

The effects of gypsum application to agricultural soils on water extractable phosphorus and Olsen extractable phosphorus concentrations

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1. Background

This project is a collaboration between Herefordshire Council and Lancaster University, funded by Herefordshire Council. In 2025, Herefordshire farmer Ben Taylor-Davies approached Herefordshire Council to share his awareness of the potential for gypsum to influence water soluble phosphorus concentration within soil. Herefordshire Council and Lancaster University co-designed the approach described below to provide a rapid analysis of the hypothesis utilising Herefordshire soils. These trials also build on emerging academic research that has highlighted the potential for gypsum application to reduce water soluble phosphorus concentrations within soil, such as the GYPREG project within land draining to the Baltic Sea (<https://www.raceforthebaltic.com/gypreg>)

2. Approach

Gypsum application and incubation of soils

Four soils were supplied by Herefordshire Council to Lancaster University for testing on 22nd October 2025. These soils were coded F1 SaL; F2 CL; F3 SaScL; and F4SiCL. Hereafter, these soils are coded F1, F2, F3 and F4. On receipt, the soils were air-dried under ambient laboratory conditions for 18 days to achieve constant weight. The soils were then sieved to 4.75 mm in order to remove large stones and vegetation fragments from the samples. For each of the four soil types, 1 kg sub-samples of the sieved soil were added to four foil trays, creating a total of 16 samples across the four soil types. For each soil type, the four 1 kg soil samples were treated to provide:

1. One tray containing a control soil treatment, receiving no gypsum addition (Control)
2. One tray containing soil receiving the equivalent of 1 tonne gypsum/hectare (G1)
3. One tray containing soil receiving the equivalent of 3 tonnes gypsum/hectare (G3)
4. One tray containing soil receiving the equivalent of 5 tonnes gypsum/hectare (G5)

Gypsum for application to the soils was supplied by Herefordshire Council to Lancaster University. The required mass of gypsum to achieve the application rates described above (Control = 0 g; G1 = 0.48 g; G3 = 1.43 g; and G5 = 2.38 g) was weighed and distributed evenly across the surface of the 1 kg sub-samples of soil in the foil trays. The soil and gypsum amendment was then thoroughly mixed by hand using a plastic scoup within each foil tray, for a uniform period of 2 minutes. The appropriate volume of deionized water was then added to each of the 16 foil trays to achieve the equivalent of 80% water holding capacity in the soils, using a fine mist spray bottle to distribute the water approximately evenly across the soil surface in each foil tray. Deionised water was applied to the surface of the soil on four individual dates: 20th November; 26th November; 9th December and 22nd December 2025, with samples allowed to dry under ambient laboratory conditions and return to air-dry conditions between

each application of water. This approach meant that four wet-dry cycles, ranging between air-dry and 80% water holding capacity conditions, were imposed on soils within each individual tray.

Soil extraction and analysis

Following the incubations described above, each 1 kg sample of soil was sieved to 2 mm. Subsequently, three * 2 g samples of soil from each of the 16 foil trays were weighed into new 50 ml HDPE centrifuge tubes for determination of water extractable phosphorus (WEP). To each centrifuge tube, 20 mls of >18.2 M Ω milliQ water was pipetted and samples were shaken in a constant temperature incubator for 1 hour at 20 °C. After the extraction, samples were filtered using new, 0.45 μ m pore size polyethersulfone syringe filters and filtrates collected for soluble reactive phosphorus (SRP) analysis within 24 hours. A further three * 2 g samples of <2 mm soil from each tray were weighed into separate new 50 ml HDPE centrifuge tubes for Olsen-extractable phosphorus analysis. To each centrifuge tube, 40 mls of 0.5 M NaHCO₃ solution that had previously been adjusted to pH 8.5 was added. Samples were shaken in a constant temperature incubator for 30 minutes at 20 °C. After the extraction, samples were filtered using new Whatman number 2 filter papers and filtrates collected. These filtrates were diluted 1:10 using >18.2 M Ω milliQ water and stored for SRP analysis within 24 hours.

The concentration of SRP in both WEP and Olsen-P filtrates was analysed colourimetrically on an AQ2 Discrete Analyser (SEAL Analytical). Analysis of SRP was equivalent to USEPA Method 365.1 in which phosphate ions react with an acidic molybdate reagent to form an antimony phospho-molybdate complex, which is chemically reduced by ascorbic acid. Calibration standards for SRP were created using TraceCERT® certified phosphorus reference materials and validated using two independent check standards made from potassium dihydrogen orthophosphate salt. A difference between observed values and expected values for both check standards of <10% was deemed to represent an acceptable instrument calibration. A random selection of 10% of samples were subjected to repeat analyses to quantify precision of the SRP data, with coefficients of variation typically below 10%.

3. Results

Figures 1-4 below report results for Olsen extractable P and WEP across each of the four soil types analysed in the research reported here. Average concentrations of Olsen extractable P and WEP were similar within soils F1 and F2 (c.38 mg/kg for Olsen extractable P and c.5 mg/kg for WEP), but increased significantly within soil F3 (c.63 mg/kg for Olsen extractable P and c.9 mg/kg for WEP) and again within soil F4 (c.112 mg/kg for Olsen extractable P and c.20 mg/kg for WEP).

Considering data from across all four soil types together, the application of gypsum to soils at G1, G3 or G5 rates resulted in significant decreases in WEP concentration compared to control soils, although WEP concentrations following G3 and G5 treatments did not differ significantly from each other. However, the specific patterns across G1, G3 and G5 treatments did vary between individual soils. In soils F1 and F2, WEP concentrations only decreased significantly compared to control soils following gypsum applications at G3 and G5 rates, with no significant difference found between G3 and G5 treatments in these two soil types. In contrast, within both

F3 and F4 soils, gypsum application at G1, G3 and G5 rates was associated with significant decreases in the concentration of WEP compared to control soils. For soil F3, significant decreases in the concentration of WEP were observed as gypsum application increased from G1 to G3 and from G3 to G5. For soil F4, significant decreases in the concentration of WEP were observed between G1 and G3/G5 applications, although no significant change in WEP concentration was observed between G3 and G5 applications for this soil. The average decrease in the concentration of WEP ranged between 3 and 13% compared to control soils for G1 applications, but reached between 18 and 36% following G5 applications (Table 1).

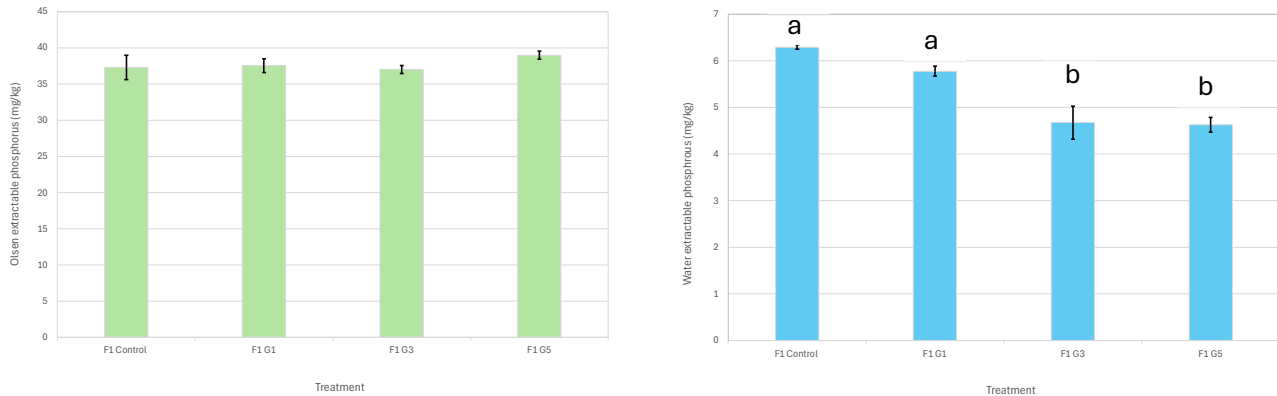


Figure 1. Olsen extractable phosphorus and water extractable phosphorus concentrations for F1 soil following Control, G1 (1 tonne/hectare), G3 (3 tonnes per hectare) and G5 (5 tonnes per hectare) applications of gypsum. Error bars show one standard deviation and columns show average concentrations from three replicate analyses of each treatment. Letters above each column denote significant differences between treatments, absence of any letters shows no significant difference across any treatment.

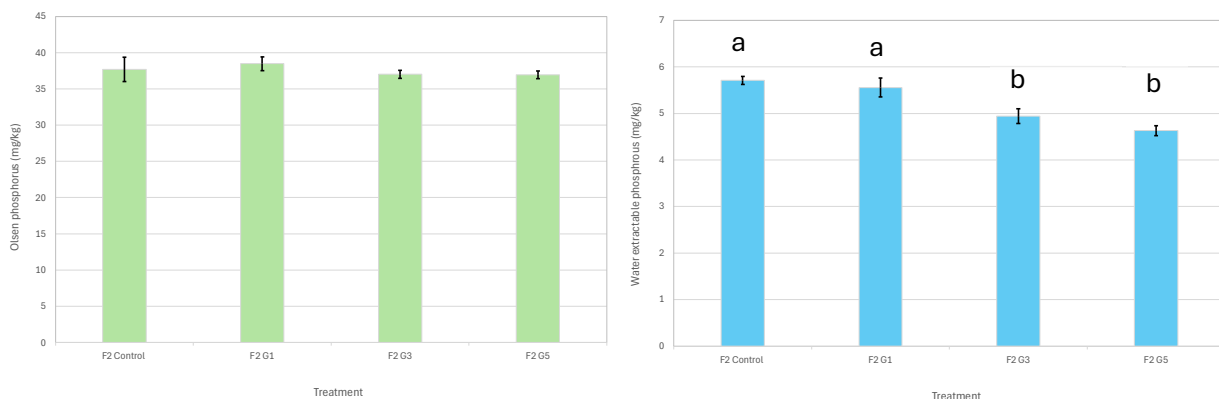


Figure 2. Olsen extractable phosphorus and water extractable phosphorus concentrations for F2 soil following Control, G1 (1 tonne/hectare), G3 (3 tonnes per hectare) and G5 (5 tonnes per hectare) applications of gypsum. Error bars show one standard deviation and columns show average concentrations from three replicate analyses of each treatment. Letters above each column denote significant differences between treatments, absence of any letters shows no significant difference across any treatment.

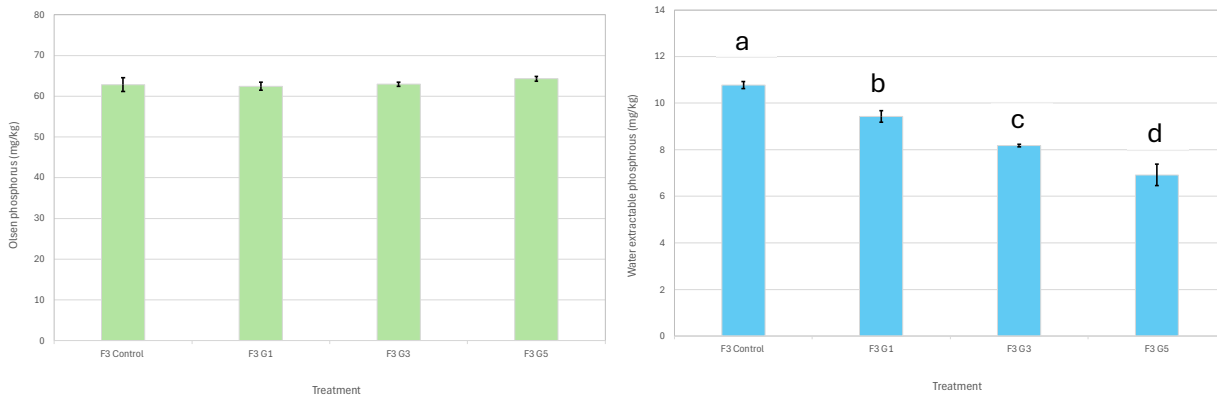


Figure 3. Olsen extractable phosphorus and water extractable phosphorus concentrations for F3 soil following Control, G1 (1 tonne/hectare), G3 (3 tonnes per hectare) and G5 (5 tonnes per hectare) applications of gypsum. Error bars show one standard deviation and columns show average concentrations from three replicate analyses of each treatment. Letters above each column denote significant differences between treatments, absence of any letters shows no significant difference across any treatment.

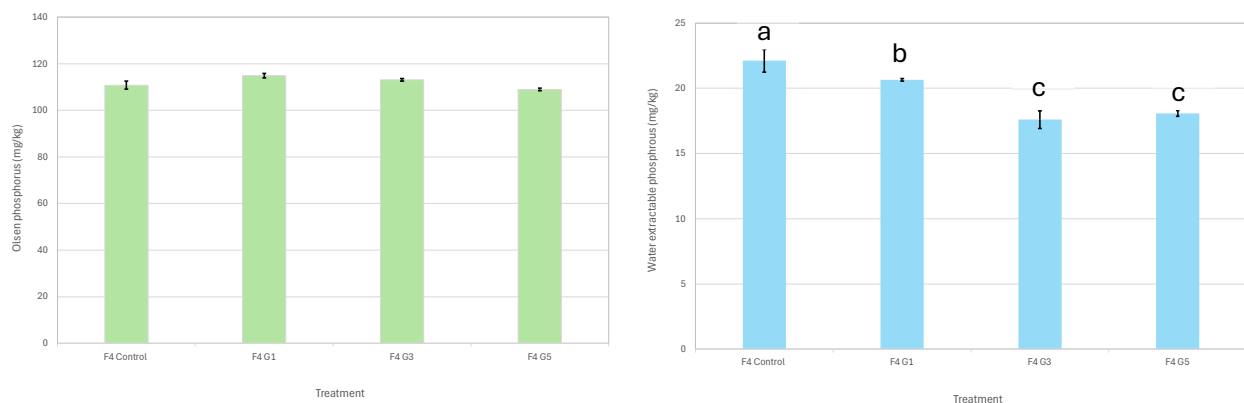


Figure 4. Olsen extractable phosphorus and water extractable phosphorus concentrations for F4 soil following Control, G1 (1 tonne/hectare), G3 (3 tonnes per hectare) and G5 (5 tonnes per hectare) applications of gypsum. Error bars show one standard deviation and columns show average concentrations from three replicate analyses of each treatment. Letters above each column denote significant differences between treatments, absence of any letters shows no significant difference across any treatment.

Table 1. Summary of water extractable phosphorus (WEP) and Olsen extractable phosphorus concentrations for soils F1-F4 following Control, G1 (1 tonne/hectare), G3 (3 tonnes per hectare) and G5 (5 tonnes per hectare) applications of gypsum.

Treatment	Average WEP (mg/kg)	Standard deviation WEP (mg/kg)	Change in WEP compared to control soil (%)	Average Olsen extractable P (mg/kg)	Standard deviation Olsen extractable P (mg/kg)
F1 Control	6.29	0.05	n/a	37.28	1.70
F1 G1	5.77	0.11	-8.2	37.53	0.96
F1 G3	4.67	0.35	-25.8	36.99	0.55
F1 G5	4.63	0.16	-26.5	38.97	0.55
F2 Control	5.71	0.09	n/a	37.72	1.34
F2 G1	5.56	0.20	-2.6	38.48	0.01
F2 G3	4.94	0.16	-13.4	37.01	1.11
F2 G5	4.63	0.11	-18.9	36.94	0.41
F3 Control	10.78	0.15	n/a	62.84	0.76
F3 G1	9.43	0.24	-12.5	62.42	1.04
F3 G3	8.18	0.06	-24.1	62.94	2.11
F3 G5	6.92	0.46	-35.8	64.27	0.95
F4 Control	22.12	0.87	n/a	110.82	4.26
F4 G1	20.66	0.09	-6.6	114.84	0.29
F4 G3	17.60	0.67	-20.4	113.17	1.12
F4 G5	18.07	0.23	-18.3	108.99	3.61

In contrast to WEP, the treatment of soils with gypsum had no significant effect on the concentration of Olsen-extractable P compared to control soils that received no gypsum.

4. Conclusions

The trials reported here reveal that significant decreases in water-extractable phosphorus concentrations in soil can be achieved via the application of gypsum to soil. These decreases can reach up to 36% compared to control soils, depending on soil type and gypsum application rate. Importantly, no significant change in the agronomically-relevant Olsen extractable P concentration was observed in the trials reported here, meaning that gypsum application appeared to have no impact on the crop-available forms of P determined by Olsen extraction.

The impacts of gypsum application on water-extractable P do depend on soil type and were observed during relatively short-duration laboratory experiments in the work reported here. Therefore, the following areas of additional work are recommended in order to build on these highly positive initial laboratory trials:

1. Testing the effects of gypsum application on water-extractable and Olsen-extractable P across a wider range of soils from Herefordshire, to confirm the positive impacts reported here from initial laboratory trials.

2. Undertaking larger-scale plot or field trials under realistic agricultural production systems and weather (e.g. rainfall) conditions is required, to determine the longer-term and larger-scale impacts that follow gypsum application to soil.
3. Work to determine the impact of gypsum application to soil on a wider range of chemical, biological and physical soil properties is required, to fully understand both the environmental and agronomic impacts of gypsum application.