**Technical Report FY 2019**

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**Title:** Assessment of potassium and phosphorus mining in soybean fields in North Dakota

**INTRODUCTION**

Potassium (K) is the last of the so-called “big three” soil nutrients - nitrogen, phosphorus (P), and potassium. Its role in soybean production is essential in the crop’s photosynthesis and metabolism. Even though it plays a vital role in enhancing crop resistance to water stress, many producers don’t apply K fertilizers to their fields in ND. Reasons not to apply include high soil test K and low yield increase, if any, due to K application. But recent concerns about K and P mining (removal without supplementation) in soybean fields, have brought up concerns that, crops are probably producing less than their potential if soybean production continues without supplemental K. Another aspect relating to K management in ND is the effect of soil sampling and handling on the analysis of K in soil. Sampling time, soil condition at time of sampling, and method of storage are known to reduce reliability in the correlation between soil test results and K recommendations. When the soil is sampled and dried before submitting to the lab for analysis, the results are probably going to be different than a subset of samples that were refrigerated before sending to the lab and analyzed wet. This is important because it is only when a good estimate can be made from analysis of the available K in soil that K fertilizer recommendations can be effective.

**Objectives**

* 1. Determine how much potassium (K) and phosphorus is being removed in soils across soybean fields without replacement
  2. Determine the effects of soil handling and chemical analysis on soil test values
  3. Determine the effects of potash application on soybean performance

**MATERIALS AND METHODS**

This trial was conducted in 2018~~,~~ to estimate the removal of K from soil by unfertilized soybeans following harvest, on a single unfertilized soybean plot with four replicates at Minot, Hettinger, and Williston, ND. At a fourth site in Carrington (CREC), the trial was designed to estimate K and P removed by soybeans from a 27-year old cropping systems trial. That trial was designed as a randomized complete block with split-block arrangement. Each block was a main plot of either a no-till (NT) or a conventional till (CT), and each block was divided into four smaller sized, sub-plots which were planted to corn that received variable N rates (0, 50, 100, and 150 lbs N/ac) the previous year. Each of the N treated plots was subdivided into two sub-sub plots (50 x 15) that either did not receive K (0 lbs K or the check) or received 50 lbs K. The sub-plot N treatments were standard practice that had been maintained on each tillage main plot for several years. At each of the other locations, before soybean was seeded in spring, a homogenized composite sample of eight soil cores was taken from the top six inches of each plot. Each sample was divided into two separate bags; one group was refrigerated and the other was air-dried. The samples were sent to AgSource Laboratories, Ellsworth (IA) for wet analysis of K (<https://www.agsourcelaboratories.com/Portals/11/Tech%20Bulletins-Ag/Agro%20Wet%20Potassium%20Testing-F-17161-17.pdf>). This laboratory also analyzed the P levels in the soybean pre-plant and post-harvest soil samples using the Mehlich-3 extraction method (which is different form the Olsen method used in North Dakota). In mid-season and at harvest soil samples were again collected to determine the change in available K. Aboveground biomass was also collected, weighed, dried, ground and analyzed for K concentration and the differences in response to K treatment. At harvest, soil samples were analyzed for P and K, and soybean seeds were dried, ground, and analyzed for nutrient removal. Yields are available from CREC and Minot. Soil samples from Minot, Hettinger, were from 0 to 6, and 6 – 12 inches of the top soil, from each of four replicates of soybean produced without fertilization.

**RESULTS AND DISCUSSIONS**

**Effect of K on seed yield, quality, and biomass.**

At the CREC site, yields were low, about 33 bushels on average, due to long periods of drought in 2018. Monthly rainfall was below normal throughout the growing period except June. Across treatment combinations of K fertilization, tillage, and N rates applied to previous crop, there were neither any interaction effects nor main treatment effects on yields (Table 1). The lack of yield response was probably due to initial high soil test K levels, and mid-season mineralization. Seed test weight (TWT) was significantly greater under NT than CT. There was an interaction effect on TWT between K fertilization and N applied in the previous years, with an indication that seed TWT was enhanced by K for plots that had previously been fertilized with N but not the untreated plots (Figure 1). There were no treatment effects on seed protein and oil content. Biomass was significantly different between N treatments from previous years. It was not evident why biomass was greatest from previously non-fertilized N plots, then less as N increased from 50 to 100 lbs but not at 150 lbs. A significant interaction effect on biomass, between K application and tillage showed that K enhanced biomass production under NT but had no significant effect under CT.

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| **Table 1. Soybean yield, test weight (TWT), and biomass response to potassium under conventional till (CT), no-till (NT), and N fertilization of previous corn crop at CREC** | | | | | |
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| **K Rate (P)** | **Yield** | **TWT** | **Protein** | **Oil** | **Biomass** |
| Lbs/ac | Bu/ac | lb/bu | % | % | lbs/ac |
| 0 | 31.3 | 54.98 | 32.80 | 20.60 | 3776b |
| 50 | 29.3 | 55.49 | 33.21 | 20.47 | 4441a |
|  |  |  |  |  |  |
| **N rate (previous year)** |  |  |  |  |  |
| 0 | 31.8 | 55.55 | 33.20 | 20.43 | 6461 |
| 50 | 31.8 | 55.21 | 32.60 | 20.69 | 3584 |
| 100 | 23.7 | 55.24 | 32.66 | 20.76 | 1756 |
| 150 | 33.9 | 54.93 | 33.57 | 20.25 | 4633 |
|  |  |  |  |  |  |
| **Tillage** | |  |  |  |  |
| Conventional (CT) | 31.5 | 53.96b | 32.91 | 20.74 | 4395 |
| No Till (NT) | 29.2 | 56.51a | 33.10 | 20.32 | 3822 |
|  |  |  |  |  |  |
| **Effects** | **--------------------------Significance (P> F)---------------------------** | | | | |
| K Rates (K) | 0.2702 | 0.0255 | 0.2923 | 0.2535 | **0.0328** |
| N Rates ( N) | 0.4146 | 0.2906 | 0.8550 | 0.4199 | **0.0003** |
| Tillage | 0.6679 | **0.0001** | 0.2752 | 0.4966 | 0.4556 |
| N x K | 0.7511 | **0.0451** | 0.5725 | 0.6297 | 0.5541 |
| Tillage \* K | 0.8529 | 0.1423 | 0.7885 | 0.9741 | **0.0193** |
| Tillage \* N | 0.8290 | 0.9628 | 0.7403 | 0.7466 | 0.7180 |
| Tillage \* N \* K | 0.8649 | 0.5703 | 0.2472 | 0.0963 | 0.8231 |
| TWT – Test weight;  Values with same letters within a column are not statistically different at 90% confidence level | | | | | |
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**K and P removed with seeds at harvest**

At Williston, soybean yields were quite low. Average yield for the four replicates was 16.4 bushels, ranging from 12.1 to 19.6 bushels. Average K (as K2O) and P (P­2O5) removed with the seeds at harvest was 18.1 lbs/ac of K2O, and 8.3 lbs of P2O5, respectively. That equates to 1.1 lbs of K removed per bushel, and 0.51 lbs per bushel removed.

At CREC, average yield was 34 bushels. For each bushel of soybean produced, 1.2 lbs of K and 0.54 lbs of P, were removed with the seeds. These numbers are relatively low compared to amounts reported to be removed by each bushel of soybean seeds in Michigan. According to the Michigan State University Extension, soybean removes 1.4 lbs K and 0.8 lbs P per bushel. (<https://www.canr.msu.edu/news/nutrient_removal_rates_by_grain_crops>). Removal of P per bushel of soybeans can vary quite often because of low yields due to droughts, and low available soil P. From a 2017 unpublished trial at the NDSU Oakes Irrigation Research site in North Dakota, for a soybean crop that averaged about 69 bushels, 0.65 lbs P was removed per bushel.

**Changes in soil test K and P before and after soybeans**

Soil analysis results of K from initial soils sampled, mid-season soil sampled, and post-harvest soil sampled, showed that the soil test levels were generally greater at mid-season than before planting for both NT and CT plots (Fig 2). This was due to higher availability of K for plots that received K fertilizer, and due to mid-season K mineralization. This observation is supported by the greater K analysis in July for plots that did not receive K. This probably explains why yields were not significantly affected by K. At harvest, some of the soil available K was depleted by the crop uptake, which explains the drop in K levels (Fig 2). Like with K, soil test P levels following harvest at Hettinger and CREC (Figure 3), were evidently not less than before planting, indicating that some P mineralization may have contributed to P uptake by the plant. This probably would explain, at least in part, why, despite a high P removal rate by soybeans, yields are often less responsive to P application in the Carrington area and many parts of North Dakota.

**Relationship between K analysis of refrigerated versus oven-dried soil samples**

Soil samples before planting, at mid-season, and post-harvest and their sub-sampled duplicates, which differed by the way they were stored, were analyzed by the wet method of the AgSource Laboratories (Ellsworth, IA) and the relationship of the results presented on figure 4. The results showed a strong correlation (r2 from 0.84 and 0.99) between K analysis of refrigerated and oven dried samples from Minot and CREC. Meanwhile, it is not clear why the relationship was weak for samples from Hettinger. Soil test results from soybean plots at Minot, CREC, and Hettinger showed that the refrigerated samples produced higher K values compared to the dried samples. There was a wide variation in the change (%) in K between the two storage methods. Of the eight samples analyzed within the top six inches, four of them had K levels that were from 18 to 25% greater for the refrigerated samples than the air-dried samples. This probably supports the assertion that available K levels change with storage of soil or the soil moisture status.

**CONCLUSION**

Tillage, previous crop N treatment, and K had no effect on soybean yields. Though soil K is removed by soybean during uptake and harvest of the grain, the change in soil analysis of K does not reflect the amount removed, nor was the final soil K level less than the initial level. Because of temporal changes in K levels due to soil moisture, and differences due to soil clay types, farmers are advised to use state certified laboratory interpretation and recommendations for K based on soil sufficiency ranges. For a 34-bushel soybean crop at CREC, each bushel removed about 1.17 lbs of K, and 0.54 lbs P, which is lower than for other farming regions where yields are much higher. Analysis of refrigerated or oven dried soil showed similar correlation, suggesting both methods can be used to store samples. However, the state recommended methods may depend on soil types, and farmers are advised to use interpretation of soil analysis results from their respective state extension services and certified laboratories which set different ranges of sufficiency for K in soil.

**REFERENCES**

Michigan State University Extension, 2017. <https://www.canr.msu.edu/news/nutrient_removal_rates_by_grain_crops>