**Investigating Relationships between Haney H3A-4 And Conventional Soil Tests For Plant Nutrients In Kansas Soils**

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## ABSTRACT

Use of a soil test to determine fertilizer application rates requires correlation and calibration to crop yield response and/or total nutrient uptake. The Haney H3A soil test procedure has gained popularity in recent years for soil health evaluation and has been used in some circles to adjust fertilizer management practices. However, data relating this test to current soil fertility tests, relative crop yield, or total nutrient uptake are nonexistent in Kansas soils. The objective of this study is to evaluate the correlation between H3A soil test phosphorus and potassium with soil tests currently used in Kansas (e.g. Mehlich-3), and investigate the relationship between these soil test P and K values and total nutrient uptake in corn (Zea mays L.). Soils from a nitrogen response study were extracted using both Mehlich-3 and H3A (ver. 4) soil test procedures. Mehlich-3 and Haney extractable P and K were positively correlated ($r = 0.9$ and 0.91, respectively) in data combined from all sites. Linear regression models fit to the combined data indicate that Mehlich-3 extracts approximately 25% more P and 250% more K. The RMSE of these models (15.4 mg P $kg^{-1}$ and 83.4 mg K $kg^{-1}$) indicate that existing calibration based on Mehlich-3 values are not suitable for use with H3A-4.

## INTRODUCTION

The availability of phosphorus (P) and potassium (K) is typically assessed with a soil test and a calibration curve relating test values to relative yield or nutrient uptake. Several soil tests for P and K have been introduced over the years. Historically, Bray-1 and Olsen have been the dominant soil test methods used for P analysis in the Central Plains region, while ammonium acetate has been used for base cations (e.g. K, Ca, Mg, Na). Usage of Bray-1 vs Olsen is largely dependent on soil pH, where Bray-1 is preferred in acidic soils and Olsen in calcareous soils. The Mehlich-3 (M3) procedure has gained popularity in recent years, and is intended for use in acidic to neutral pH soils. It has been dubbed a "universal" extractant by some, due to its ability to extract multiple nutrients across a wide range of soil pH. When combined with modern spectroscopic techniques (e.g. ICP-OES), this procedure allows for the simultaneous measurement of multiple macro and micronutrients from a single extract. This has led to wide adoption of the M3 soil test procedure at labs across the US.

One criticism of the M3 procedure, particularly with regards to P assessment, is due to the nature of its chemistry. The M3 solution has a pH of 2.5 and is strongly buffered. This acidity, in conjunction with the presence of $F^-$, increases the solubility of Al- and Ca-bound P and reduces its re-precipitation during the extraction process. These actions are thought by some to over-estimate the availability of P in some soils, as the extraction environment is quite different than what would be observed in the rhizosphere.

The Haney H3A extracting solution was developed with these criticisms in mind, and is intended to simulate the chemistry of actively growing roots more closely (Haney, Haney et al. 2006). The H3A extracting solution is comprised of a dilute mixture of organic acids, but has undergone numerous iterations since its initial development (Haney, Haney et al. 2017). The current iteration, version 4, is comprised of malic, citric, and oxalic acids, and has a weakly buffered pH of approximately 3.75 (Haney, Haney et al. 2017). This method has been adopted by some soil testing labs and is typically used in soil health assessments. Data relating H3A-4 soil test values to relative crop yield and nutrient uptake are nonexistent in Kansas soils. The primary objectives of this study are to investigate relationships between M3 and H3A-4 soil test P and K, and their relationships to relative total P and K uptake in corn.

## MATERIALS AND METHODS

Field studies were initiated at multiple sites across the state of Kansas during the 2017, 2018, and 2019 corn growing seasons, 14 site-years in total (Table 1). Treatments consisted of N, P, and K fertilizer combinations applied at rates ranging from 0 to 200 lbs N $ac^{-1}$, 0 or 80 lbs $P_2O_5$ $ac^{-1}$, and 0 or 100 lbs $K_2O$ $ac^{-1}$. These treatments were applied to 10 ft wide by 40 ft long plots. Plots were arranged as a randomized complete block design with four replications at each site. Measurements collected include whole plant dry biomass at R6 growth stage, R6 biomass and grain NPK content, and harvest grain yield. Soil samples were collected from each plot using a hand probe to a depth of six inches prior to treatment application. Soil measurements include soil pH, M3 and H3A-4 extractable P, K, Ca, Mg, Al, Cu, Fe, Mn, and Zn.

Soil samples were dried at 40 °C and ground to pass a #10 sieve. Soils were extracted following procedures for M3 and H3A-4. Briefly, M3 extractions were performed using 2 g of soil and 20 mL of M3 extracting solution (0.2N $CH_3COOH$, 0.013N $HNO_3$, 0.015N $NH_4F$, 0.25N $NH_4NO_3$, and 0.001N EDTA) and shaken for five minutes at 180 cpm (Mehlich 1984). H3A-4 extractions were collected by mixing 2 g of soil with 20 mL of H3A-4 extracting solution (0.35 g $L^{-1}$ citric acid monohydrate, 0.55 g $L^{-1}$ malic acid, and 0.225 g $L^{-1}$ oxalic acid dihydrate) and shaken for 10 minutes at 180 cpm. H3A-4 extracts were centrifuged at 3500 rpm for 5 minutes. All extracts were filtered through Whatman 2V filter paper. Extractable P was measured at 660 nm using a colorimeter (Lachat QuikChem 8500 Series 2). Extractable K was determine using ICP-OES (Varian 720-ES). Soil pH was measured from 1:1 soil-water suspensions using a pH meter equipped with glass electrodes (Skalar, Inc).

Relationships between Mehlich-3 and H3A-4 extractable nutrients were evaluated using linear regression models. Relationships between relative nutrient uptake and soil test P and K were investigated using linear plateau and quadratic plateau models. Data analyses were performed in R version 3.6 (R Core Team, 2019) and evaluated at the 95% confidence level.

## RESULTS AND DISCUSSION

Mehlich-3 and H3A extractable P and K were highly correlated (r = 0.90 and 0.91, respectively) and exhibit a linear relationship in combined data (Figures 1, 2). On average, M3 extracted approximately 25% more P and 250% more K than H3A-4 (Figures 1, 2). The RMSE of these regression models (15.4 mg P kg $soil^{-1}$ and 83.4 mg K kg $soil^{-1}$) is too large to allow for estimation of M3 P or K from H3A-4 P or K for the purposes of fertility recommendations. Existing calibration curves for soil test P and K for Kansas soils are based on either Mehlich-3 or Bray-1. These data clearly illustrate that separate calibrations would be required to make fertilizer recommendations from H3A-4 P or K soil tests.

Relative total P and K uptake ($RTU_P$ and $RTU_K$) were calculated based on above ground biomass production, grain production, and P and K contents of these biomass. Relationships between $RTU_P$ and $RTU_K$ and soil test P and K were not significant (Figure 3,4,5,6). The critical soil test P and K values for corn in Kansas are 20 mg P $kg^{-1}$ and 130 mg K $kg^{-1}$. This lack of response was consistent across N application rates, and is likely the due to relatively high soil test concentrations of P and K in these soils (Table 1, Figure 3,4,5,6). Future studies should target low P and K soils.

Mehlich-3 and H3A-4 extractable P and K appear highly correlated in Kansas soils. However, RMSE values of regression models indicate that these relationships are not strong enough to simply convert H3A-4 soil test values to M3 values for fertilizer recommendations. Existing calibration and correlation data relating conventional soil tests to relative yield and nutrient uptake are likely not appropriate for use with the H3A-4 soil test.

## REFERENCES

Haney, R. L., E. B. Haney, et al. (2006). "Development of a New Soil Extractant for Simultaneous Phosphorus, Ammonium, and Nitrate Analysis." Communications in Soil Science and Plant Analysis **37**(11-12): 1511-1523.

Haney, R. L., E. B. Haney, et al. (2017). "Removal of Lithium Citrate from H3A for Determination of Plant Available P." Open Journal of Soil Science **07**(11): 301-314.

Mehlich, A. (1984). "Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant." Communications in Soil Science and Plant Analysis **15**(12): 1409-1416.

**Table 1.** General site descriptions, and soil chemical and textural parameters for 14 experimental sites included in the study. All sites were located across Kansas. Soil parameters were measured from composite soil samples representing the site. Phosphorus (P) and potassium (K) were determined using Mehlich-3 soil test.

| SiteID | Year | County | Tillage | pH | OM | P | K | CEC | Sand | Silt | Clay |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | % | - - - soil ppm - - - | | $cmol_c$ $kg^{-1}$ | - - - - - % - - - - - | | |
| 1 | 2017 | Riley | Conv. | 6.7 | 2.8 | 41 | 250 | - | 16 | 60 | 24 |
| 2 | 2017 | Riley | Conv. | 6.9 | 2.9 | 41 | 260 | - | 8 | 54 | 38 |
| 3 | 2017 | Mitchell | No-till | 5.8 | 3.0 | 26 | 430 | - | 18 | 60 | 22 |
| 4 | 2017 | McPhers. | Conv. | 7.7 | 3.4 | 83 | 718 | - | 26 | 44 | 30 |
| 5 | 2018 | Franklin | Conv. | 6.1 | 3.0 | 15 | 96 | 22.2 | 14 | 62 | 24 |
| 6 | 2018 | Mitchell | No-till | 5.7 | 2.7 | 56 | 520 | 27.7 | 16 | 52 | 32 |
| 7 | 2018 | Mitchell | No-till | 5.2 | 3.2 | 30 | 234 | 27.1 | 26 | 44 | 30 |
| 8 | 2018 | Mitchell | No-till | 5.6 | 3.9 | 23 | 463 | 24.7 | 22 | 48 | 30 |
| 9 | 2019 | Mitchell | No-till | 4.9 | 3.4 | 68 | 368 | 25.7 | 16 | 56 | 28 |
| 10 | 2019 | Mitchell | No-till | 5.4 | 3.3 | 75 | 534 | 25.5 | 8 | 60 | 32 |
| 11 | 2019 | Riley | Conv. | 5.8 | 1.8 | 32 | 270 | 13.8 | 34 | 52 | 14 |
| 12 | 2019 | Shawnee | Conv. | 6.7 | 1.6 | 42 | 140 | 8.0 | 52 | 38 | 10 |
| 13 | 2019 | Republic | Conv. | 5.7 | 3.6 | 6 | 408 | 22.2 | 20 | 56 | 24 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 2019 | McPhers. | No-till | 6.2 | 3.4 | 139 | 560 | 21.3 | 24 | 52 | 24 |

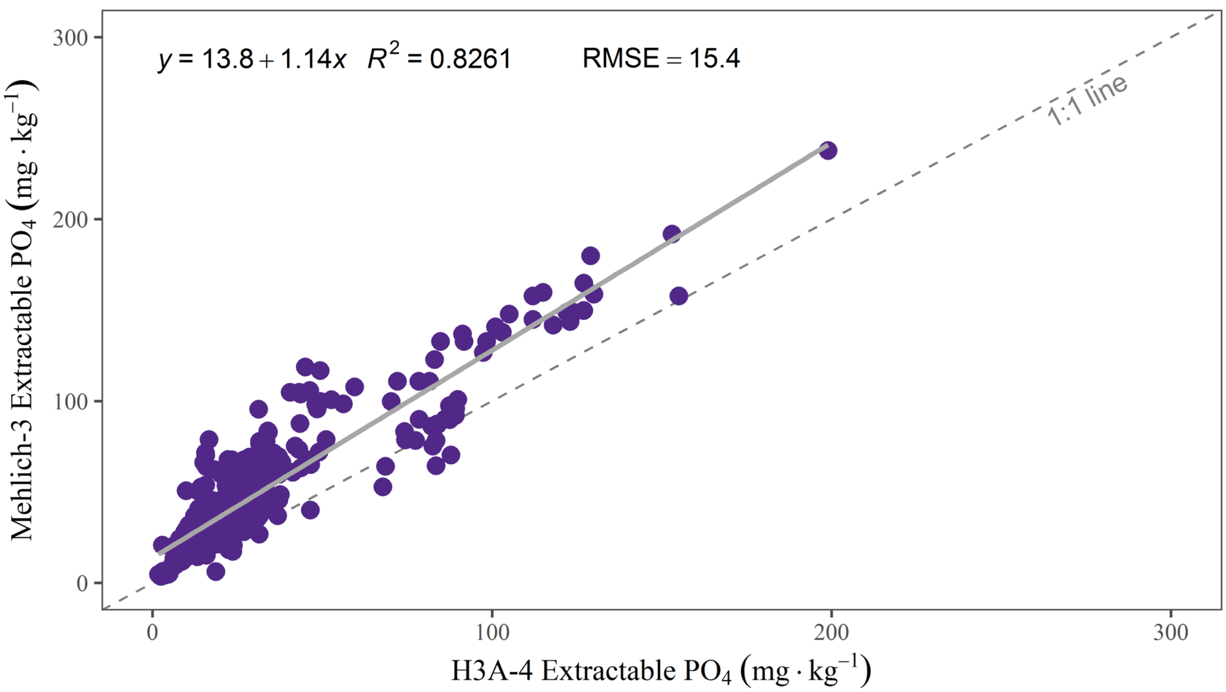


**Figure 1**. Mehlich-3 (horizontal axis) and H3A-4 (vertical axis) extractable orthophosphate from soils collected from plots at each site. The combined data show a positive linear relationship between the two soil test methods for P, with M3 extracting approximately 30% more P than H3A-4.

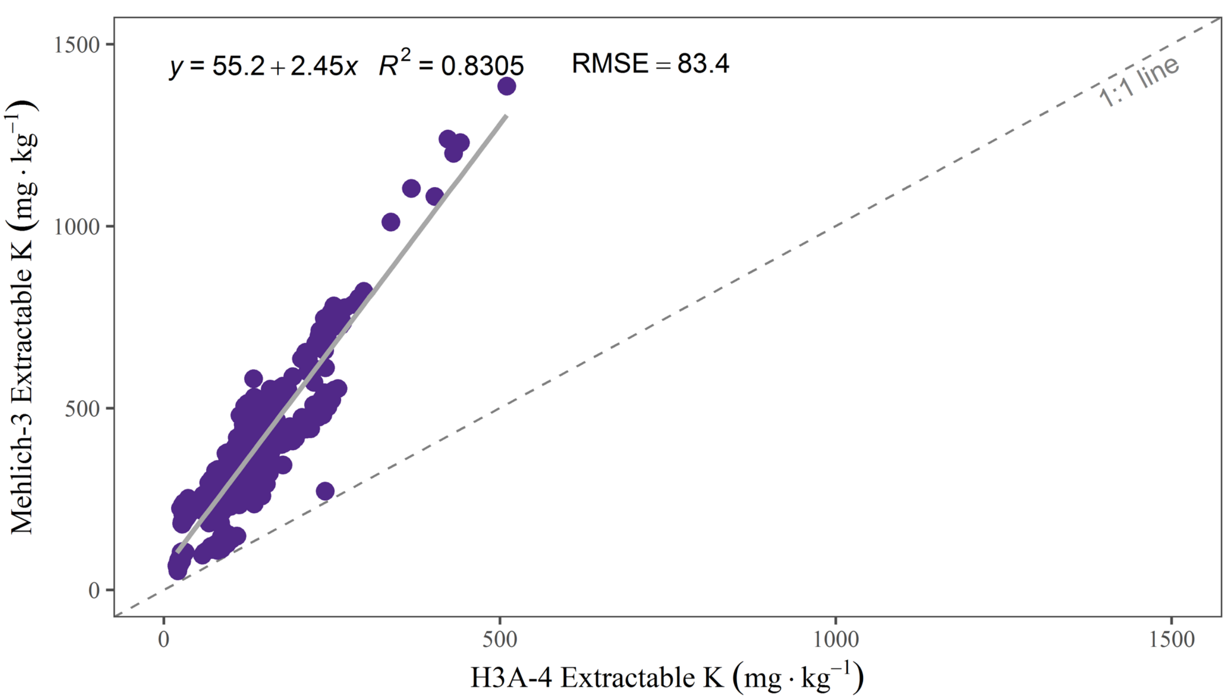

**Figure 2**. Mehlich-3 (horizontal axis) and H3A-4 (vertical axis) extractable potassium (K) measured from soil samples representing the 0-6 in (15 cm) soil layers. M3 K and H3A-4 K exhibit a positive linear relationship in these combined data, with M3 extracting approximately three times more K than H3A-4.

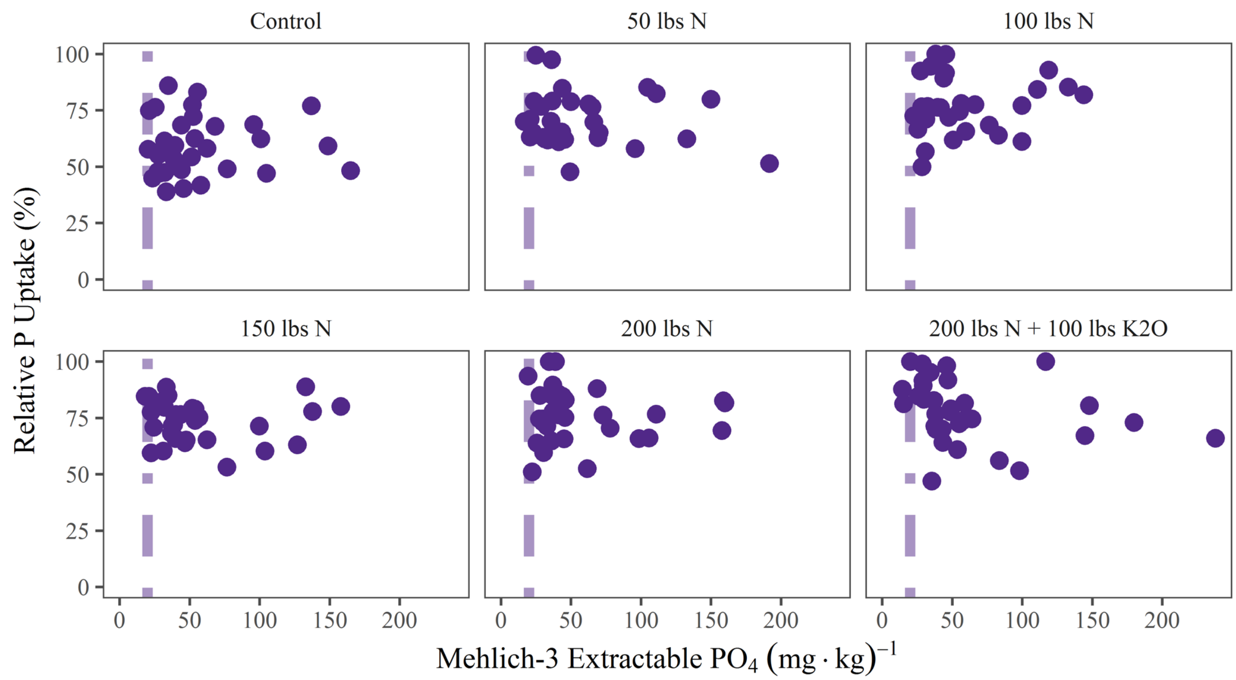


**Figure 3.** Mehlich-3 extractable orthophosphate (horizontal axis) vs. relative total phosphorus (P) uptake (vertical axis) for all sites combined. Data were grouped by fertility management practice. Facet labels indicate the amount of N, P, or K fertilizer added on a per acre basis, where the "Control" plots received zero added nutrients.

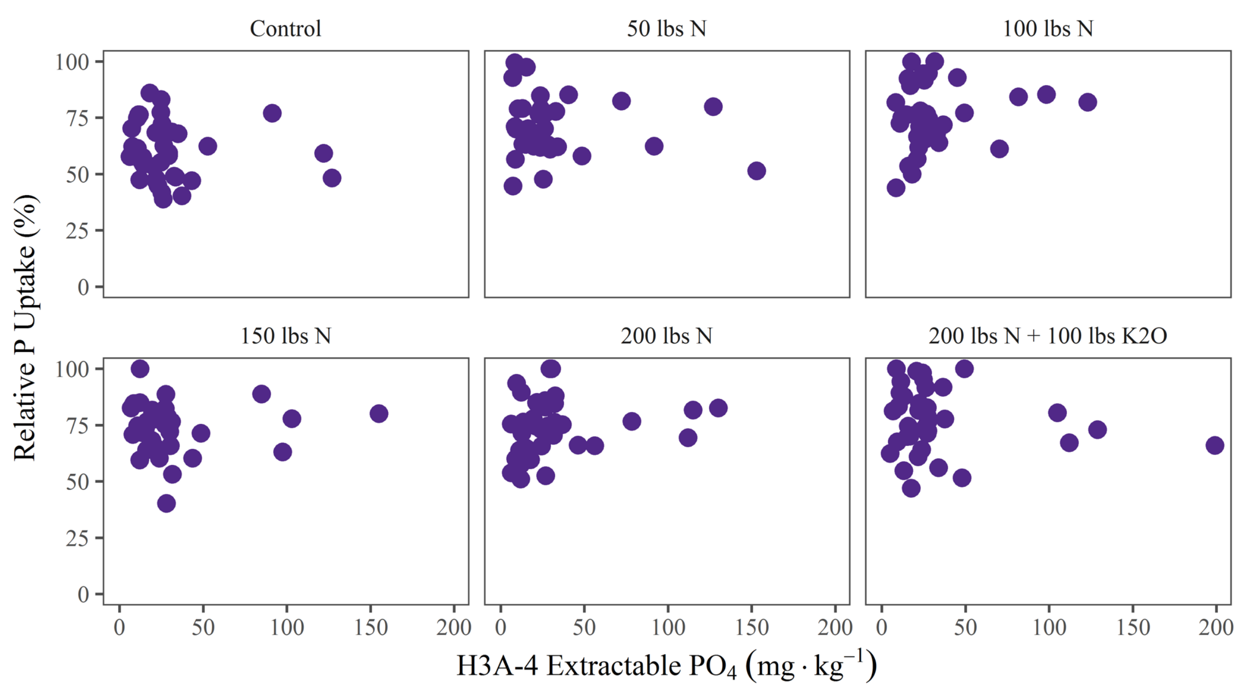


**Figure 4**. Haney H3A-4 extractable orthophosphate (horizontal axis) vs relative total phosphorus (P) uptake

(vertical axis) for all sites combined. Data were grouped by fertility management practice. Facet labels indicate the amount of N, P, or K fertilizer added on a per acre basis, where the "Control" plots received zero added nutrients

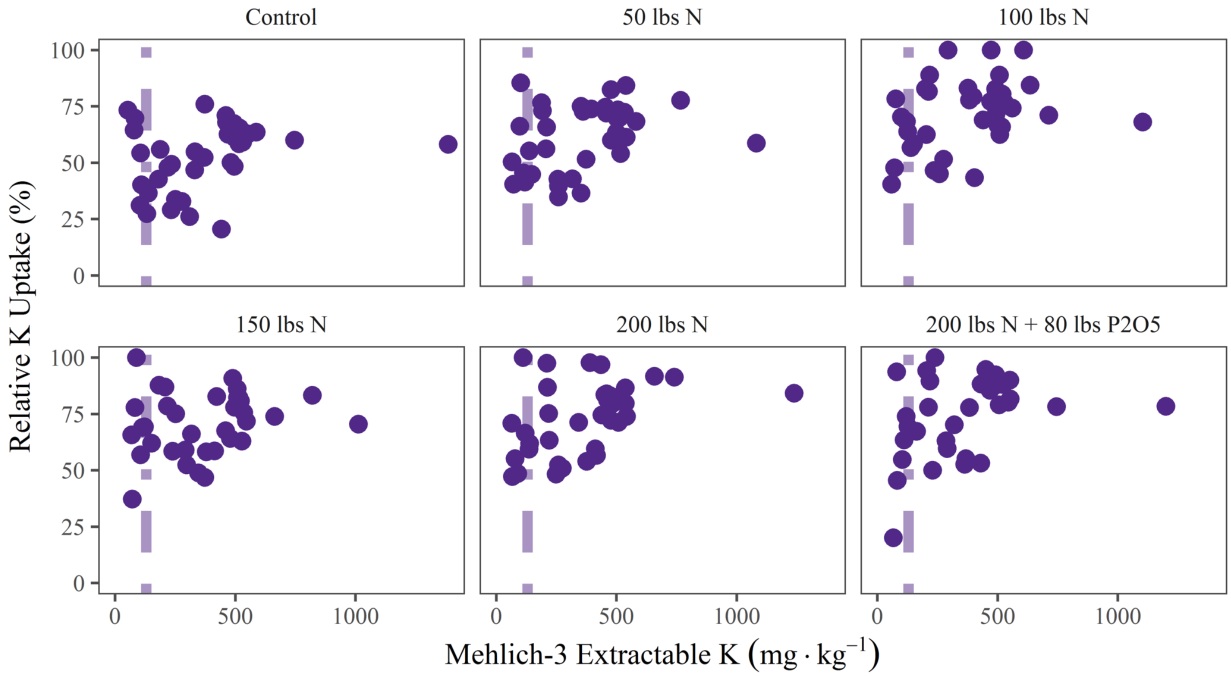


**Figure 5**. Mehlich-3 extractable potassium (horizontal axis) vs relative total K uptake (vertical axis) for all sites combined. Data were grouped by fertility management practice. Facet labels indicate the amount of N, P, or K fertilizer added on a per acre basis, where the "Control" plots received zero added nutrients.

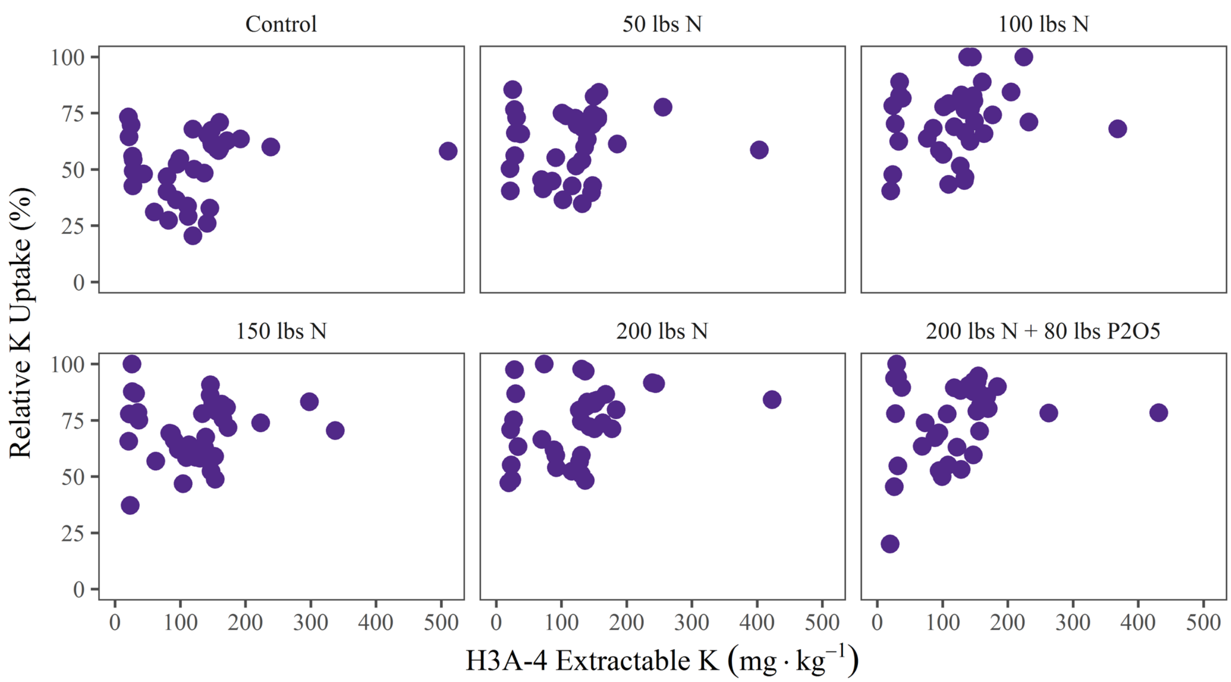


**Figure 6.** Haney H3A-4 extractable potassium (horizontal axis) vs. relative total K uptake (vertical axis) for all sites combined. Data were grouped by fertility management practice. Facet labels indicate the amount of N, P, or K fertilizer added on a per acre basis, where the "Control" plots received zero added nutrients.