for pH, organic matter, cation exchange capacity (CEC), extractable calcium (Ca) and magnesium (Mg), and Ca saturation were 5.6, 4.1%, 19 meq/100g, 2105 and 294 ppm, and 55% Ca saturation at Boone and 5.6, 3.4%, 17 meq/100g, 1908 and 268 ppm, and 57%, respectively. Soil test methods were those recommended for the north central region (NCERA-13, 2015) and soil water-extractable P was measured by the method described by Pote et al. (1996). Phosphorus and potassium (K) were applied in the fall of each year. Initial treatments replicated three times were commercial granulated gypsum broadcast at rates of 0, 250, 500, 1000, 2000, and 4000 lb/acre in the fall. The 250-lb rate applied 43 lb S/acre, which is at the high end of S rates suggested for corn or soybean in the region. After harvest of the first-year crop (soybean), all plots were split into two halves to apply either no gypsum or the same initial rates each year. Soil samples (6-inch depth) and plant samples were taken at the crops V5 to V6 growth stage (in June) to assess potential early treatment effects on soil P and soil sulfate-S and on plant growth and nutrient uptake. Vegetative tissue and grain samples were analyzed for total nitrogen (N), P, K, Ca, Mg, S, boron (B), copper (Cu), iron (Fe), manganese (Mn), and zinc (Zn). After each grain harvest in the fall, soil samples were collected from depths of 0-6 and 6-12 inches and were analyzed as for the initial soil samples plus water-extractable P. In the spring of the third year, after all treatments had been applied, undisturbed soil samples (6-inch depth) were taken from all replications of selected treatments to measure aggregate stability by the method by Kemper and Rosenau (1986). Results were expressed as mean weight diameter (MWD) and the percentage of aggregates with a diameter of 1.0 mm or larger (greater values indicate better soil structure).

For the study of gypsum effects on total and dissolved P loss with surface runoff interacting with the timing to a first runoff event after the application we used a field rainfall simulation technique. Two trials were conducted in different no-till fields and years, both with Clarion loam soil (Typic Hapludolls) beginning in the fall (October) after soybean harvest. The first trial site had 5 ppm Bray-1 P (6-cm depth), pH 6.7, 3.2% organic matter, and 66% residue cover. The second trial site had 29 ppm Bray-1 P, pH 5.9, 3.3% organic matter, and 95% residue cover. First-site treatments replicated three times were 100 lb P_2O_5/acre applied alone or with gypsum 0, 500, 1000, or 2000 lb/acre using granulated or finely ground gypsum. The timings to a first runoff event after the materials application to different set of plots were within 2 days, after 15 days, or natural snowmelt runoff from first snowfall to early spring plus a final last rainfall simulation because there was little snow cover that winter. Second-site management and treatments were similar to those used for the first site except that only granulated gypsum was applied with or without the same P rate and no spring rainfall simulation was needed because there was high snow cover and snowmelt runoff. Runoff was analyzed for total P and filtered runoff (0.45 um) was analyzed for dissolved reactive P. Soil loss also was measured but is not shown.

RESULTS

Gypsum effects on crop and soil properties

Gypsum did not affect crop yield in any year at NERF but Boone increased soybean yield in the last year (a year with excess rainfall at this site that limited yield) with no statistical differences among application rates. Yield of the control was 36 bu/acre whereas the average across all treatments receiving gypsum was 50 bu/acre. Gypsum often increased S content of crop vegetative plant tissue but not of grain, and had no consistent effects on other macro-, secondary, or micro-nutrients (not shown).

Gypsum greatly increased soil S at June sampling dates each year (0-6 inches) and slightly reduced water-extractable P in one year at both sites (not shown). Gypsum also greatly increased soil S at depths of 0-6 and 6-12 inches at both sites, although the effects varied greatly over time and across sites (Figs. 1 to 3). The lowest rate seldom increased soil S over the control and the residual effects of higher single applications decreased sharply over time. However, annual rates higher than 500-lb rate resulted in very high soil S levels and significant leaching to a depth of 6-12 inches.

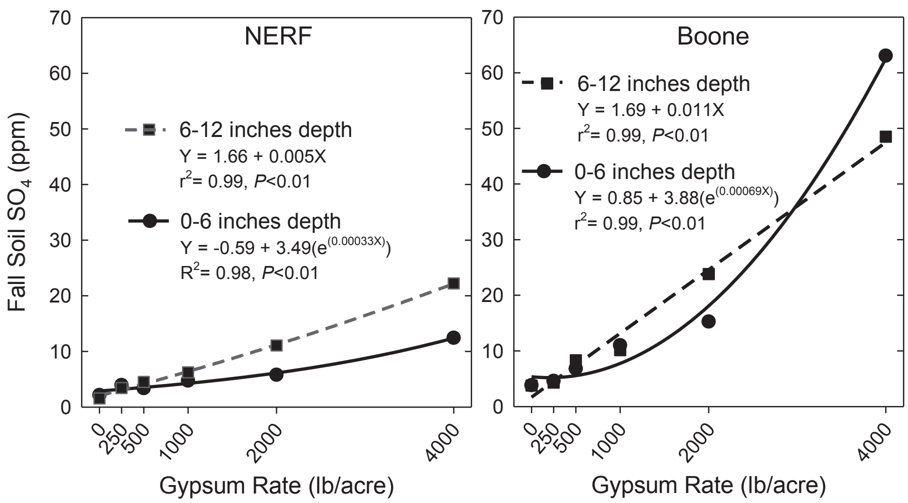

Fig. 1. Effects of first year gypsum application rates on post-harvest soil S.

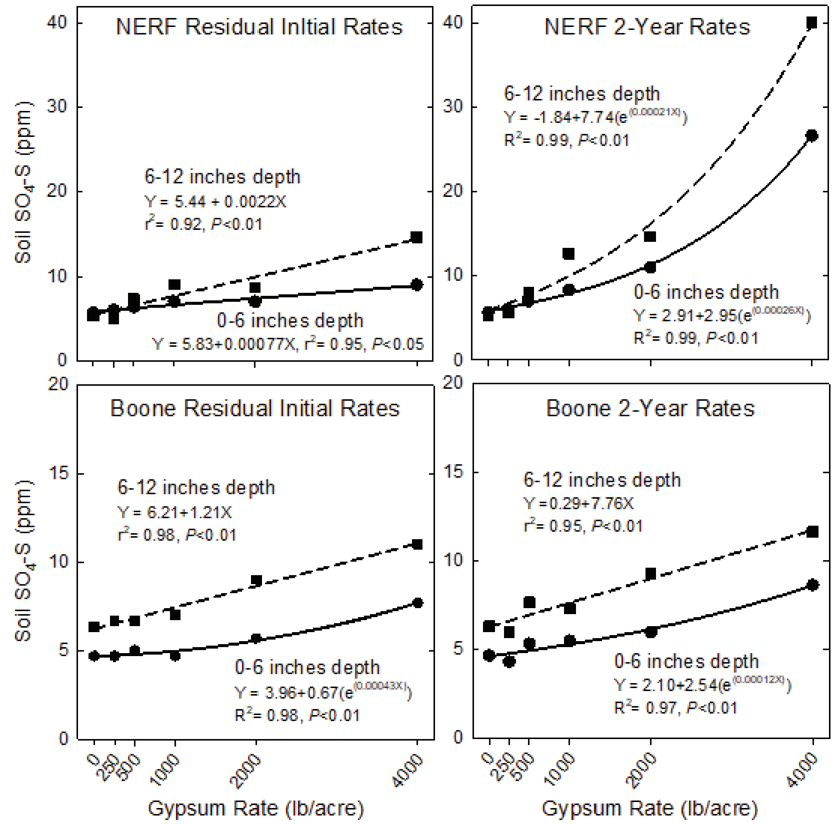

Fig. 2. Effects of single or annual gypsum applications on soil S after the second crop.

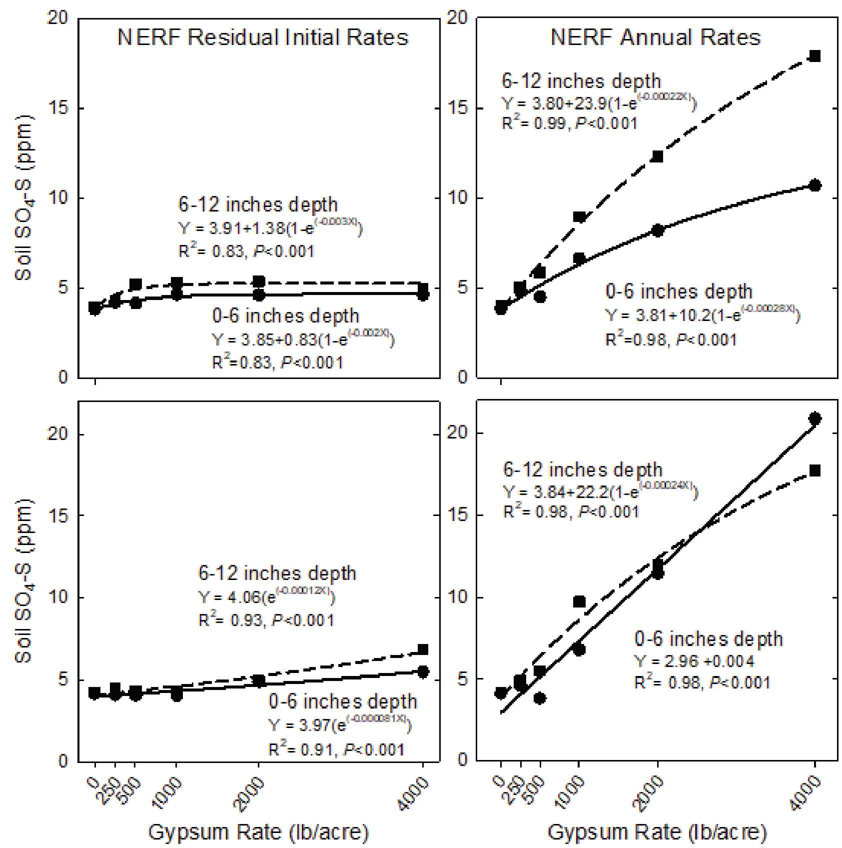

Fig. 3. Effects of single or annual gypsum applications on soil S after the third crop.

Figure 4 shows results for some of the other soil measurements that were affected by gypsum. By the end of the third year of the study, gypsum application increased soil extractable Ca and Ca saturation but decreased extractable Mg. In spite of linear or curvilinear observed responses, large differences were between initial or annual rates of 1000 lb/acre or higher compared with the control or lower rates.

Aggregate stability of untreated or treated soil as indicated by mean weight diameter (MWD) and the percentage of aggregates with a diameter of 1.0 mm or larger (greater values indicate better soil structure) was better at NERF than at Boone. Figure 5 shows results of the aggregate stability expressed only by MWD because results for aggregate size were proportionally similar at both sites. Gypsum did not affect aggregate stability at Boone. At NERF, however, gypsum single initial or annual rates of 2000 or 4000 lb/acre improved aggregate stability compared to the control or lower rates. It is remarkable that gypsum improved aggregate stability only at the NERF site, where it was better than at Boone and where gypsum did not increase crop yield.

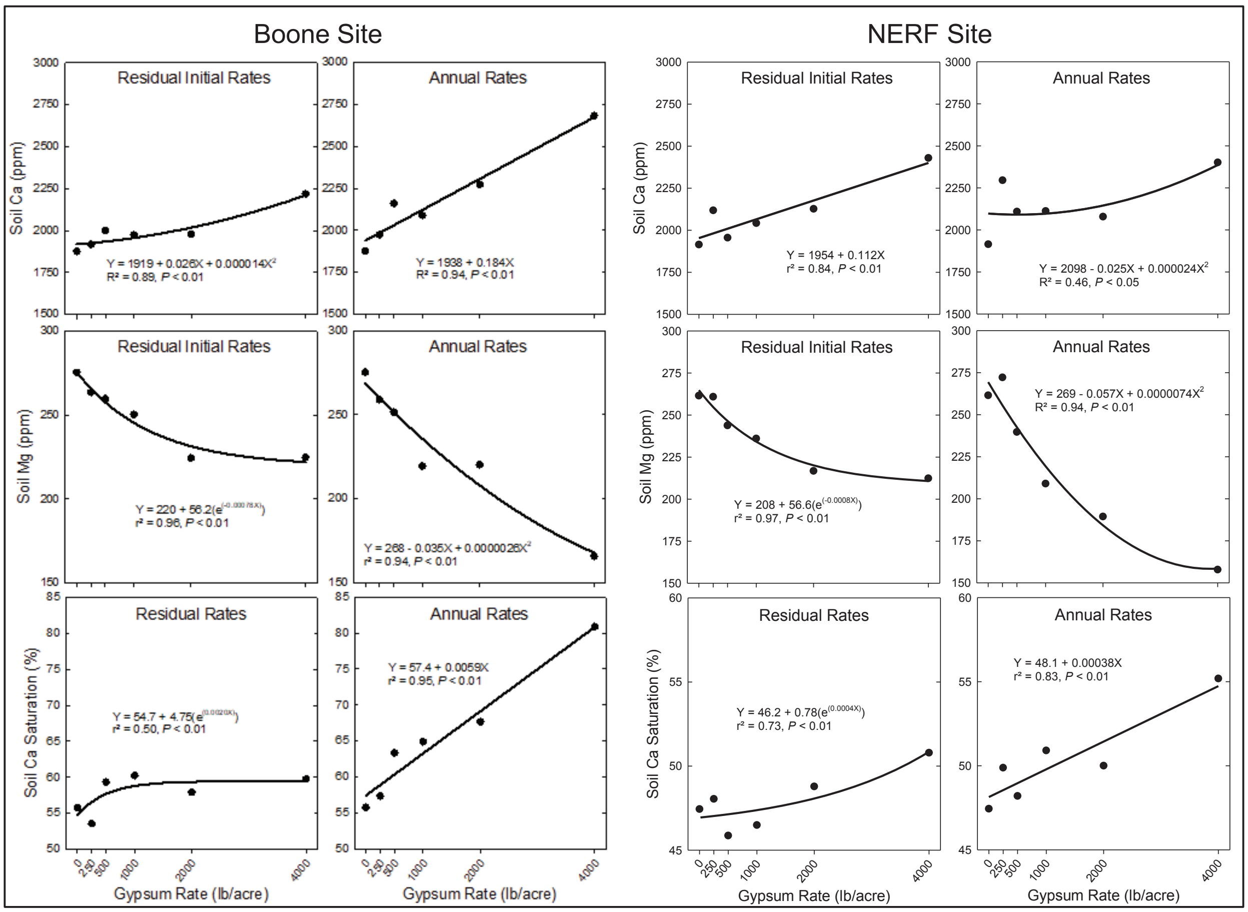

Fig. 4. Soil Ca, Mg, and Ca saturation after the third crop at depth of 0-6 inches at two sites as affected by single or annual gypsum applications rates.

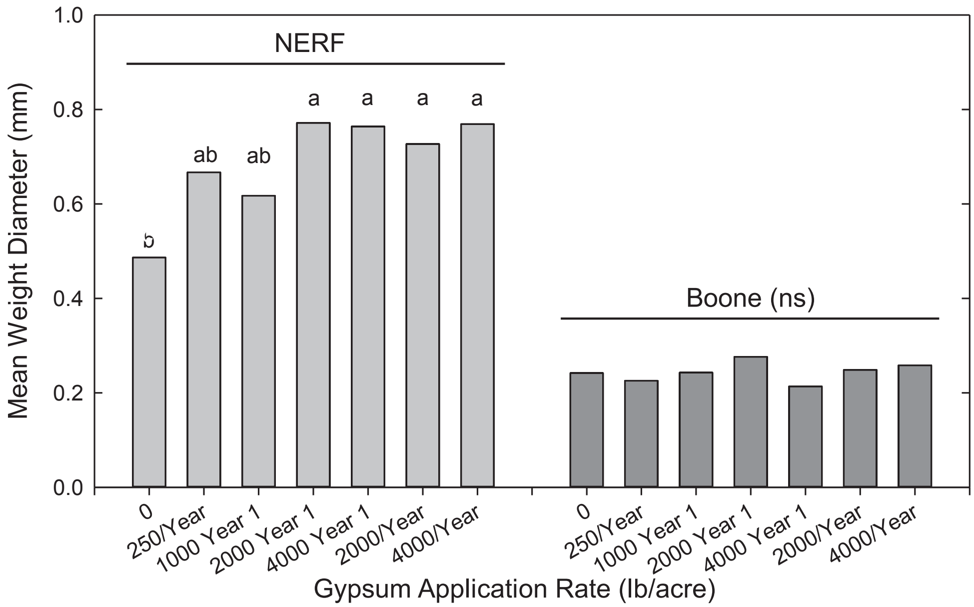

Fig. 5. Effects of selected gypsum single initial or annual applications on soil aggregate stability at the end of two three-year trials expressed as mean weight diameter. Bars with similar letters indicate no differences at $P \leq 0.05$; ns, not significant.

Gypsum effects on dissolved P loss with runoff

Figures 6 and 7 summarize results of gypsum effects on dissolved (DRP) and total P loss with surface runoff at two trial sites. Gypsum application rates of 500 to 2000 lb/acre using granulated or finely ground sources did not affect DRP or total P losses at any trial and for any time to runoff treatment. Additional research with natural rainfall and a longer evaluation time would be desirable to confirm these results.

CONCLUSIONS

Increasing gypsum rates increased sulfate-S levels in the top 6 inches of soil, with no increase for a rate of 250 lb/acre, small for rates of 500 and 1000 lb/acre and large for rate of 2000 and 4000 lb/acre. The highest S increases were observed with annual gypsum applications, with significant S leaching to a depth 6 to 12 inches with applications greater than 500 lb/acre/year. The highest annual gypsum rates increased soil Ca, decreased Mg, and increased Ca saturation at both sites. However, gypsum rates higher than needed to supply S for crops did not increase yield further at any site and improved soil aggregate stability only at one site. The runoff study showed no gypsum source or rate effects on dissolved or total P loss with surface runoff.

Overall, we conclude that gypsum application at rates higher than needed to supply S for crops may improve some soil chemical and physical properties but crop yield increases are unlikely. Benefits from applying high gypsum rates may be more likely in soils with much poorer physical and chemical properties.

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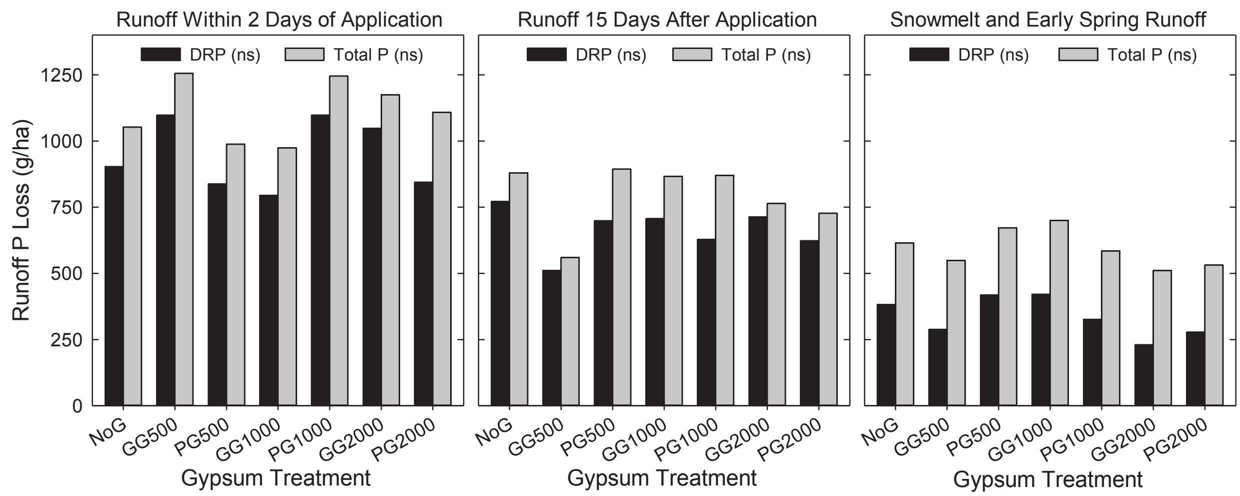

Fig. 6. First-year site runoff dissolved reactive P (DRP) and total P loss for events at different times after fall applied P (No G) and P applied with granulated (GG) or powdered (PG) gypsum.

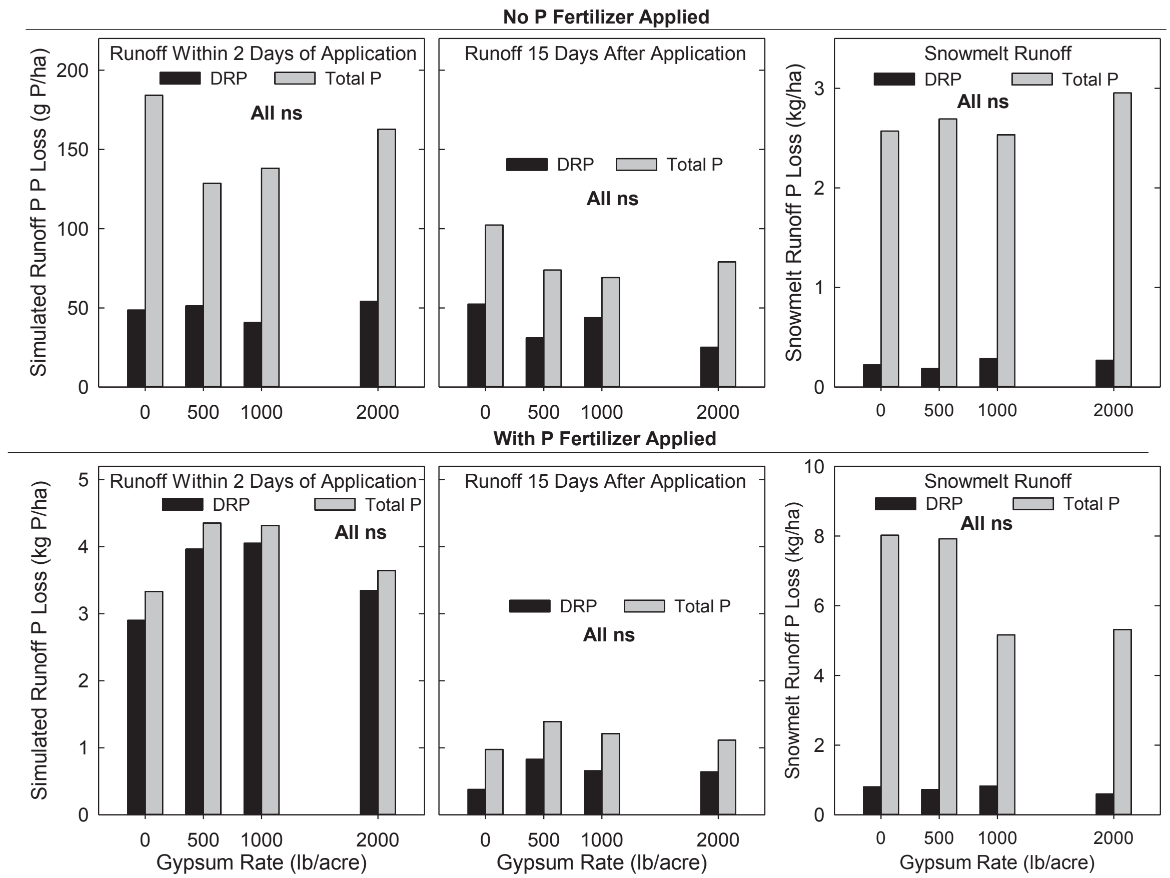

Fig. 7. Second-year site dissolved reactive P (DRP) and total P losses for runoff events at different times after fall applied granulated gypsum with or without P fertilizer.

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