PHOSPHORUS AND POTASSIUM IMPACTS ON FIELD CROP PRODUCTION IN THE INTERMOUNTAIN WEST

Megan Baker and Matt Yost
Utah State University, Logan, UT
(775)-293-7011 megbaker1100@gmail.com

ABSTRACT

Macronutrients such as phosphorus (P) and potassium (K) are essential nutrients for plants, with fertilizers often supplementing soil nutrients to increase crop productivity. Fertilizer recommendations can vary significantly depending on the source and affect farm profitability considerably. Guidelines in Utah and many other states in the Intermountain West were developed decades ago and need to be evaluated. Current Utah State University (USU) recommendations identify 15 and 150 ppm (Olsen) as critical soil test values for P and K, respectively. As a part of national efforts to improve regional and state-level soil fertility guidelines, on-farm trials in 2021-2025 across Utah evaluated current USU Fertilizer Guidelines for P and K in common crops to the region.

Trial nutrient, duration, treatment rates, and crops grown varied across six sites for eleven and five total site-years of P and K trials, respectively. Fertilizer treatments were evaluated in alfalfa (*Medicago sativa*), corn (*Zea mays*), and winter wheat (*Triticum aestivum*) using crop yield, nutritive value, and economic returns. At repeating sites (sites 3-5), soil samples were collected by plot prior to fertilizer application each spring to assess soil nutrient changes. At site 6, P fertilizer source and timing were evaluated in addition to application rate. Preliminary results indicate that crop yield and quality were not impacted by K applications regardless of fertilizer rate or initial soil test value. Fertilizer P increased alfalfa yield with rates ≥ 50 lb P_2O_5/ acre across three years, but forage nutritive value was not affected. Wheat yield increased with rates ≥ 30 lb P_2O_5/acre at site 6, with the fall applications yielding higher than the spring and P fertilizer source having no impact. These results indicate that USU fertilizer guidelines should possibly be reduced and that recommendations should be tested >1-2 years to evaluate potential yield and profit losses from under-fertilization.

INTRODUCTION

Phosphorus (P) and potassium (K) are two of the most common nutrients applied in crop production and have greatly contributed to crop yield improvements over the last 60 years (Weibe & Gollehon, 2006). Excessive applications of these nutrients can pose economic and environmental harm, with contamination of surface and ground water from excess P a growing concern (Carpenter, 2005). Soil tests assess nutrient status in the soil and direct fertilizer applications (Dahnke & Olson, 1990). Fertilizer recommendations can vary significantly depending on the source and impact crop profitability considerably (Baker et al., 2026; Zhang et al., 2021). Guidelines in Utah and many other states in the region were developed decades ago and need to be evaluated and potentially updated (Lyons et al., 2023; Spargo et al., 2022). Current Utah State University (USU) recommendations identify 15 and 150 ppm (Olsen) as critical soil test values for P and K, respectively. As a part of national efforts to improve regional and state-level soil fertility guidelines, this work aims to 1) evaluate current USU fertilizer recommendations in common field crops, 2) compare impacts of P fertilizer source and application timing on wheat production, and 3) assess economic returns on fertilizer applications.

MATERIALS AND METHODS

Field research for these experiments was conducted in six fields on farms across the state of Utah in 2021-2025 to evaluate crop response to phosphorus (P) and potassium (K) fertilizer applications. Trial duration and crops grown varied among sites, with treatments compared in alfalfa (*Medicago sativa*), corn (*Zea mays*), and winter wheat (*Triticum aestivum*; Table 1). A composite soil sample comprising of 25-30 cores (12 × 0.75 in i.d.) collected in the spring at each site prior to trial establishment was analyzed to assess baseline soil fertility. Samples were air-dried for 6 to 10 days, ground to 0.08 in (2 mm), and mixed to ensure uniformity prior to analysis at the Utah State University (USU) Analytical Laboratory. The Olsen bicarbonate extract measured soil P and K, with ascorbic acid/molybdate blue colorimetric and atomic adsorption used to analyze P and K, respectively. To prevent nutrient deficiencies and isolate treatment impacts, USU fertilizer guidelines directed fertility needs for nutrients besides the trial nutrient at each site (Cardon et al., 2008).

Table 1. Crop and soil characteristics for each site.

Site #	Trial Nutrient	Trial Years	Crop	Soil pH	Organic Matter (%)	Soil P (ppm)	Soil K (ppm)
1	P and K	2021	Corn	7.8	2.1	7	374
2	P and K	2021	Corn	8.0	3.7	10	130
3	P and K	2023-2025	Alfalfa	7.9	1.4	9	71
4	P	2023-2024	Corn-Wheat	7.8	1.9	13	199
5	P	2023-2025	Corn-Wheat-Corn	7.7	2.6	6	277
6	P	2025	Wheat	7.8	1.2	13	69

Fertilizer treatment rates varied among sites (Table 2), with all treatments hand-broadcast in the spring of each year at sites 1-5 as dry, granular products. Triple superphosphate (TSP; 0-45-0) and muriate of potash (0-0-60) supplied P and K, respectively, for fertilizer treatments. At site 6, P fertilizer source and application timing were compared in addition to application rate. At this site, monoammonium phosphate (MAP; 11-52-0) and TSP treatments were each applied at rates of 0, 30, 60, 90, and

120 lb P_2O_5/acre in both in the fall and spring, with applied nitrogen (N) from MAP treatments balanced across all plots using ammonium nitrate (34-0-0) in the spring of 2025. Plot dimensions were 15 × 30 ft at sites 1-5 and 10 × 40 ft at site 6, with plots six rows wide at corn sites (sites 1, 2, 4, and 5). Crop yield was measured at each site using standard hand-harvest methods or research-scale machinery. Forage subsamples were dried and ground after harvest to calculate treatment yields. All samples were analyzed using near-infrared spectroscopy (NIRS) to assess nutritive value using their respective crop equations. The legume hay equation measured or calculated crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), total digestible nutrients (TDN), relative feed value (RFV), and relative forage quality (RFQ) of alfalfa samples. The unfermented corn silage equation determined CP, ADF, NDF, TDN, and starch content for silage corn samples. Whole-grain wheat samples were evaluated using CP, starch, gluten, and Zeleny values produced by the wheat equation. At sites where trials were repeated (sites 3-5), composite soil samples collected by plot (6-8 cores) prior to fertilization each year evaluated fertilizer impacts on soil nutrient levels. Economic returns on fertilizer applications were determined using fertilizer costs from local fertilizer dealers and crop prices from regional reports and United States Department of Agriculture National Agricultural Statistics Service (USDA-NASS, 2023).

Crop and soil data were analyzed by site using the MIXED procedure of SAS (SAS Version 9.4 SAS Institute Inc.). The (Pairwise Difference) PDIFF procedure of SAS was used for mean separations using Fisher's protected LSD at $\alpha = 0.05$.

Table 2. Treatment fertilizer application rates at sites 1-5.

Site #	P Rates (lb P_2O_5/acre)	K Rates (lb K_2O/acre)	Control
1	50, 100, 150, 200	60, 120, 180, 240	0P/0K
2	50, 100, 150, 200	60, 120, 180, 240	0P/0K
3	0, 50, 100, 150, 200, 250	0, 60, 120, 180, 240	0P/0K, 0P, and 0K
4	0, 50, 100, 150, 200, 250	-	0P
5	0, 50, 100, 150, 200, 250	-	0P

RESULTS AND DISCUSSION

Silage Corn

Phosphorus and potassium applications rarely impacted silage corn yield or nutritive value. At sites 1 and 2, all fertilizer treatments were similar to the 0P/0K control in 2021. At site 5, overall yields were higher in 2025 than 2023, but P treatments did not differ from the 0P control in either year. At site 4, P application did not increase yield, but the 200 and 250-lb P rates had lower nutritive value than the control and 150-lb treatments. The higher P treatments averaged 25.8, 46.1, and 69.9% for ADF, NDF, and TDN, respectively, while the control and 150-lb treatments averaged 22.2, 41.2, and 72.2% for these quality parameters, respectively.

Alfalfa

At site 3, the year × treatment interaction was significant for yield, as were the main effects of year and treatment. The 0P/0K control and 0P control treatments yielded similarly and were consistently the lowest every year (Figure 1). All K treatments received 150 lb P_2O_5/acre and all P treatments received 120 lb K_2O/acre to ensure that these nutrients would not be limiting. Potassium applications had no impact on alfalfa yield, with all K treatments yielding similarly to the 0K control. The 0K control yielding higher than the 0P/0K control and 0P control treatments indicates that P applications of any rate increased alfalfa yield while K applications did not.

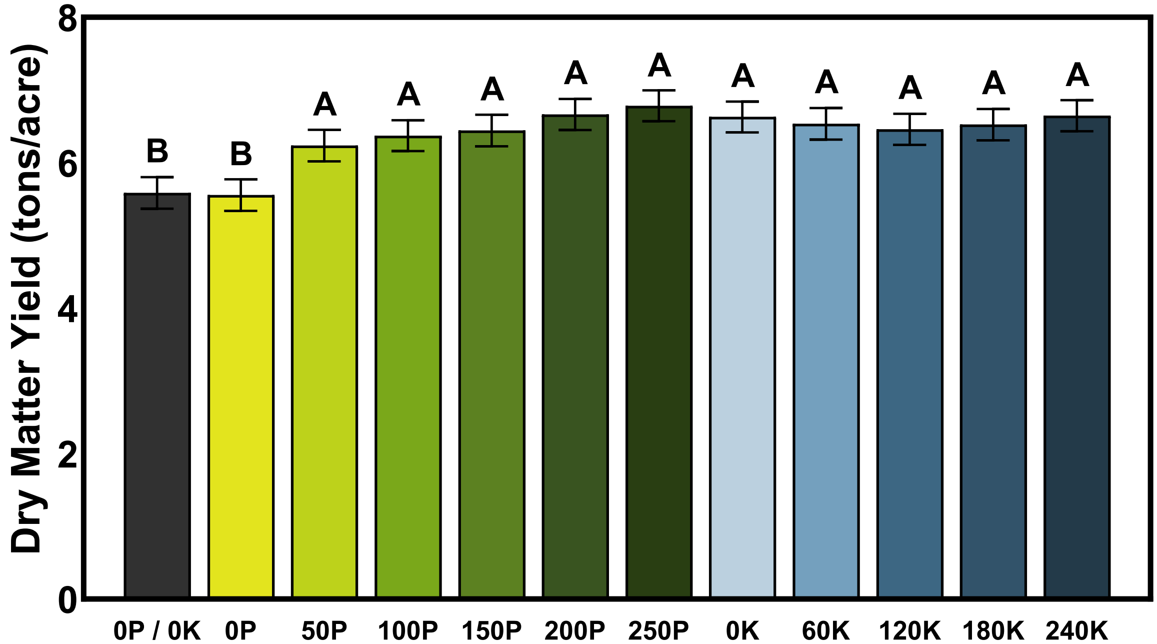

Figure 1. Alfalfa dry matter yield across years (2023-2025) at site 3. Letters above bars represent means separations conducted by treatment using $\alpha = 0.05$.

Phosphorus and K treatments were analyzed separately and without the 0P/0K control to isolate nutrient impacts. All P rates increased yield compared to the 0P control, but the 250-lb rate was significantly higher than the 50-lb rate. Alfalfa yield was not affected by K application, with all rates yielding similarly to the 0K control. Fertilizer applications did not impact forage nutritive or market value, with all alfalfa classified as 'Supreme' forage using USDA Hay Quality Designation Guidelines (USDA-Agricultural Marketing Service [USDA-AMS], 2003).

Wheat

Phosphorus applications did not impact wheat yield at sites 4 or 5 in 2024. At site 4, grain gluten content was higher for the control than the 50, 100, and 150-lb treatments, but no other differences in nutritive value were observed at either site.

At site 6, the timing × rate interaction was significant for yield, as were the main effects of timing and rate. All fall-applied P applications increased yield by 10-20 bu/acre, but the spring application treatments did not differ from one another (Figure 2A). Fall P treatments yielded higher than spring treatments, yielding 136.7 and 130.1 bu/acre, respectively. When P rate was evaluated across both timings and sources, all P rates yielded higher than the control, and the 60 and 120-lb rates higher than the 30-lb rate (Figure 2B). Fertilizer source and its interactions were not significant, indicating that TSP and MAP fertilizers performed similarly. Phosphorus applications had no impact on wheat nutritive value.

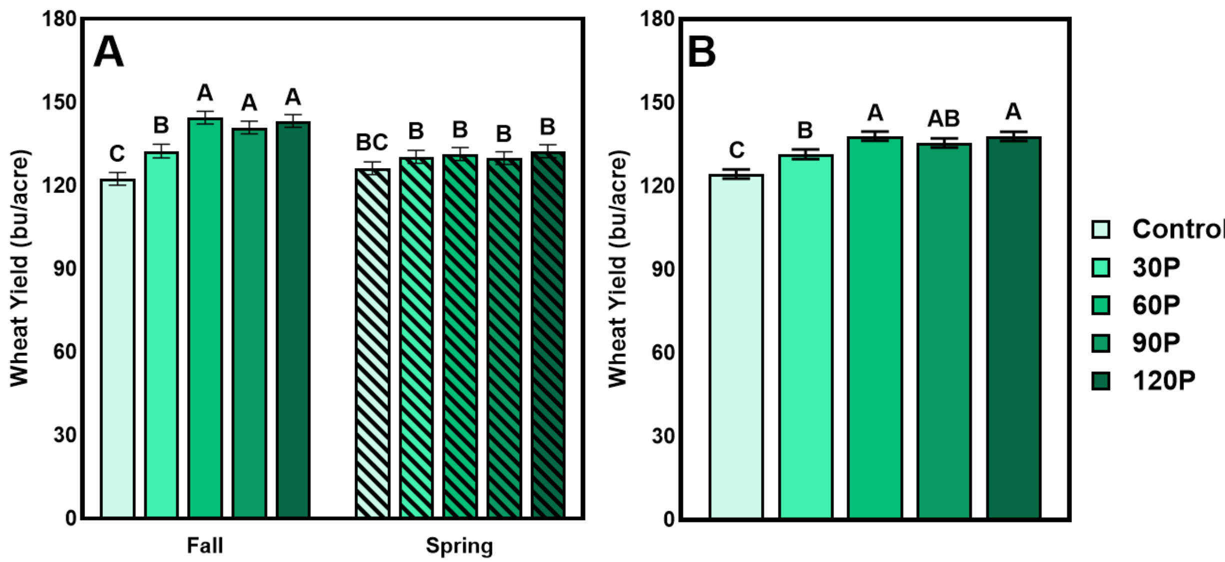

Figure 2. (A) Wheat yield at site 6 by application timing where the timing × rate interaction was significant with spring applications denoted by striped bars. (B) Wheat yield by P application rate across timings and fertilizer sources. Letters above bars represent means separations conducted by treatment using α = 0.05.

CONCLUSIONS

Potassium applications had no impact on crop productivity at any site regardless of crop grown, K rate applied, or initial soil test levels. Phosphorus applications increased alfalfa yield at site 3 with rates ≥ 50 lb P_2O_5/acre but did not affect forage nutritive value. Wheat yields at site 6 increased with P rates ≥ 30 lb P_2O_5/acre, with fall applications yielding higher than spring applications and P source having no effect. Silage corn yield was not affected by P or K applications, but forage nutritive value differences were observed at one site. The low frequency of crop impacts and economic returns of P and K fertilization in low-testing soils in this study indicates that USU fertilizer guidelines should possibly be reduced and that recommendations tested >1-2 years to evaluate potential yield and profit losses from under-fertilization.

REFERENCES

Baker, M., Yost, M., Creech, J. E., Cardon, G., Gale, J., Price, S., Pace, M., Wytsalucy, R., Zesiger, C., Nelson, M., & Violett, R. (2026). Comparison of various fertilizer recommendations for forage crops in the Western United States. *Crop Science, 66,* e70223. https://doi.org/10.1002/csc2.70223

Cardon, G., Jotuby-Amacher, J., Hole, P., & Koenig, R. (2008). *Understanding your soil test report*. Utah State University Extension. AG/Soils/2008-01pr.

Carpenter, S. R. (2005). Eutrophication of aquatic ecosystems: Bistability and soil phosphorus, *Proc. Natl. Acad. Sci. U.S.A.* 102 (29) 10002-10005, https://doi.org/10.1073/pnas.0503959102

Dahnke, W.C. and Olson, R.A. (1990). Soil Test Correlation, Calibration, and Recommendation. In Soil Testing and Plant Analysis, R.L. Westerman (Ed.). https://doi.org/10.2136/sssabookser3.3ed.c4

Lyons, S. E., Clark, J. D., Osmond, D. L., Parvej, M. R, Pearce, A. W., Slaton, N. A., & Spargo, J. T. (2023). Current status of US soil test phosphorus and potassium recommendations and analytical methods. *Soil Science Society of America Journal*, 87, 985–998. **https://doi.org/10.1002/saj2.20536**

Spargo, J. T., Lyons, S. E., Clark, J. D., Osmond, D. L., Parvej, R. M., Pearce, A. W., Slaton, N. A., Saffire, D., Alford, S., Allen, T., Arnall, B., Buob, T., Camberato, J. J., Cardon, G., Culman, S. W., Davenport, J. R., Fernandez, F. G., Florence, R., Flynn, R., … Zhang, H. (2022). A Survey to Evaluate the Current Status of Land Grant University and State Department of Agriculture Soil Fertility Recommendations and Analytical Methods (Version 1). *Ag Data Commons*. https://doi.org/10.15482/USDA.ADC/1526506

United States Department of Agriculture-Agricultural Marketing Service (USDA-AMS). (2003). *Hay quality designation guidelines*. AMS Livestock, Poultry, and Grain Market News. https://www.ams.usda. gov/sites/default/files/media/HayQualityGuidelines.pdf

USDA National Agricultural Statistics Service (USDA-NASS). (2023). NASS—Quick stats. USDA National Agricultural Statistics Service. https://data.nal.usda.gov/dataset/nass-quick-stats

Weibe, K., & Gollehon, N. (2006). *Agricultural resources and environmental indicators* (EIB-16). US Department of Agriculture Economic Research Service. https://www.ers.usda.gov/publications/pubdetails/?pubid=44109

Zhang, H., Antonangelo, J., Grove, J., Osmond, D., Slaton, N. A., Alford, S., Florence, R., Huluka, G., Hardy, D. H., Lessl, J., Maguire, R., Mylavarapu, R., Oldham, J. L., Pena-Yewtukhiw, E. M., Provin, T., Sonon, L., Sotomayor, D., & Wang, J. (2021). Variation in soil-testbased phosphorus and potassium rate recommendations across the southern USA. *Soil Science Society of America Journal, 85*, 975–988. https://doi.org/10.1002/saj2.20280