# Building Potassium Fertilizer Guidelines that Include Soil Classification Information

**PI and Collaborators**
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Kris Osterloh and Doug Malo, SDSU Soil Pedology; David Clay, SDSU, Soil Biogeochemistry

**Summary**

Soil potassium (K) levels are being increasingly reported below 160 ppm, the critical level where fertilizers become recommended to optimize corn yield. However, there is still a 30-60% chance of no yield increase when soil test K levels are between 41 and 160 ppm. To improve the accuracy of K recommendations in North Dakota they also included clay type information in their recommendation guidelines because clay type can influence K availability to crops. Improving our understanding of the influence clay mineralogy has on crop response to K also has the potential to improve K recommendations in South Dakota (SD). Clay mineralogy also influences the risk of sodium dispersion and its subsequent effect on erosion. The objective of this project is to create new soil specific K fertilizer recommendation guidelines. The data from this study will be used to update current K recommendations for corn in SD. The update will help growers optimize their crop yield and economic profit.

**Goal and Objectives**

The goal and objective of this project is to create new soil specific K fertilizer recommendation guidelines for SD.

**Results:**

- Soil samples were collected for soil health, soil fertility, and soil mineralogy prior to planting and fertilization.
- Completed K rate study at 6 locations throughout central and eastern South Dakota.
- Graduate student has been selected and started.

Six potassium rate field studies were conducted in 2020.Preplant soil samples were taken from each of the four replications at each site from 0 to 6 and 6 to 24 inches. Notable soil test parameters included soil test K, water soluble K, and total K (ppm), CEC (meq/100g), and % clay content (Table 1). Soils in the central portion of the state had higher levels of K in the soil compared to the eastern portion of the state. Using a threshold of 160 ppm K, however, all the sites, including those in the eastern portion of the state, contained a mean soil test K level above 160 ppm. Therefore, each site was noted as having a “very high” K level, according to SDSU’s Fertilizer Recommendation Guide. In fact, only 2 soil samples (one at Beresford and one at Badger, both 6-12”) were found to be below 160 ppm. As a result, corn yield did not increase from applied K fertilizer at any of the six research locations (Figure 1). There were trends in these sites but no statistically significant increases.

**Table 1.** Average preplant soil chemical and physical properties (0–6 in.) at six research sites in central and eastern South Dakota in 2020.

| Soil Test† | SERF | Kingsbury | Potter | Tripp 30 in. | Tripp 60 in. | McCook |
|---|---|---|---|---|---|---|
| P | 23 | 38 | 10 | 7 | 8 | 11 |
| K | 206 | 277 | 493 | 625 | 695 | 193 |
| SOM | 5.2 | 5.9 | 3.1 | 5.7 | 5.8 | 4.4 |
| pH | 5.3 | 5.8 | 6.3 | 7.7 | 7.7 | 6.2 |
| CEC | 26 | 28 | 20 | 40 | 41 | 25 |
| Texture | SCL | CL | L | C | C | CL |
| S:I | 0.74 | 5.14 | 0.92 | 1.66 | 1.30 | 7.18 |

† P, Phosphorus, Olsen-P, ppm; K, Potassium, Ammonium Acetate, ppm; SOM, Soil Organic Matter, Loss on Ignition, %, pH, 1:1; CEC, Cation Exchange Capacity, meq $100g^{-1}$; ST, Soil Type, SCL, Silty Clay Loam, CL, Clay Loam, L, Loam, C, Clay; S:I, Smectite:Illite Ratio

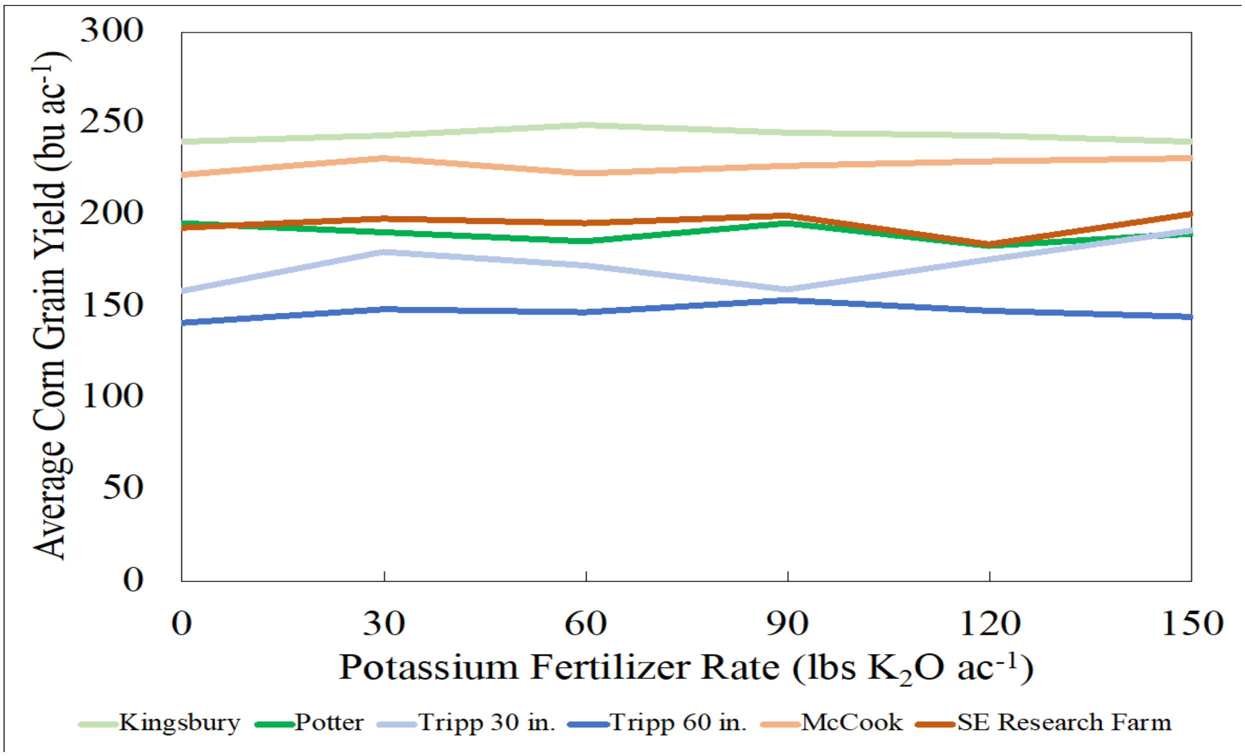


**Figure 1:** Average yield response to various K rates across central and eastern South Dakota in 2020.

The final aspect of this study evaluated the influence of clay mineralogy on the response of corn grain yield to K fertilizers. Research conducted in North Dakota by Breker et. al. (2019) found that the critical level for soil test K may be higher for soils which exhibit a larger smectite:illite ratio. It was found that for soils with a smectite:illite ratio greater than 3.5, the critical level for soil test K was approximately 200 ppm. For a soil with a smectite:illite ratio less than 3.5, the critical level was found to be approximately 128 ppm. The research site in McCook county had a smectite:illite ratio greater than 3.5 and a soil test K level below North Dakota's critical value of 200 ppm at 193 ppm. However, no significant response to fertilizer-K was found at this site (Table 1; Figures 2 and 3).

Except for the Beresford site, sites in the central portion of the state had a much lower smectite:illite ratio than the eastern portion of South Dakota. In addition to having a considerable amount of K in the soil, the narrower smectite:illite ratio found in the central portion of South Dakota indicates that more K in the soil is available for plant uptake, and subsequently the critical level of K in the soil may be lower. Likewise, portions of eastern South Dakota with lower levels of K in the soil, as well as broader smectite:illite ratios, may require more K fertilizer, as highly charged smectites will hold onto K ions very tightly in the soil. Further evaluations will be conducted in the upcoming years to better understand the impacts of clay mineralogy with K fertilizers.

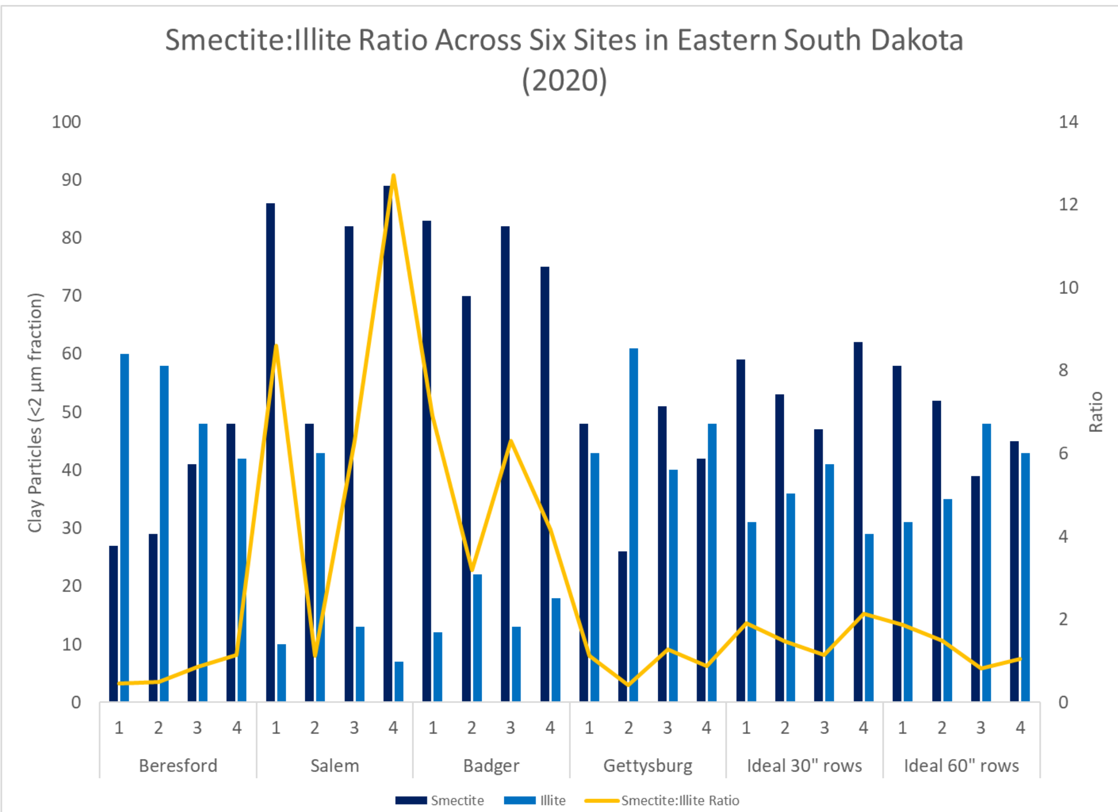


**Figure 1.** Clay particle fraction and smectite to illite values and ratio for six sites across central and eastern South Dakota in 2020.

**Impacts:**

- Knowledge of the relationship between potassium and soil fertility and soil health measurements will be reevaluated to determine the need to update potassium recommendations for South Dakota.
- Knowledge will be increased of the relationship between soil health measurements and agricultural management practices.
- Training of a graduate and several undergraduate students in soil fertility.
- Extension research report published with the Southeast Research Farm's annual research report.

**Project Budget (As of Jan. 1, 2020):**

| Budget Category | Budget | Total Expenses | Available Balance |
|---|---|---|---|
| Salaries | 42,454.00 | 18,925.43 | 23,528.57 |
| Benefits | 5,717.00 | 3,446.26 | 2,270.74 |
| Travel | 8,000.00 | 271.01 | 7,728.99 |
| Contractual | 29,802.00 | 2,672.68 | 27,129.32 |
| Supplies | 4,000.00 | 3,084.81 | 915.19 |
| Tuition remission | 7,602.00 | - | 7,602.00 |
| **Total** | **$97,575.00** | **$28,400.19** | **$69,174.81** |

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**Summary**

Properly calibrated potassium (K) fertilizer recommendations (KFRs) are critical for improving crop yields and maintaining environmental stewardship. Recent innovations in soil and crop management suggest that certain soil factors, including clay mineralogy, can be used to predict optimal K requirements in corn. The objectives of this study include 1) correlate soil K levels to corn yield, 2) calibrate KFRs with clay mineralogy data, and 3) determine the relationships among clay mineralogy, K uptake, and fertilizer requirements. During the 2020-2021 growing seasons, 15 field trials were established across central and eastern South Dakota. The experimental design used was a randomized complete block design with four replications. Treatments of potash fertilizer were broadcast applied at 6 different rates: 0-150 lbs. $K_2O$ ac.$^{-1}$ in 30 lb. increments. A linear plateau model correlating soil test potassium (STK) to relative yield suggested that South Dakota's K critical level could shift from 160 to 169 ppm. Calibrating K fertilizer rates to corn yield resulted in accurate prediction of optimal KFRs at 12 of the 15 sites. Initial results showed that including clay mineralogy in the calibration process could not confidently be used to predict corn yield response.

**Goal and Objectives**

The goal and objective of this project is to create new soil specific K fertilizer recommendation guidelines for SD.

**2022 Results:**

- Studies have been established at 5 field sites.
- Soil samples were collected for soil health and soil fertility prior to planting and fertilization.
- Fertilizer treatments of potassium rates ranging from 0-120 lbs ac$^{-1}$ were applied.
- Potassium fertilizer rates to achieve 4% and 7% K base saturation were applied at planting.
- V6 plant samples were taken and are currently being processed in preparation for analyzing for nutrient analysis.

**Soil Test Potassium Correlations**

Selected soil test parameters, including smectite and illite clay content, are reported in Table 1. Soil test K levels ranged from 132 to 735 ppm, with only sites 9, 10, and 12 reporting STK levels below 160 ppm. Figure 1 displays the linear plateau model for sites 5, 6, 9, 10, 12, 13, and 14, with STK ranging from 132 to 202 ppm. According to current KFRs in South Dakota, a yield response is unlikely to be observed in soils >160 ppm. In this study, the linear plateau model climbed past 160 ppm and plateaued at 169 ppm, suggesting that a higher percentage of maximum yield could be achieved by raising the K critical value to 169 ppm.

**Potassium Fertilizer Recommendation Calibrations**

Of the 15 field trials conducted, only two (sites 10 and 15) were observed to positively respond to K fertilizer treatments. To optimize corn yield, K fertilizer would need to be applied at rates of 60 and 37 lbs. $K_2O$ ac.$^{-1}$ at sites 10 and 15, respectively. While the yield response was anticipated for site 10 (STK = 132 ppm), a yield response was not expected at site 15, where STK was exceptionally higher than the current 160 ppm K critical level (STK = 327 ppm). Although the agronomic optimum KFR was observed, neither site required K fertilizer to yield at economic optimal levels (assuming \$0.65 lb.$^{-1}$ K and \$6.00 bu.$^{-1}$ corn price), which is consistent with conclusions from other studies.

Table 1. Select soil test data (0-6 in. sample depth) for the 15 field trials in this study.

| | Soil Test Parameter† | | | | | |
|---|---|---|---|---|---|---|
| Site | pH | CEC | EC | K | Smectite | Illite |
| | | meq 100 g$^{-1}$ | mmhos cm$^{-1}$ | ppm | --------- <2 µm fraction --------- | |
| 1 | 7.5 | 40.3 | 0.50 | 634 | 55.3 | 34.3 |
| 2 | 7.7 | 39.2 | 0.59 | 735 | 48.5 | 39.3 |
| 3 | 6.2 | 21.6 | 0.25 | 501 | 41.8 | 48.0 |
| 4 | 5.9 | 29.5 | 0.22 | 322 | 77.5 | 16.3 |
| 5 | 6.1 | 25.6 | 0.19 | 200 | 76.3 | 18.3 |
| 6 | 5.3 | 24.1 | 0.16 | 202 | 36.3 | 52.0 |
| 7 | 6.8 | 13.7 | 0.13 | 241 | 51.5 | 38.8 |
| 8 | 6.0 | 17.2 | 0.11 | 287 | 34.8 | 51.5 |
| 9 | 6.1 | 14.3 | 0.11 | 132 | 43.5 | 44.8 |
| 10 | 7.2 | 22.7 | 0.31 | 143 | 80.8 | 13.0 |
| 11 | 8.0 | 29.3 | 0.40 | 436 | 54.0 | 36.8 |
| 12 | 6.1 | 22.2 | 0.44 | 155 | 39.8 | 47.0 |
| 13 | 6.4 | 14.1 | 0.22 | 161 | 19.0 | 65.0 |
| 14 | 5.3 | 21.9 | 0.16 | 170 | 41.0 | 45.3 |
| 15 | 6.1 | 18.7 | 0.21 | 327 | 14.3 | 70.8 |

† pH, 1:1 soil water; CEC, cation exchange capacity; EC, electrical conductivity; K, potassium, ammonium acetate-extractable

Sites differed considerably in STK levels and mean maximum yields (MMY) (Table 2). However, only sites 10 and 15 showed positive yield responses to K fertilizer treatments. According to current South Dakota KFRs, using STK and MMY at each site, K fertilizer should be applied at 60 lbs. $K_2O$ ac.$^{-1}$ at sites 9, 10, and 12 to optimize yield, while the remaining sites should not have any K fertilizer applied. Based on the observed yield responses, it was found that 60 lbs. $K_2O$ ac.$^{-1}$ should be applied to site 10, and 37 lbs. $K_2O$ ac.$^{-1}$ should be applied to site 15, while the remaining sites should have no K fertilizer applied. Therefore, when comparing current and optimum recommendations, KFRs were accurately predicted for 12 of the 15 sites. Over-applications of K fertilizer occurred at sites 9 and 12, while an under-application occurred at site 15.

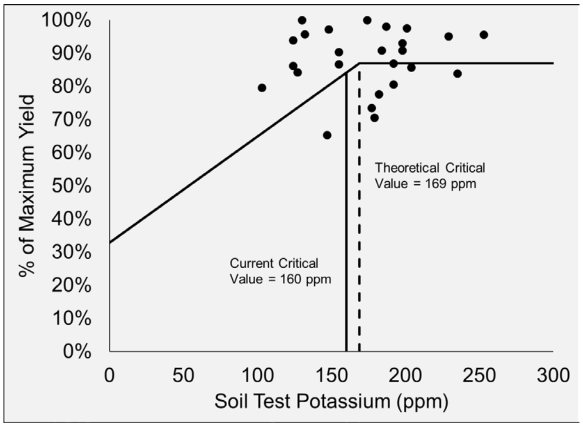


Figure 1: Linear plateau for correlation analysis.

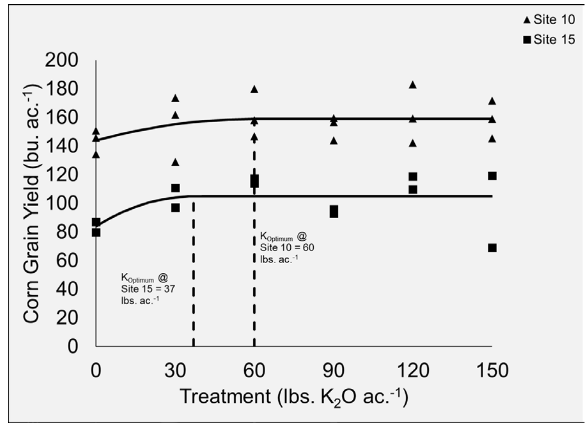


Figure 2: Quadratic plateau for calibration analysis.

Table 3: Soil test potassium, clay mineralogy, yields, and fertilizer recommendations.

| Site | K | S:I† | MMY‡ | Mean $RY_0$§ | Yield Response⁋ | Current KFR* | Optimum KFR†† |
|---|---|---|---|---|---|---|---|
| | ppm | | bu. $ac.^{-1}$ | % | | -------------lbs. $K_2O$ $ac.^{-1}$ | ------------- |
| 1 | 634 | 1.6 | 192 | 83 | No | 0 | 0 |
| 2 | 735 | 1.2 | 153 | 92 | No | 0 | 0 |
| 3 | 501 | 0.9 | 196 | 100 | No | 0 | 0 |
| 4 | 322 | 4.8 | 249 | 96 | No | 0 | 0 |
| 5 | 200 | 4.2 | 231 | 96 | No | 0 | 0 |
| 6 | 202 | 0.7 | 200 | 96 | No | 0 | 0 |
| 7 | 241 | 1.3 | 193 | 99 | No | 0 | 0 |
| 8 | 287 | 0.7 | 229 | 100 | No | 0 | 0 |
| 9 | 132 | 1.0 | 163 | 99 | No | 60 | 0 |
| 10 | 143 | 6.2 | 168 | 91 | Yes | 60 | 60 |
| 11 | 436 | 1.5 | 155 | 94 | No | 0 | 0 |
| 12 | 155 | 0.8 | 233 | 100 | No | 60 | 0 |
| 13 | 161 | 0.3 | 48 | 86 | No | 0 | 0 |
| 14 | 170 | 0.9 | 187 | 96 | No | 0 | 0 |
| 15 | 327 | 0.2 | 167 | 82 | Yes | 0 | 37 |

† S:I, smectite:illite ratio
‡ MMY, mean maximum yield, calculated as maximum yield from treatment means
§ Mean $RY_0$, mean relative yield from control treatment, calculated as yield of control plot divided by MMY
⁋ Significant quadratic plateau curve ($\alpha = 0.05$)
* Current South Dakota KFRs *Note*: 60 lbs. $K_2O$ is minimum recommendation when STK <160 ppm
†† Theoretical optimum KFR obtained from quadratic plateau modeling

## Integrating Clay Mineralogy

Clay mineralogy can impact the K fertilizer rate needed to optimize corn yield. It is theorized that a yield response to K fertilization may be observed, even if STK exceeds the soil test critical value, if there are more smectite than illite clays in the soil. Smectite clays are highly charged and exhibit shrink/swell dynamics, which hold onto $K^+$ ions tightly and temporarily fix K under dehydrated conditions. The K critical level in North Dakota was adjusted based on relative amounts of smectite and illite clays in the soil, in which soils containing 3.5 times or more smectites than illites increased the critical level to 200 ppm. Nitric acid-extractable K was found to be most exchangeable for kaolinitic soils, followed by mixed soils, and least exchangeable for smectitic soils. This finding may be a reason for observing a yield response to K at STK levels above the current critical soil test level, as demonstrated in Breker et al. (2019).

In this study, the STK correlation findings demonstrated that the critical STK value for South Dakota may need to increase from 160 to 169 ppm (Figure 1). However, none of the sites in this study (1, 2, 4, 5, 7, and 11) that had STK levels >160 ppm and S:I >1.0 showed a yield response. While the STK level at site 15 was 327 ppm, the S:I value of 0.2 was the lowest of all sites, suggesting that clay mineralogy was not responsible for the yield response at that site. While clay mineralogy could not confidently be used as a prediction tool for KFRs in the first two years of this study, five additional field trials conducted in 2022 may provide further insights for this research.

**Impacts:**

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**Products:**

- One Abstract and poster presentation and two oral presentations of study results at the ASA/CSSA/SSSA annual International Conference
- Two Proceedings paper and poster presentations at the North Central Soil Fertility and Extension Conference in Des Moines, IA
- Extension article regarding the potassium deficiency during a drought.
- Two Research reports published in the annual Southeast Research Farm's annual research report.

**Budget:**

**Project Budget (As of Dec. 1, 2022):**

| Budget Category | Budget | Total Expenses | Available |
|---|---|---|---|
| Salaries | $38,175.00 | $30,493.09 | $7,681.91 |
| Benefits | $5,660.00 | $3,766.17 | $1,889.62 |
| Travel | $4,500.00 | $961.36 | $233.66 |
| Contractual | $48,000.00 | $9,391.27 | $1,522.40 |
| Supplies | $4,500.00 | $18,088.13 | -$5,867.26 |
| Tuition remission | $7,906.00 | $6,452.70 | $1,453.30 |
| Capital Equipment | $0.00 | $0.00 | $0.00 |
| Non-Capital Equipment | $0.00 | $74.08 | -$74.08 |
| F&A (Indirect) Charges | $0.00 | $0.00 | $0.00 |
| **Total** | **$108,741.00** | **$69,226.80** | **$6,839.55** |

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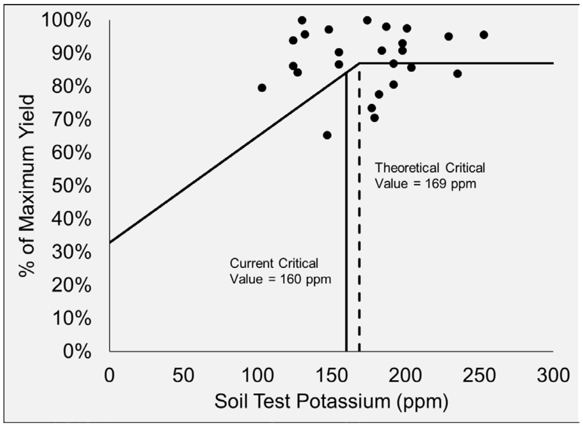


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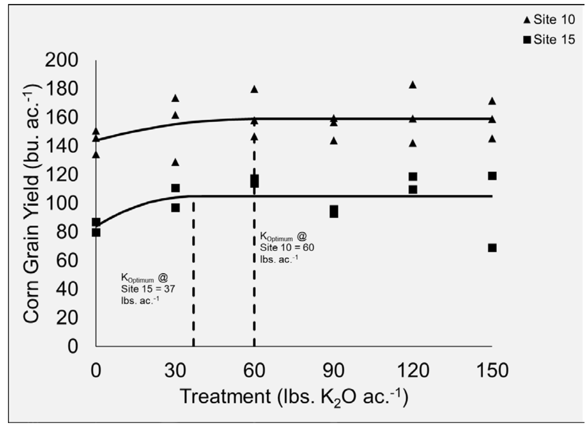


Figure 2: Quadratic plateau for calibration analysis.

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**Budget:**

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| Budget Category | Budget | Total Expenses | Available |
|---|---|---|---|
| Salaries | $37,361.00 | $26,157.56 | $11,203.44 |
| Benefits | $5,682.00 | $2,631.17 | $3,050.83 |
| Travel | $4,500.00 | $1,584.69 | $2,915.31 |
| Contractual | $48,000.00 | $20,837.23 | $27,162.77 |
| Supplies | $4,500.00 | $3,075.63 | $1,424.37 |
| Tuition remission | $7,678.00 | $4,703.00 | $2,975.00 |
| Non-Capital Equipment | $0.00 | $303.92 | -$303.92 |
| **Total** | **$107,721.00** | **$59,293.20** | **$48,427.80** |