COMPARING SOIL TESTING METHODS FOR SOIL ORGANIC MATTER, LIME REQUIREMENTS, AND DEVELOPING A PHOSPHORUS SOIL TEST CORRELATION

by

ROBERT J. FLORENCE

B.S., Auburn University, 2008
M.S., Auburn University, 2011

AN ABSTRACT OF A DISSERTATION

submitted in partial fulfillment of the requirements for the degree

DOCTOR OF PHILOSOPHY

Department of Agronomy
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2015

Abstract

The Kansas State University Soil Testing Laboratory currently uses the Walkley-Black (WB) method for soil organic matter (SOM) estimations, the Shoemaker-Mclean-Pratt (SMP) buffer for lime recommendations, and bases the soybean phosphorus (P) critical value for P fertilizer recommendations off other crops. Hazardous waste is produced from WB and SMP creating a health hazard for workers, and substantial cost for handling and disposal. The substantial increase in land area devoted to soybean creates the need to validate currently assumed soil test P critical value and check the current P recommendations for that crop. Overarching objectives of this dissertation are to find suitable non-hazardous replacements for WB and SMP, and to find the soybean P critical value in Kansas.

Three common methods used to estimate SOM are WB, dry combustion (DC), and loss on ignition (LOI). An experiment was set up using 98 Kansas soils to compare WB, scooped and weighed, LOI scooped, and DC weighed. All methods correlated well to each other with LOI to weighed WB, LOI to DC, and WB weighed to DC, having correlation coefficients of 0.97, 0.98, and 0.98, respectively. The lowest variability was observed with DC, followed by WB weighed, LOI, and then WB scooped with average standard deviations of 0.04, 0.13, 0.17, and 0.24, respectively.

Two non-hazardous alternatives to the SMP buffer to determine soil lime requirement are the Sikora buffer, and the modified-Mehlich buffer. Sikora's buffer is designed to mimic SMP. Buffer values alone or Mehlich's equation may be used to calculate lime requirements. Thirty seven soils with a pH less than 5.8 were incubated at lime rates 0, 2240, 4480, 8960, and 17920 kg ECC ha^{-1}. Amount of lime required to reach pHs 6.0, 6.3, and 6.6 was calculated. Mehlich's equation better predicted lime requirements for all target pHs and buffers than buffer pH alone. The Sikora buffer with Mehlich's equation provided a better lime estimation than the Mehlich buffer using Mehlich's equation..

A P correlation and calibration study was conducted with soybeans at 23 sites in Eastern Kansas from 2011 to 2014. Soil Mehlich-3 P available P was compared to relative soybean yield at these sites.. Soybean P critical value was found to be between 10 and 15 or 11.6 mg kg^{-1} using

Cate-Nelson, and linear-plateau models, respectively. A linear response to P and relative yield was observed on soils testing between 3 and 8 mg kg^{-1}, but not on higher testing soils.

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Dedication

I dedicate this work to Angela, Samuel, future kids, my mom and dad, and Uncle Terry and Aunt Dennine

Chapter 1 - Soil testing and interpretation, a literature review

"Producers would not dare go to the field without checking the oil in their tractor engines. One should approach soil testing in a similar manner."

– Franzen and Cihacek (1998).

Introduction

Soil testing is a valuable tool in assessing a field's fertility. It allows one to know if nutrients are present in adequate quantities, the soil pH is adequate, and the amount of soil organic matter (SOM) present, all important in designing a nutrient management program. The first step in soil testing is sampling. The three main sampling techniques commonly used are whole field, management zone, and grid sampling. All sampling methods rely on taking an adequate number of sub-samples, to the proper depth. Once a proper sample is collected, and sent to a laboratory, it is analyzed for crop nutrients, pH, and SOM. Nutrients are extracted with specific chemical extracts design for different soils and regions. Interpretations of the nutrient data should be based on fertilizer correlation and calibration data conducted in that region with the crop being fertilized. Fertilizer recommendations may be made using a number of different recommendation systems. The two most commonly used in the US are the Nutrient Sufficiency and Build and Maintain philosophies. In many cases adjusting for yield levels, and fertilizer use efficiency. Measuring SOM is important for nitrogen (N) credits. There are also several common methods to estimate SOM each having advantages and disadvantages.

Soil sampling

A soil sample's reported value and interpretations are only as good as the sample itself (Jackson, 1958). Sampling may be divided into three strategies: whole field, management zones, and grids. Proper sampling relies on proper depth control and an adequate number of subsamples. Sampling will also change with banded fertilizer and ridge tilling

Sampling strategies

Field Sampling

Sampling strategies commonly used are whole field, management zone, and grid sampling. Whole field sampling is done by Zig zagging up and down a field, while randomly taking an appropriate number of cores (15-20) to represent the field (Figure 1). It is the easiest and lowest cost sampling method used. Whole field sampling results in one sample per field. Since there is no knowledge of differences in nutrient availability across the field a single fertilizer application rate would then be applied to the whole field, regardless of field size.

Field sampling does not provide information on differences across the area in fertility status which might arrive from differences in natural factors such as soil or drainage, past fertilizer applications or differences in crop removal due to different crops being grown in different parts of the field.

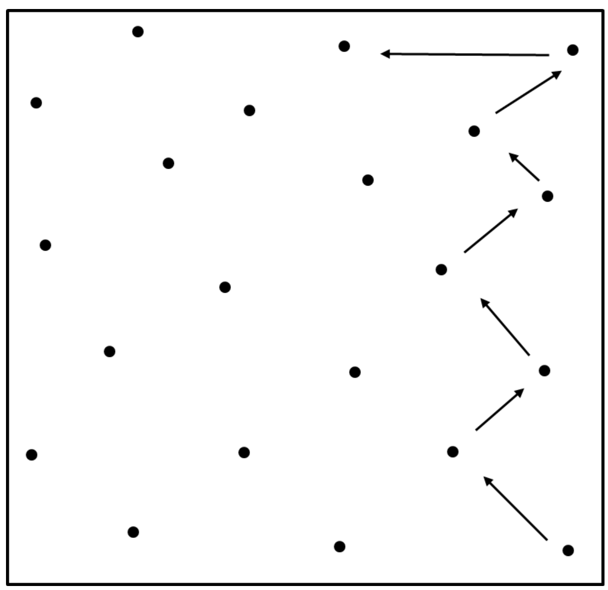

Figure 1-1. An example of how one would sample a field using the whole field strategy.

Management Zones

The management zones approach divides an area based on known differences. These differences may be soil characteristics, yield maps, by past managements, or a combination. Soil properties that one could build zones by are soil texture and slope. A reason one may divide a field by texture would be for N applications. Sandier soils would allow for more nitrate to leach through, than soils higher in clay. Soil slope plays a role in soil water availability, crops higher on a slope may be restricted by water and have lower yield potential.

Yield maps may be used to find areas that average higher or lower yields. This is important because one can figure which parts of the field may need more or less fertilizer. Higher yielding spots may also be removing more fertilizer than applied causing a lowering of the soil test values, opposite is true for lower yielding spots. By managing higher and lower yielding areas different fertilizer may be targeted to where it is needed. Once zones are established they may be sampled as if they were a whole field sample.

Past and current managements may be used to determine management zones. If it is known that manure was more heavily applied to one spot of a field compared to another, that spot would be higher in P and K. Areas that are near spots where cattle were or are currently feed would also be higher in nutrients than areas further away. Terraces make for an easy management zone as they naturally break up the landscape. A section that has a circle pivot on it may be broken into sections that are irrigated versus those that are not irrigated. A farmer may also choose other managements to divide a field.

An example of breaking a field into management zone may be found in Figure 1-2. Zones 1 to 3 were established following the slope and organic matter gradient, zone 4 is an area of the field that has a higher yield average, and zone 5 is a section of the ground that is sandy.

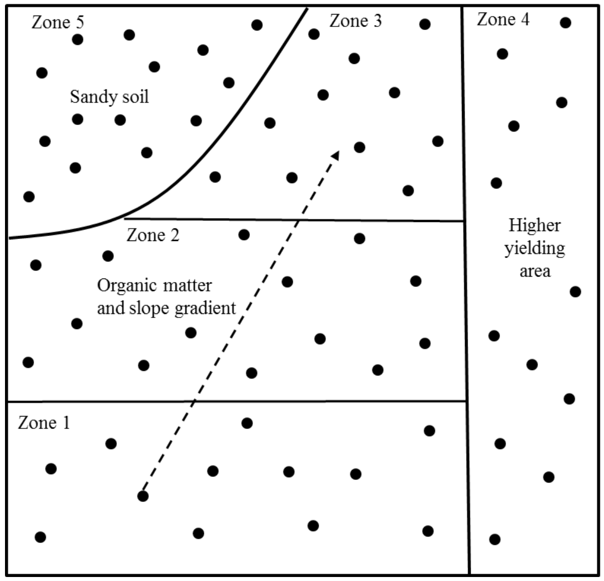

Figure 1-2. An example of how one would sample a field using the management zone strategy.

Grid Sampling

Grid sampling has the highest labor requirements and cost, but gives the greatest potential for observing field variation. Using this approach one lays a grid over a field, and samples either within the grids created or at intersections of lines. If sampling within a grid, zig-zaging while taking multiple subsamples is again recommended. If sampling on interesting lines it is recommended to take multiple subsamples within a set radius of the interesting lines (Figure 1-3). Sampling on intersections versus in grid impacts how one maps the soil results and applies fertilizer. Sampling on intersections requires one to interpolate values between points. These interpolations may vary by geographic interpolation formula used. With GPS and variable rate application equipment one may make targeted applications of fertilizer. Sampling with in grids, does not require interpolation, as the grid themselves become small management zones. Fertilizer is them applied at the recommended rate by zone.

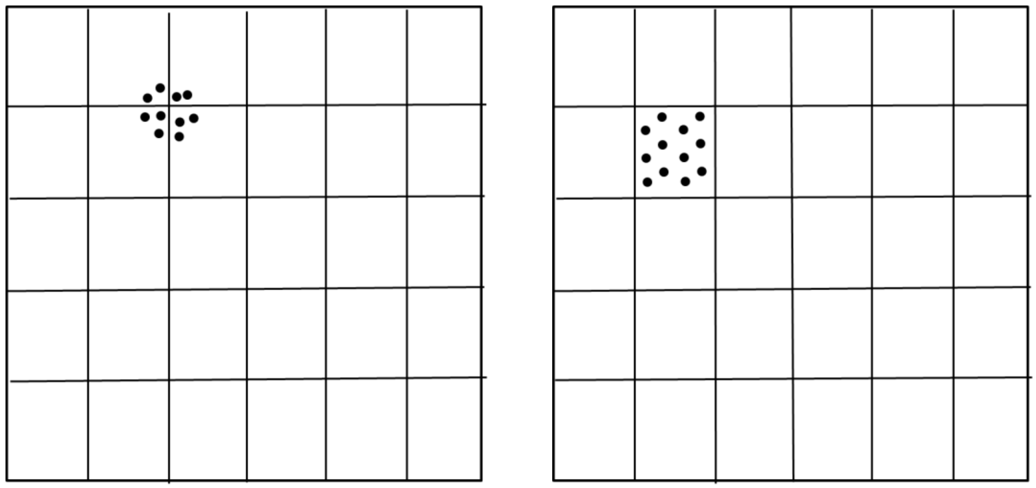

Figure 1-3. An example of how one would sample a field using the grid sampling strategy by either sampling around an intersection (left) or in a grid section (right).

Grid sampling a field has the benefit of allowing one to truly see field variability with pH and different nutrients, especially if variation exists in a pattern not known to the farmer. Over time one can begin to see how lime and fertilizer regimes are affecting the soils nutrient and pH status. One can get a picture of how evenly fertilizer, lime or manure is being applied. Adjustments can be made to fertilizer regimes if one sees over time that an area's soil test values are going up or down. While grid sampling has a high up front cost compared to the other methods, it may save farmers money if fertilizer can be applied in a more efficient, directed manner. Results from grid sampling could also increase the total amount of fertilizer a farmer uses.

Sample depth

Consistent sampling to a proper depth is crucial for accurate interpretations. Sample depth is dependent upon nutrient mobility. Soil immobile plant nutrients such as phosphorus (P), potassium (K), and zinc (Zn) will accumulate at a soil's surface. Because of their location in the soil profile, and because of fertilizer trials being based on shallow sampling test results, soil sampling for immobile nutrients is suggested by many universities to be between 0-15 to 0-20 cm sampling depths. Kansas State University recommends a 0-15 cm depth, while the

University of Nebraska-Lincoln recommends a 0-20 cm sample for example. Mobile nutrients such as Nitrate (NO_3^-), Sulfate (SO_4^{-2}) and Chloride (Cl^-) will readily move below 0-15 cm and sampling for them is suggested to be as deep as the intended crop roots will grow. Again, the depth recommended, for mobile nutrients will vary, In Kansas this is normally suggested to be 0-60 cm (Liekam et al. 2003a), while in Nebraska it is 90 cm.

Consistency in sampling depth is important when sampling, especially in no tillage systems. Untilled fields will have a steep gradation of P and K from 0 to 20 cm, while tilled fields will have a more homogenous nutrient content with depth (Wolkowski, 2006). Sampling deeper than 0-15 or 20 cm, especially in untilled fields, will cause surface nutrients to be diluted by lower nutrient subsoil. This sample dilution will result in a lower concentration compared to a 0-15 or 20 cm sample, and may result in a higher than needed fertilizer recommendation. Conversely, sampling shallower will result in a higher concentration of nutrients in the sample and can lead to a lower fertilizer recommendation than needed. Not carefully watching sampling depth can result in higher variability and lower precision in the sampling process.

Number of subsamples

Soil is a highly heterogeneous material, and taking enough subsamples or cores to comprise a soil sample is critical to minimize error associated with the sampled value. A field's nutrient varibity on unfertilized or manure applied fields may be minimal, unless different soil types are present (Peck and Soltanpour, 1990). Nutrient applications or grain nutrient removal will begin to increase variability. This can be due to non-uniform applications or practices such as fertilizer banding. Figure 1-4 uses Stein's equation to show how core numbers per composite sample affect soil test value error. As field variability increases, number of cores to have an equal amount of confidence in that sample also increases. This stresses the importance for taking an adequate number of cores per sample. Fertilizer recommendations could be vastly different from one sampling to another if a land owner is not aware of their variability.

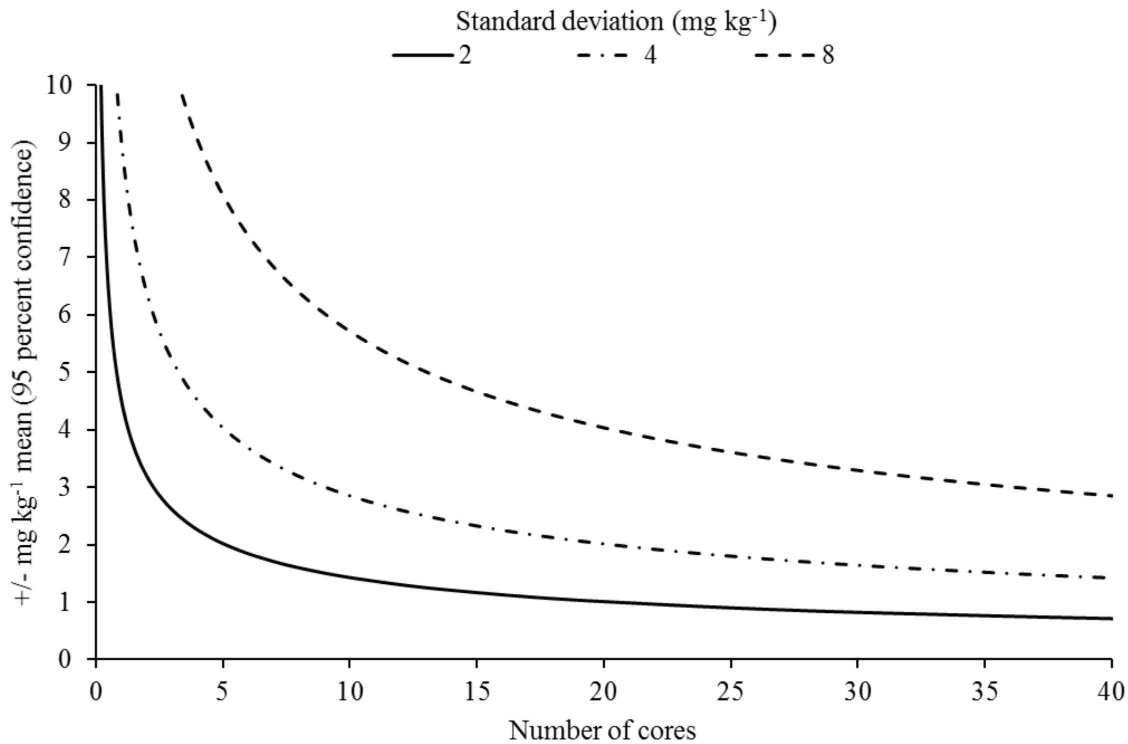

Figure 1-4. Accuracy to 95 percent confidence for soils with a 2, 4, and 8 mg kg^{-1} standard deviation of soil test levels with an average of 16 mg kg^{-1}, as number of cores taken increases.

If a farmer wanted to know the variability or the appropriate amount of samples to take to get a good estimate of the fields true mean they could first take ten to twenty individual cores sampled randomly from the area of interest. These core would not be combined together, but would be tested separately for various nutrients and pH. For each nutrient tested one then calculates the variance, s^2, across the samples (Equation 1.1).

Equation 1-1. Variance:

$s^2 = [\ \sum (\text{individual core value} - \text{average core value})^2] / (\text{number of cores} - 1)$

Next one decides on a tolerance level, or the distance from the mean value, and the confidence level they are willing to accept. The tolerance level is the plus or minus associated with the results and may also be determined to be a percent from the mean. For example if we had a soil test of 20 mg P kg-1 and one wanted an accuracy of plus or minus 10 percent, then the distance from the mean would be 2 mg kg^{-1}. The confidence level is how confident the statistics are that the field true mean will be captured with a set number of cores. If one uses a 95 percent confidence level then, 95 percent of the time the determined number of cores will give a soil test value that falls within the determined tolerance level. The confidence level is entered into Stein's equation as a t-value from a t-table. If one wants confidences of 90, 95 or 99 percent then the t-value entered would be 1.83, 2.26, or 3.25, respectively.

Equation 1-2. Stein's equation:

Number of cores = $[(\text{t-value})^2 \times (\text{sample variance})] / (\text{distance from mean in mg kg}^{-1})^2$

An example would be if a field had a ten core P average of 20 mg kg^{-1}, a variance of 12, wanted a plus or minus of 10 percent, or 2 mg kg^{-1}, and 95 percent confidence.

Number of cores = $[(2.26)^2 \times (12)] / (2^2) = 61 / 4 = 15$ cores.

Sampling in banded and ridge till fields

Proper sampling may be further complicated by fertilizer banding or ridge tilling. Accounting for banded fertilizer applications is important because it creates higher nutrient concentration strips in a field. If one sample a field that has had previous application there is the chance they will either get a majority of cores from a non-banded area, or a banded area. This would cause soil test results to be artificially lower or higher than the actual field average. Fernandez and Schaefer (2012) suggest that when banding has occurred, a sampling strategy of one in row to three out of row samples be taken. Kitchen et. al. (1990) proposed a sampling technique to accurately estimate a field's average. They proposed one takes a random draw of samples and place them in a bucket. While simultaneously drawing random samples, they also suggest taking a sample perpendicular to the banding direction and half the banded distance. This second sample is placed in a separate container. Both the random and random plus half the banded distance samples are analyzed. The sample with the lowest value is assumed to be more accurate.

Adjusting sampling strategies for ridge tilling is important because of soil mixing. Ridge tillage is a system where a soil is built into hills about 15 cm tall, when row crops are 30 to 45 cm tall. The ridges are left through harvest. When the next year's crop is planted the top of the ridge is moved to the valley (Pfost, 1993). This can cause mixing of applied fertilizers in the soil, as well as the question of where in the ridge to sample. Franzen and Chihacek (1998) suggests sampling midway between a ridge's peak and valley.

Testing Soil Properties Which Influence Fertilizer Needs

Once a soil sample has been collected, it is submitted to a lab for testing, primarily a series of chemical tests, with the ultimate goal of obtaining recommendations for the amounts of lime and fertilizers that need to be applied to optimize crop yield. The recommendations provided may differ based on the specific goals and objectives of the person submitting the sample, and the laboratory providing the recommendations. Therefore it is important that the goals of both parties be clearly understood.

Soil nutrients are measured using a series of chemical extracts. Some extracts are used specifically for one nutrient while other may be used on multiple nutrients. A number of extracts have been developed to measure the level of available nutrients in soils. Soil P extracts for example, have differing effectiveness depending on a soils properties. Some of these properties include soil pH, aluminum content, clay content, free carbonates, or the chemical forms of P available in the soil In addition to differences in the amount of P which may be accounted for in a soil based on the extract or test used, how the P content of the extract is measured can also vary the results obtained.

Examples of nutrient specific extracts commonly used are potassium chloride, calcium phosphate, and calcium nitrate for NO_3^-, SO_4^{-2}, and Cl^- , respectively, (Gelderman and Beegle, 1998; Combs et al., 1998; and Gelderman et al.1998). Metals such as zinc (Zn), iron (Fe), manganese, (Mn) and copper (Cu) may be chelated with Diethylenetriaminepentaacetic acid (DTPA) (Whitney, 1998), extracted with weak acids such as 0.1M HCl, or the Mehlich 1 double acid extract (Sims and Johnson, 1991). Calcium (Ca), K, and magnesium (Mg) may be extracted with the Mehlich 1 (Mylavarapu and Miller, 2014) or Mehlich 3 (Zhang et al., 2014) extract in Southeastern U.S. soils, while 1 N ammonium acetate is commonly used on North Central U.S. soils (Warncke and Brown, 2012).

In the case of P many extracts have been designed with various chemical components to extract P from different pools. Mehlich 1 was designed for Southern U.S. soils and uses 0.05 M hydrochloric acid (HCl) and 0.0125 M sulfuric acid (H_2SO_4). The combination of acids extracts P bound to iron (Nelson et al., 1953). Bray-Kurtz P-1 uses 0.03 M ammonium fluoride (NH_4F) and 0.025 M HCl. Bray-Kurtz P-2 increased the concentration of HCl in Bray-Kurtz P-1 to 0.1 M. (Mehlich 1984; Bray and Kurtz, 1945). The combination of HCl and NH4F is used to extract large amounts of P bound to calcium, and iron and aluminum to a lesser extent (Olsen and Sommers, 1982)

Because these extracts are comprised of acids, soils having high amounts of carbonate will neutralize them, resulting in low P extraction. To prevent this, and also keep P bound as $CaPO_4$ out of solution, Olsen (1954) recommended a bicarbonate solution for calcareous soils. Soil P extracts measure different P fractions. Olsen's bicarbonate solution measures Fe bound P, while the Bray-Kurtz P-1 measures P bound to aluminum (Al) and Ca (Fixen and Grove 1990; Maida, 1978). Many laboratories determine a soil's pH before analyzing for P. If a soil was acidic Bray-Kurtz P-1 was used, if alkaline Olsen's bicarbonate extract was used.

Mehlich (1984) designed his Mehlich-3 extract to chelate metals, but it is also successful for extracting P on high pH soils as well. Because of this many laboratories in the North Central US, with both acidic and alkaline soils, prefer to use Mehlich-3 for P extraction today. Mehlich 3 and Bray-Kurtz P-1 were found to extract amounts of P highly correlated to oxalate measured Al and Fe (Michaelson and Ping, 1986; Fixen and Grove 1990).

Method of chemical analysis performed on a soil's extracted solution can give different results. Heckman et al. (2006) show that soil P measured by inductively coupled plasma – optical emission spectroscopy (ICP-OES) is 2.0 to 1.5 higher than colorimetric for Morgan and modified Morgan, respectively. Mallarino (2003) also observed ICP-OES P to be higher than colorimetric P. Mallarino (2003) further suggests that the additional P measured by ICP-OES is not organic P, but states that speculation of what it is exactly is debatable. Colloidal particles with P may be passing through the filter paper and while not reacting with the color reagents when performed colorimetrically, the ICP may be destroying the colloids releasing P to be measured.

Interpretation of Soil Test Results

Interpretation of soil nutrient extract values is normally based on a process of fertilizer correlation and calibration. The amount of fertilizer recommended to apply can differ based on the objectives of the grower, and the philosophy of the organization making the recommendations. Therefore it is important that these objectives be clear and understood by all parties.

Fertilizer Correlation

Nutrient concentrations measured are only as valuable as its supporting fertilizer correlation data. A fertilizer correlation compares yields obtained in unfertilized areas to those obtained in fertilized areas at a given extract nutrient concentrations to determine if a response to fertilizer would be expected. Many sites across multiple years are required to build a reliable correlation. Because actual yields vary by site, relative yield is used. A soil is deemed sufficient in nutrient when fertilizer applications do not increase relative yield. This point is referred to as critical level or concentration. Critical values differ by data analysis method, extract used for the soil test, crop, and previous crop.

Correlation experiments are conducted across a range of years, soils, and crop management systems. To allow pooling data across years and locations, relative yield is used. Relative yield = (yield of observed plot / yield of plot with no limiting nutrients) x 100. Evans (1987) showed that yield and relative yield give similar mathematical responses and critical value from a two year P soybean correlation study. Relative yield has also been shown to be consistent when yields are improved due to a more favorable moisture regime. Melsted and Peck (1977) point to the work by Stanberry et al. (1955) showing that when P rates or water regimes are varied on alfalfa, relative yields remained similar while actual yield increased.

Once a correlation test has been performed, and an extract chosen, the next step is to determine the soil test critical level for that extract. The soil test critical value is the soil test nutrient level, below which, fertilizer applications compensate soil nutrients leading to a yield increase. Crops grown on soil test levels above the critical level have a very low probability of having a yield response to fertilizer. This may be accomplished by using various curve fitting procedures such as the Cate-Nelson, linear plateau, quadratic or exponential models. Cate and Nelson (1971) developed a procedure to divide fertilizer trial data into two soil test levels, where fertilizer did or did not increase yield. Their model begins with drawing a vertical and horizontal line over the data. One then moves the lines to maximize number of points in lower left and upper right quadrants. Cate and Nelson's (1971) approach to Freitas et al (1966) cotton response to soil K is seen in figure 1-2.

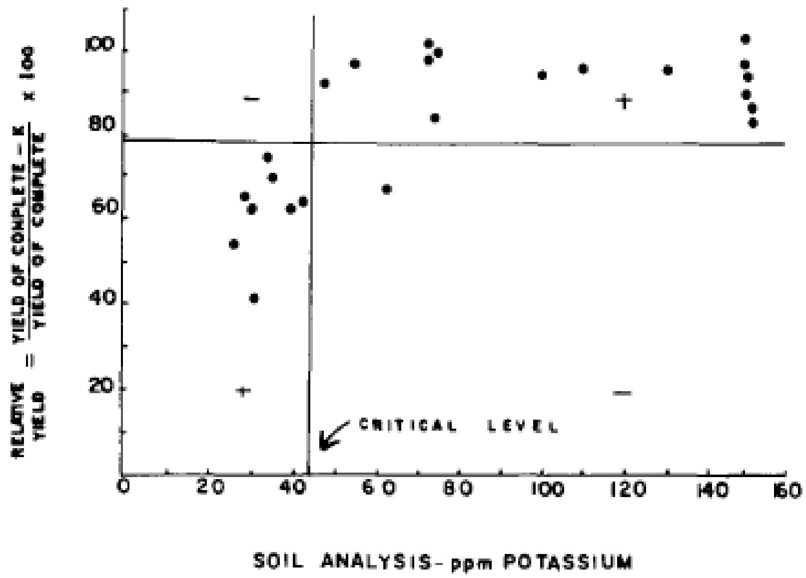

Figure 1-5. Cate and Nelson's (1971) graph and approach to visually determine a critical level on cotton yield and soil potassium from Freitas et al. (1966).

Mallarino and Blackmer (1992) observed that Cate-Nelson gave a slightly lower corn Bray-Kurtz P-1 P critical level, 13 mg kg^{-1}, than when compared to linear plateau, 15 mg kg^{-1}, quadratic, 24 mg kg^{-1}, or exponential 26 mg kg^{-1}. Examination of linear-plateau, quadratic, and exponential P corn and soybean critical levels have also been made by Dodd and Mallarino (2005). Figure 1-3 presents their data which shows linear plateau, quadratic, and exponential model give soybean P critical values of 12.4, 17.8, and 20.8 mg kg^{-1}, respectively. Deciding which of these models is correct may be debatable. One could argue that because one would not fertilize when soil test levels are detrimentally high, a quadratic model is not appropriate. Quadratic models may also inflate critical levels when optimal yields on high testing soils are achieved over a long testing range without detriment to yields. Economics of determined critical values may be best the best judge.

Mallarino and Blackmer (1992) compared economics of different models by creating a scenario based on 25 sites used to determine critical concentrations by Cate-Nelson, linear plateau, quadratic, and exponential. Results from applying 25 Kg P ha^{-1} fertilizer on one hectare sites determined by the various critical levels show that Cate-Nelson, linear plateau, quadratic to

90 percent sufficiency, and exponential to 90 percent sufficiency, gave profits of 421, 320, 26, and 26 US$ ha^{-1}, respectively. Mallarino and Blackmer (1992) point out that highest profit was achieved using a model in which one appropriately moves two lines, instead of complex mathematics.

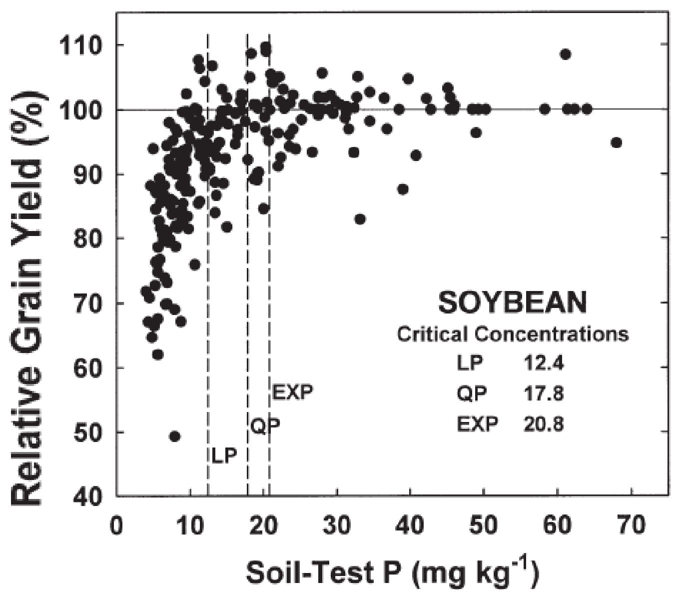

Figure 1-6. Dodd and Mallarino's (2005) graph showing linear-plateau (LP) , quadratic (QP), and exponential (EXP) critical levels for soybean relative yield and soil Bray-Kurtz P-1 soil P levels.

Critical levels will also vary by extract. Mallarino and Blacker (1992) show that corn sufficiency levels for Bray-Kurtz P-1, Mehlich-3 and Olsen are 15, 14 and 6 mg kg^{-1} P, respectively, using linear plateau. Heckman et al. (2006) summarized current critical levels of Northeastern US states and their critical values. New Jersey uses a P critical value of 23 and 36 mg kg-1 for Mehlich-1 and 3 extracts, respectively. Maryland also uses a higher Mehlich-3 critical value than Mehlich-1 of 25 and 50 mg kg^{-1}, respectively.

Different crop nutrient demands affect critical level. Dodd and Mallarino (2005) observed a linear plateau critical value of 15 and 12 mg kg^{-1} Bray-Kurtz P-1 P for corn and soybeans, respectively. Michigan State University (Warnke et al., 2004) provides Bray-Kurtz P-1 P critical levels for corn and soybeans to be 15 mg kg^{-1} with wheat being 25 mg kg^{-1}. Kansas State University has one single P critical value for corn, soybeans, and wheat. This number was arrived at by grouping corn, milo, and wheat data into a single correlation graph, Figure 1-4, (Courtesy of D.B. Mengel). Critical values declared by crop aggregation may be termed "rotational critical values" and are intended to not let soil test values drop below the most limiting crop.

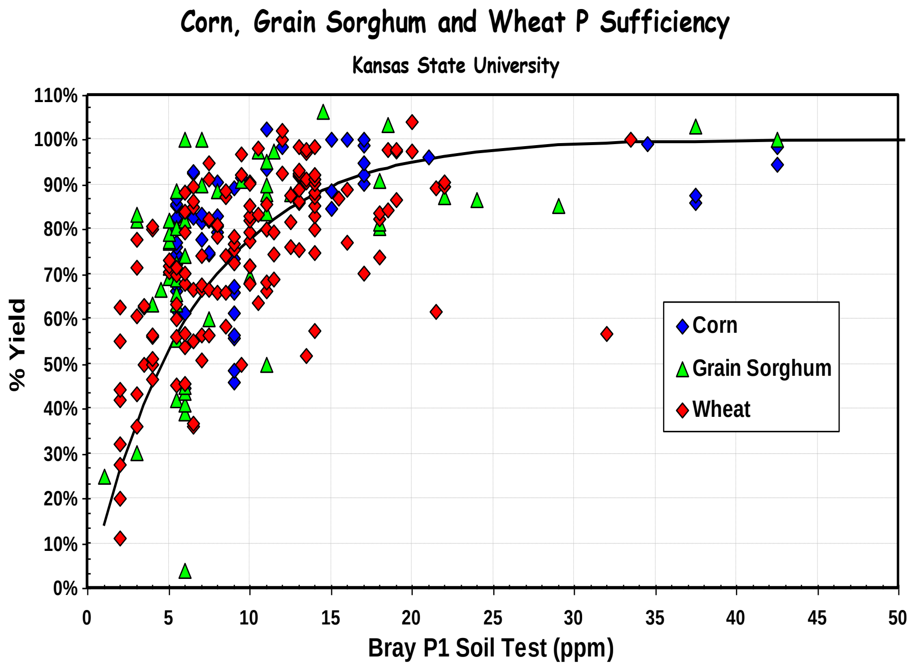

Figure 1-7. Relative yield of corn, grain, sorghum, and wheat to Bray-Kurtz P-1 soil test P values in Kansas, courtesy of D. Mengel.

Previous crop can affect P critical value. Wortmann et al. (2009) observed a Bray-Kurtz P-1 P critical value of 10 mg kg^{-1} for soybeans following corn, and 20 mg kg^{-1} for continuous soybeans.

There are also instances in which fertilizer correlation studies fail to work. Heckman et al. (2006) compared modified-Morgan, Bray-Kurtz P-1, and Mehlich 3 P extracts and their fertilizer correlation to 64 experimental corn sites in Northeast US. Using Cate-Nelson analysis they failed to find a critical value.

Fertilizer Calibration

A calibration study is similar to a correlation in that yields of fertilized and unfertilized area, across a range of soil test values is performed. The main difference is that a calibration study uses multiple rates, while correlation only uses one rate. Using multiple fertilizer rates allows one to observe possible yield increases with increasing fertilizer rates. Once data is collected across multiple soil test values, Barber (1967) suggests to group yield response to fertilizer by similar soil test values. He initially suggests to start with three soil test groups and as more data is added more groups may be formed (Figure 1-5).

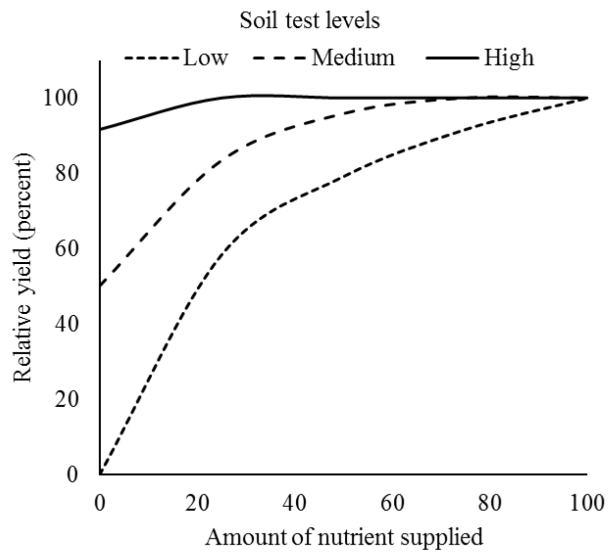

Figure 1-8. Adaption of Barber's (1967) graph to show how to approach developing a calibration between a crop's yield and nutrient applications.

Fertilizer recommendations

Two fertilizer philosophies are sufficiency and build-up and maintain. Sufficiency recommendations are intended to "feed the crop", while build-up and maintain are aimed at "feeding the soil" (Olsen et al., 1987). Comparisons show that sufficiency recommendations are more profitable, and do not deplete soil nutrients. Fertilizer rates applied by farmers may increase with higher yields. Fertilizer placement may increase fertilizer use efficiency causing recommended rates to lower.

Sufficiency

Barber (1967) states that a sufficiency recommendation should be to apply enough fertilizer to economic optimum, and not attempt to build soil nutrient levels. Dahnke and Olsen (1990) break down sufficiency recommendations into three categories, low, medium, and high.

Low testing soils usually receive fertilizer rates above crop removal. Medium recommendations are almost equal to crop removal. High testing soils receive less than crop removal or no fertilizer. An example of sufficiency recommendations may be seen in Kansas State University's P soybean fertilizer recommendations (Table 1-1).

Table A-1. Example of Kansas State University P fertilizer recommendations to 2 Mg ha^{-1} soybeans and the fraction that recommendation is of estimated crop removal.

Soil Test P	**Fertilizer Recommendation†**	**Fraction of Crop Removal‡**
mg kg^{-1}	kg P ha^{-1}	
0-5	29	2.5
5-10	22	1.9
10-15	12	1.0
15-20	7	0.6
20+	0	0.0

† Sufficiency P recommendation for 2 Mg ha^{-1} soybeans

‡ Crop removal assumes 5.8 kg P Mg^{-1}

By applying less than crop removal on high testing fields, nutrient status will eventually decrease. Routine testing of fields is crucial to monitor a nutrients level and adjust fertilizer rates accordingly. If one follows sufficiency rates for an extended period, soil test values will level out. Using Kansas State Universities' sufficiency recommendations, if a farmer fertilizes for and obtains 4 Mg ha^{-1} soybeans and 12.5 Mg ha^{-1} corn, with soybean and corn P removal rates of 5.8 and 2.3 kg P Mg^{-1}, respectively, soils would equilibrate to 7 mg kg^{-1} P. Once soils have equilibrated, a farmer would annually apply fertilizer near crop removal rates. If lower yielding years occur, fertilizer residual will be picked up in following year's soil test, subsequently dropping recommended rates.

Bray (1945) modified Mitscherlich's (1900) equation to estimate fertilizer needs.

Equation 1-3. Mitscherlich's equation.

$$\text{Log}(A - y) = \log A - c_1 b_{1.}$$

Components are defined as A is maximum yield obtain when the interested nutrient is sufficient. Y is percent relative yield, c is proportionality constant, and b is amount of available nutrient in the soil. Bray (1945) points out that A is not meant to represent a “theoretical” maximum yield, as other nutrients may be limiting. Bray (1945) modified Mitscherlich model as he observed different proportionality constants for wheat, corn, and soybeans to be 0.009, 0.015, 0.017, respectively Figure 1-6. Bray (1945) further proposed calculating fertilizer requirements from the Mitscherlich equation by determining how much nutrient is needed for optimum growth, measuring soil nutrient level, and applying fertilizer to make up the difference. A proportionality constant is applied to fertilizer recommendations as all fertilizer applied is not plant absorbed. Bray’s modified Mitscherlich equation then becomes

Equation 1-4. Bray’s (1945) Modified Mitscherlich equation.

$\text{Log}\,(A\text{-}y) = \log A - (c_1 b_1 + cx)$.

Where y is yield goal, x is fertilizer needed, and c is the proportionally constant of applied fertilizer. If one knew c and x, then one could graph the Bray-Mitscherlich equation for a crop of their choice. An example of figuring out how much P to apply to corn is found in Figure 1-9. The relationship Bray observed between soil P and relative corn yield is graphed. If a field tested 30 kg P ha^{-1}, and wanted 98 percent relative yield then they would need to add 20 kg P ha^{-1}. Since fertilizer is not 100 percent absorbed by the plant a correction factor would be needed to account for fertilizer efficiency less than 100 percent.

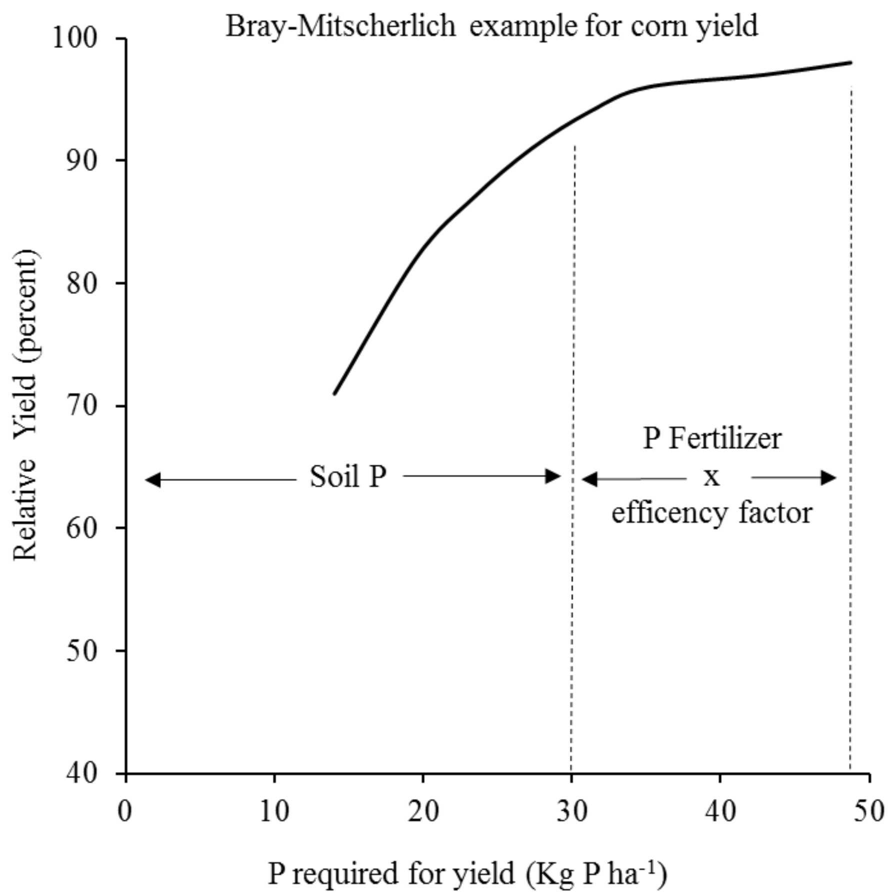

Figure 1-9. Example of how one would estimate a fertilizer recommendation for corn using Bray's (1945) corn relative yield to soil P relationship. Log (A-y) = log A – (c_1b_1 + cx). y is relative yield goal, x is fertilizer needed, b is amount of available nutrient in the soil, and c is the proportionally constant of 0.015 for corn.

Build-up and maintain

Liekam et al. (2003b) state build-up and maintain fertilizer recommendations are not intended to provide maximum profit in any specific year, but to reduce chances of nutrient deficiency. In build-up and maintain strategies soil test levels will eventually equilibrate, just as sufficiency recommendations. The difference is the rate at which fertilizer applications and soil nutrient equilibrate is faster and the nutrient level at which equilibrium is obtained is higher (Dhanke and Olsen, 1990). The build-up and maintain approach takes into consideration, soil nutrient buffering capacity, current soil test level, critical soil test level, years to reach desired level, and crop removal. Once these variables are defined the fertilizer recommendation may be calculated by adding the fertilizer required to build the soil level to or above the critical level plus the crop removal.

In order to build soil nutrients one needs to know a soil's buffering capacity, level to build, and years to build over. A soil's buffering capacity, in this context, is the amount of fertilizer required to raise the nutrient status one mg kg^{-1}. Buffering capacities of P used by Kansas State University is 3.6 kg P (Liekam et al. 2003a), and 4.0 kg P for Purdue, Ohio State, and Michigan State Universities (Vitosh et al. 1995). Wisconsin University differentiates P buffering capacity by soil texture with loamy and sandy soils requiring 3.6 and 2.4 kg P, respectively, to raise soil test levels 1 mg kg^{-1} (Laboski and Peters 2012). Dodd and Mallarino (2005) observed that different soils required different amounts of P fertilizer to raise soil test one mg kg^{-1}, but argues that a direct comparison may not be appropriate because of various initial soil test P levels and P fertilizer rates. Build rates may also be divided over a set number of years to lower yearly cost.

Soil test levels are built to a crop's critical level (Likam et al., 2003; Warncke et al., 2004). Currently critical values for both corn, soybeans, and wheat are not considered equal by many states. When different crops in a rotation have different critical values, recommendations are to build using the most limiting critical value. University of Nebraska-Lincoln has two separate critical values for soybeans and corn at 12 and 25 mg kg^{-1} Bray Kurtz 1.

Maintenance recommendations are used to keep or "maintain" a soil's current soil test P or K level. The recommendations are equal to crop nutrient removal at harvest, with the intention of replacing the amount of nutrient removed from the soil by the crop. Maintenance recommendations are added on to build recommendations, at soil test values below a determined critical level. Once a soil is built to critical concentrations, maintenance fertilizer is only recommended. To maintain the soil's nutrient level one needs to know nutrient grain removal rates. Kansas State University uses 2.6 to 2.9 and 5.8 kg P Mg^{-1} of yield as crop removal rates for 15.5 percent moisture corn, and 13 percent moisture soybeans, respectively (Liekam et al., 2003a). Mallarino et al. (2003) found average P removal rates across 11 site years were 2.9 and 5.7 kg Mg^{-1} for corn and soybeans, respectively. While average removal values are near the published ones used, a wide range in variation was observed by Mallarino et al. (2003) with removal rates of 1.3 to 3.3 and 3.0 to 7.6 kg P Mg^{-1} for corn and soybeans, respectively. Knowledge of this variation is important to farmers using crop removal strategies. To account for removal variability farmers may go through the extra effort of analyzing grain or routinely soil sample and monitor test levels. If soil test levels are increasing then one is applying more fertilizer than needed, while opposite is true for a decreasing trend. Maintenance recommendations are not made when soil test values are very high, or above the critical level, allowing for a soil nutrient "drawdown" period (Warnke et al., 2004).

Maintenance rates may be determined from long term experiments with multiple fertilizer rates and yearly monitoring. Dodd and Mallarino (2005) present a graph in which soil test levels of three P rates are observed over 23 years (Figure 1-10). Soil test levels dropped with no fertilizer application as grain removed P, increased slightly with 22 kg P ha^{-1} yr^{-1}, and greatly with 44 kg P ha^{-1} yr^{-1}. Dodd and Mallarino (2005) suggest that one could interpolate a maintenance P fertilizer rate at which soil test levels would not change over time.

A possible reason why farmers would chose to apply build-up and maintain rates would be to "invest" in fertilizer now, building soil test levels to just above optimum, in order to be able to not apply fertilizer in a future year, without sacrificing yield, when cash may be more strapped and fertilizer costs are higher. In either case, it is important that farmers are told what fertilizer recommendation style they are given. This allows farmers to make monetary decisions based on their cash flow situation.

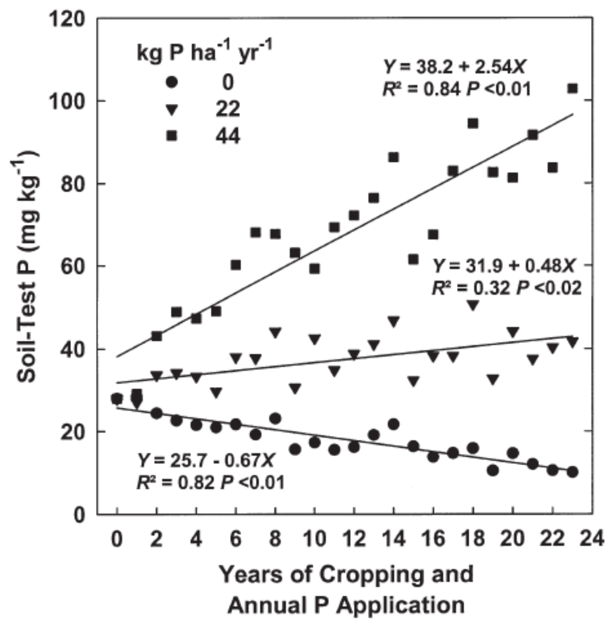

Figure 1-10. Dodd and Mallarino's (2005) graph showing soil test Bray-Kurtz P-1 levels over 23 years with annual P applications of 0, 22, and 44 kg ha^{-1} to a corn-soybean rotation.

The equation used by Leikam et al, 2003a, and Vitosh et al. (1995) to determine a soils build-up and maintain recommendation is:

Equation 1-5. Build and maintain equation by Leikam et al., (2003a):

[(critical soil test level – current soil test level) x soil buffering capacity] / years to build over

+

(Yield x crop removal)

Laboratory recommendation comparisons

Comparison of University of Nebraska – Lincoln's sufficiency and four private laboratory fertilizer recommendations was performed by Olsen (1982) on two Nebraska soils for eleven years and two more for twelve years. A purpose of this study was to compare laboratories using valid fertilizer correlation data, University of Nebraska, and those that did not, the private laboratories. Soil samples were sent to four private laboratories and to University of Nebraska's Extension Service. Corn P recommendations varied widely among laboratories, but were always higher than university recommended sufficiency rates. Yields were not different among treatments at all four sites, resulting in university recommendations being most economical.

Olsen (1982) also points out that while sufficiency recommendations over the length of the study did not result in STP depletion, private laboratory recommendations did build STP above the "sufficiency level". Olsen (1982) contends that as long as soil testing is routinely performed and test values monitored, sufficiency fertilizer recommendations are more economical, and prevent "cash flow" problems. This study was not to discredit all private laboratories, but to stress the importance that with valid correlation and calibration data "conservative" fertilizer recommendations can achieve optimal yield, while conserving natural resources.

Yield Levels

Yield levels have also been considered in fertilizer recommendations as more nutrients are required for higher yields and to replace grain removal (Barber, 1967). Dahke and Olsen (1990) show this for P fertilizer applications to various North Dakota wheat fields with various yield potentials (Figure 1-8).

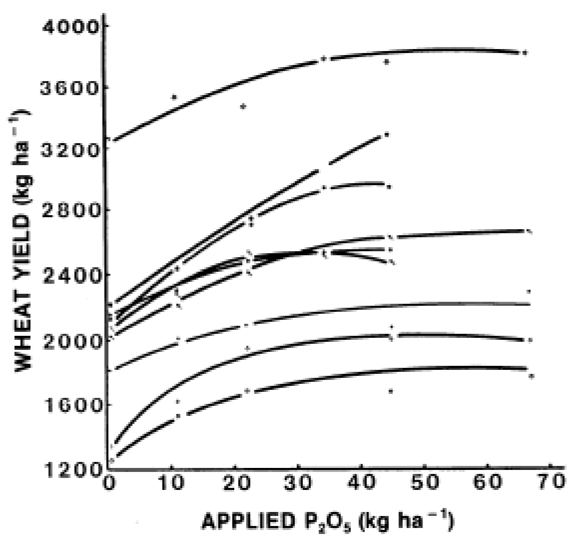

Figure 1-11. Dahnke and Olsen's (1990) graph of various sites ranging in potential wheat yield and yield response to applied P fertilizer at each site.

From this Dahnke and Olsen's (1990) graph they developed a P fertilizer recommendation graph using yield data grouped by soil P test levels (Figure 1-12). From their figure, the difference between 2000 and 4000 kg wheat ha^{-1} at 0-10 mg kg^{-1} soil test P is 13 kg P ha^{-1}. This difference shrinks to 8.7, 6.5 and 0 kg P ha^{-1} for soil test P levels of 11 to 21, 22, to

34 , and 35 + mg kg^{-1}, respectively. North Dakota State, South Dakota State, Kansas State, Purdue, Ohio State, and Michigan State Universities adjust P fertilizer rates based on a field's average yield (Liekam et al., 2003a; Franzen, 2010; Gerwig and Gelderman, 2005; Vitosh et al., 1995; and Warncke et al., 2004).

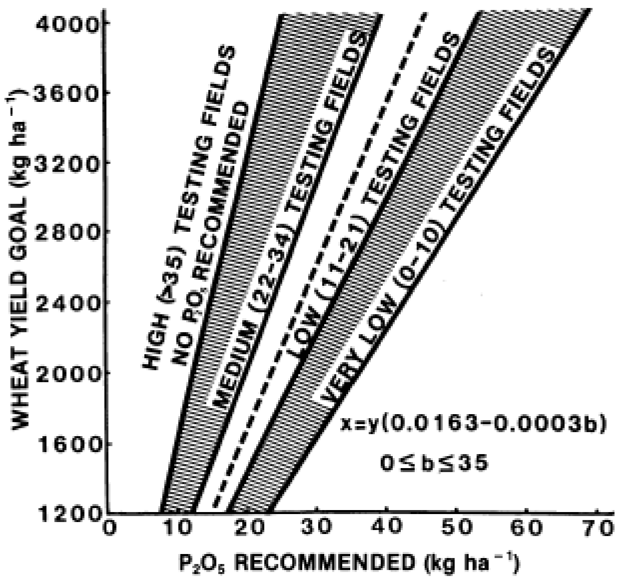

Figure 1-12. Danke and Olsens's (1990) recommended P fertilizer application rates to wheat depending on yield goal and soil test P levels.

University of Nebraska-Lincoln and Iowa State do not adjust P fertilizer rates for increasing soybean or corn yield averages (Ferguson, 2006; Chapiro et al., 2008; and Mallarino et al., 2013). Not adjusting for a field's yield potential may be justified by optimistic farmers. For the most part farmers want to maximize yield or profit, and are optimistic in how much a field will yield. Famers who ask for higher yield goals, than a field may support, will receive higher recommendations from laboratories. Also differences between low and high yielding recommendations for P and K, are not drastically different, especially on medium or high testing soils. Mallarino et al. (2013) state that medium fertilizer recommendations are near removal rates for 11 and 3.7 Mg ha^{-1} of corn and soybeans, respectively, and mention that producers may adjust recommendations based on a field's potential. If fertilizer rates given are too high, then over time soil tests will raise and fertilizer recommendations will lower. This again stresses the importance of routine soil testing and monitoring.

Fertilizer Efficiency

Increased fertilizer efficiency has been observed to lower total amounts of fertilizer required. Chapiro et al. (2008) recommend using half P rate application to corn when banding fertilizer as opposed to broadcast. Borges and Mallarino (2000) observed that banded K produced higher soybean yields, on low testing sites, than broadcast applications. Borges and Mallarino (2000) did not observed a consistent yield difference between banding or broadcast P for soybeans. Peterson et al. (1984) observed that banding efficiency over broadcast decreased as Bray-Kurtz P-1 increased for winter wheat. Welch et al. (1966) shows that banded K is more efficient than broadcast K on increasing corn yield, but that the banding to broadcast efficiency decreases with increases in soil test K.

Estimating Organic Matter

Measuring organic matter (OM) accurately and precisely is important in nitrogen (N) fertilizer recommendations, herbicide application rates, and assessing soil quality. Three common ways to estimate SOM are Walkley-Black (WB), dry combustion (DC), and loss-on-ignition (LOI). Each method measures different soil components, and has its advantages and disadvantages.

Soil OM is important when considering N fertilizer needs, certain soil applied herbicide rates, and soil quality. Mineralization of SOM releases N for crops to use. Rates of mineralization increase with warmer soils. Because of this relationship, N credits given for OM in Kansas State University differ for cool versus warm season crops. Kansas State University estimate that that for each percent SOM 11 and 22 kg N ha^{-1}, respectively, will be provided to cool season crops such as wheat and summer season crops such as corn or grain sorghum (Leikam et al. 2003). Soil texture may also affect mineralization and subsequent N credits. The University of Missouri credits each percent SOM with providing 11, 22, 45 kg N ha^{-1} to summer crops on clayey, loamy, and sandy soils, respectively (Buchholz, 1983). Weber et al. (1987) observed that an increase in SOM increased the amount of alachlor, butralin, metolachlor, Metribuzin, and Trifluralin needed for 80 percent weed control. Sikora and Scott (1996) summarized soil quality articles observing that soil organic matter speeds soil warming (Stott and Martin, 1990), increases water holding capacity, and decreases runoff (Stevenson, 1994).

Methods

Three common methods used to estimate soil C and/or SOM are Walkely-Black, Dry Combustion, and Loss On Ignition. Both the WB and DC methods estimate SOM by measuring soil C and multiplying by an assumed factor of C percentage in OM. Different soil C fractions are measured by WB and DC. One may also estimate OM by a soil's weight difference after ignition using LOI.

Walkley-Black

Easily oxidizable soil C is measured with WB. This method has undergone several changes to lower sample analysis time. These alterations have affected results given and variability. Total C recovery varies on different soils, making a universal conversion factor for WB C measured and OM difficult.

Originally WB weighed a soil sample into a 500 ml Erlenmeyer flask, added 10 mL of 1N potassium chromate, swirled, added 20 mL Sulfuric acid (at least 96%) swirled for 1 min and let sit for 30 min. After sitting, the sample was diluted to 200 mL with water and 10 mL of 85% phosphoric acid, 0.2 g sodium fluoride and 30 drops of diphenylamine indicator. The solution was then titrated with ferrous ammonium sulfate. One can then estimate OM by the equation % OM = 10 (1 – T/S) x 1.34 where T is the mL of ferrous solution required for titration of the sample, S is the mL required for titration of a blank, and 1.34 is a conversion factor assuming 76 percent C recovery (Jackson, 1958).

As potassium chromate reacts with soil C it changes color. A colorimetric analysis procedure for WB was developed by Graham (1948) where solution color was measured at 645 nm. Turbidity caused issues with colorimetric analysis lending Carolan (1948) to propose filtering the sample before colorimetric analysis.

These method differences have been observed to give different values and variability's. Sims and Haby (1971) observed colorimetric SOM = (9.8 x titrated OM) – 0.3559 with an r^2 of 0.98. Schulte observed that 25 samples sent to laboratories using titration and colorimetric procedures and found that titration and colorimetric means were 2.93 and 2.58, respectively. Colorimetric also had a higher variability than titration with standard deviation of 0.59 and 0.16, respectively. Schulte also compared filtering vs allowing a sample to settle and observed a lower mean and standard deviation with filtering.

Easily oxidizable C is not always a constant fraction of total soil C. Walkley and Black (1934) originally reported C recoveries between 60 to 86 percent. Since their work soil texture and horizons have been observed to have different C recoveries. De Vos et al. (2007) observed that soil texture affected recovery as loam, silt loam, loamy sand, sandy loam, and sand had recoveries of 58, 64, 67, 67, and 70 percent, respectively. Soil horizons showed different recoveries an A, E, B, and C horizon had C recoveries of 66, 70, 69, and 66 percent.

Commercial laboratories do not measure C recovery for every sample and adjust accordingly. Assuming that each sample has similar C recovery values may lead to incorrect OM estimations. It has been observed that soil OM is 58 percent C (Nelson and Sommers, 1982). In order to calculate OM from soil C one may multiply soil C by 1.72. If assumed recoveries are wrong, subsequent OM calculations will also be wrong.

There are several interferences that can affect WB reaction. Interferences include chloride, manganese oxides, and ferrous iron. Calcareous soils, while having the ability to neutralize sulfuric acid, do not greatly affect results.

Oxidation of potassium chromate by Cl will artificially lower a WB value (Jackson, 1958). The effects of chloride on WB may be taken into account with a correction factor by subtracting one-twelfth the Cl^- concentration from the soil OM reading. Chloride effects may also be nullified by leaching Cl^- from the soil with an asbestos filter (Jackson, 1958), or precipitating the Cl^- by adding silver sulfate. It is important to note that silver sulfate is effective up to 0.2% Cl^- (Allison, 1960), mercury oxide or mercury sulfate may also be used to prevent the oxidation of Cl^- (Jackson 1958).

Recently formed higher oxides of manganese species can interfere with chromate oxidation of the soil. Addition of 1 N iron sulfate 10 minutes before analysis will allow manganese oxides to oxidize iron sulfate instead of chromate. Excess iron sulfate is back titrated with potassium dichromate and the amount of manganese present may then be calculated (Jackson, 1958).

Ferrous iron can also affect the amount of potassium chromate available to oxidize C and can be accounted for by air drying the soil for one to two days. It is also recommended to not use iron or steel tools to grind the samples, so metallic iron does not add contamination (Walkley, 1947).

Calcareous soils have the potential to neutralize added sulfuric acid. Walkley (1947) showed that this effect is minimal on C recovery. He proposed that the neutralization reaction that occurs may also add heat to the sample compensating for neutralization of the acid. Walkley (1947) added calcium carbonate to several soils to compare their percent recovery in untreated soils and observed a recovery difference of 2 percent at most.

Dry Combustion

Total soil C is also routinely measured by DC. Dry Combustion is considered to be the gold standard for soil C work as it has highest precision of the three methods exmained (Konen et al., 2002). Commercial soil testing laboratories prefer not to use DC as it requires more soil preparation, than the other methods. Soil C is measured by combusting a soil sample so all C present is released as CO_2 where it may be measured. Several conversion factors of soil organic C to OM have been observed.

While this method is more accurate and precise, its preparation is cumbersome for labs and turnaround time unfavorable to farmers. Sample size used with DC is smaller than with WB or LOI. This makes sample homogeneity very important to obtain reproducible results. Samples must be ground to pass a 0.15 mm screen and then weighed to ten-thousandths of a gram (Nelson and Sommers, 1982). Calcareous soils also have inorganic C as carbonates and must be removed with sulfuric (Bremner, 1949) or metaphosphoric acid (Nommik, 1971) for organic C to be measured. When compared to WB or LOI where grinding to 2 mm (Gelderman and Mallarino, 1997), a scooped volume of soil are acceptable (Combs and Nathan, 1997), and not requiring acid treatments (Walkley, 1946; Ben-Dor and banin, 1989), DC requires substantially more preparation time. These factors increase labor cost and time spent per sample, which are not favorable to commercial soil testing labs.

A common instrument used to measure soil C is a LECO TruSpec CN ® (St. Joseph, MI). In this method 0.3500 g of soil is weighed into aluminum foil and twisted shut. The sample is the then dropped into a crucible where it is dry combusted at 950 ^{o}C. Emissions from the soil are converted to the oxide form with alumina oxide pellets. Sulfates are removed with LECO proprietary furnace reagents. Hydrochloric and hydrofluoric acids, are removed with magnesium oxide beads. Evolved CO_2 is measured by using a tungsten filament to emit light through a gold plated chamber where the sample is introduced. Emitted light through the sample is then filtered at 4.2 μm. A radially arranged thermophile detector translates the amount of light passing through the filter to voltage. The more CO_2 that absorbs the 4.2 μm wavelength the lower voltage recorded (LECO, 2009).

Once organic C has been measured OM may be calculated. This is historically estimated by multiplying organic C by the Van Bemmelen factor of 1.72, which assumes 58 percent C in soil OM (Nelson and Sommers, 1982). This factor has been observed to range from 1.9 to 2.2 on surface mineral soils (Broadbent, 1953; De Leenheer et al., 1957, Howard, 1965; and Loftus, 1966).

Loss-on-ignition

LOI measures a soil's weight loss after a series of drying and ignition. Proper drying and ignition times and temperature are crucial. Because LOI does not directly measure soil C or OM, it must be correlated to selected soils for predicting WB or DC OM.

The first step in LOI is drying the sample. This reduces water weight loss during ignition. Hoskins (2002) observed that air dried samples gave higher LOI values than samples dried at 110^{o} C for 2 hours. Higher LOI values were attributed to soil water loss during ignition, causing a greater weight change. In addition to soil water, water attached to gypsum will also cause weight loss during ignition. Schulte and Hopkins (1996) found drying a soil at 150^{o} C for 2 hours will eliminate weight loss during ignition from gypsum. Ben-Dor and Banin, (1989) measured weight loss of six samples each hour at 105^{o} C. They observed at least 80 percent weight loss after 2 hours and maximum weight loss occurred near 4 hours of drying.

Once a sample is dried, its weight is recorded, and then placed in a muffle furnace. Ignition temperature is important as various soil minerals lose weight at high temperatures. Ben-Dor and Banin (1989) list soil minerals and the temperature at which water is released or structural changes occur Table 1-2. Ignition temperatures below 750^{o} C will remove error from calcareous soils. Dor and Banin (1989) found that soil ignition at 400^{o} C for 8 hours did not introduce appreciable amounts of error from carbonates, phyllosilicate minerals, or iron-oxides in low amounts, on arid Isreali soils. Nathan and Combs (1991) suggest that soluble salts may interfere with LOI as hygroscopic water on magnesium sulfate and calcium chloride is released at temperatures great than 150^o C. Nathan and Combs also point out that sodium carbonate and sodium sulfate evolve CO_2 at 270^o C. Salt effects on soil LOI values has not been evaluated.

Table A-1. Temperature at which selected soil minerals lose weight. Modified from Ben-Dor and Banin, 1989.

Mineral	**^oC**
Phyllosilicates	100-200
Gypsum	100-200
Palygorskite	200-300
Halloysite	200-300
Hydrated iron-oxides	250-300
Quartz	400
Feldspar	400
Dehydroxylation of phyllosilicates minerals	450-650
Decarboxylation of carbonate	750-900

Temperatures and length of time a sample is ignited for has ranged from researcher to researcher with various relationships to OM. Schulte et al., (1991) organized past research in an easy to follow table. Tables 1-2 and 1-3 follow their format with alterations and additions. Table 1-2 compares past research relationships of LOI to WB, and Table 1-3 to DC. Ignition temperatures ranged from 360 to 500^o C, all producing high correlations of LOI to WB and DC. Linear relationships, however, differed among studies. Ranges of OM affected linear relatinoships as Storer (1984) found as OM soils from 0 to 52 percent provided a different relationship than when only examining OM from 0 to 10 percent. A minimal relationship difference was observed by Schulte et al. (1991) on various OM ranges. Konen et al. (2002) divided various US regions for LOI to DC comparisons and found that different regions produced different linear relationships, while using a similar LOI procedure. This stresses that before one uses LOI to estimate OM, a correlation study between WB or DC must be performed on soils specific to their region, and their LOI procedure.

Table A-2. Relationship between loss on ignition and Walkley-Black on various regions, with different ignition times, and temperatures.

Reference	Area	Heat (ºC)	Time (hr)	slope	Intercept	R^2	n
Ball, 1964	Wales, UK	375	16	0.79	-0.70	--	67
Davies, 1974	Wales, UK	430	24	0.85	-0.56	0.98	17
Storer, 1984	Canada and 19 States (OM 0 to 52%)	500	4	0.81	-1.47	0.98	215
Storer, 1984	Canada and 19 States (OM <10%)	500	4	0.60	-0.33	0.87	210
Ben-Dor and Banin 1989	Israel	400	8	0.84	-0.32	0.97	91
Schulte et al., 1991	Wisconsin (OM 0-60%)	360	2	0.97	-0.33	0.90	316
Schulte et al., 1991	Wisconsin (OM <10%)	360	2	1.04	-0.36	0.97	356
Rhodes et al., 1981	Sierra Leone	350	7	0.87	-0.16	0.99	10

Table A-3. Relationship between loss on ignition and dry combustion carbon on various regions, with different ignition times, and temperatures.

Reference	Area	Heat (ºC)	Time (hr)	slope	intercept	R^2	n
Goldin 1987	WA, USA; BC, Canada	600	6	0.70	-1.24	0.86	60
Konen et al. 2002	MLRA 75 (NE & KS)	360	2	0.67	-4.54	0.94	21
Konen et al. 2002	MLRA 95 (WI)	360	2	0.57	0.10	0.98	28
Konen et al. 2002	MLRA 108 (IA)	360	2	0.61	0.19	0.97	129
Konen et al. 2002	MLRA 103 (IL)	360	2	0.68	2.87	0.98	68

Lime Recommendations

Testing a soil's pH follow similar ideas as nutrient testing. A soil's pH may be measured a variety of ways, each giving different results. Interpretation of pH results is based on crop yield response to lime. Amount of lime recommended is based on how much is required to reach a target pH to maximize yield, while considering profit. In the case of fertilizer it is crop response data that is required to make fertilizer recommendation, but in lime recommendations it is a combination of soil's response to lime and what the optimal soil target pH is for the intended crop. Buffered chemicals have been design for various soils to estimate lime requirements. A soil's reaction to a buffered chemical may be compared to lime incubation studies, in order to provide a quick lime requirement estimation.

Measuring pH

Measurement of soil pH is a relatively simple idea at first, but has its intricacies. pH is the activity of the protons in solutions and reported as the negative log of proton activity. Important factors to consider when measuring a soil's pH are the ratio of soil to solution, solution's chemical composition, and soil preparation.

Ratios of soil to solution have been described in literature ranging from 1:1 to 1:10 (Jackson, 1958). A saturated paste or "sticky point method" is also described by Jackson (1958), but requires time and attention to each individual sample that is not available in commercial soil testing laboratories. Van Liorop (1990) summarized literature on soil:solution ratios, stating that ratios above saturated paste produce more repeatable values (Chapman et al., 1941; Turner and Nichol, 1958). The 1:1 ratio using 20 g of soil is advocated by Peech, (1956), as it provides enough supernatant for measurement for most soils. As the soil: solution ratio decreases, pH value reported will increase. This is explained by Jackson (1958) as more solution is added, protons are being diluted. Laboratories in the Midwest are recommended to use a 1:1 ratio of 10 g soil to 10 mL solution (Watson and Brown, 1997).

Solution composition used for measurements is also important. Water, 0.01 M Calcium Chloride ($CaCl_2$), or 1 N Potassium Chloride (KCl) may be used each with varying results. Reasons for using salt solutions are that it helps negate any effect of native salts in the soil on pH (Watson and Brown, 1997), keeps a soil flocculated (Jackson, 1958), and the measured value is not affected by probe placement depth above the soil to water interface (Van Lierop, 1990) . Soil pH measured with 0.01 M $CaCl_2$ is often lower than that of water, but a range of differences from 0 to 1 pH unit may be observed (Jackson, 1958). In low pH, low electrical conductivity soils, 1 N KCl produces pH values of about one unit less than water (Van Liorop and Tran 1979, Van Lierop 1990). A comparison of 0.01 M CaCl2 and 1 N KCl was performed by Fotyma et.

al., (1998) which showed 1 N KCl produces a pH measurement 0.5 to 0.7 units higher than 0.01 M $CaCl_2$.

Van Lirop (1990) summarized literature stressing that soil preparation before measurement is also important. Air dried soils have been observed to decrease pH reading by up to 0.6 pH units (Baver, 1927) and Collin et al. (1970) reported that oven drying may decrease pH beyond air drying. Van Lirop (1990) points out that Hesse (1971) observed a pH change of 2 units on a Pakistani soil high in sulfides.

Soil pH Interpretation

Once soil pH is measured it is important to know if it is optimal for crop growth and development. Foth and Ellis (1996) present a chart (Soil Handbook, University of Kentucky, 1970) showing nutrient availability changing over a range of soil pH. In this chart, most nutrients appear to be available between soil pH 5.5 to 7. Iron, Zn, and manganese may become deficient at pHs greater than 7. Toxicities from aluminum may occur at pH less than 5.2. This chart is useful for a general idea of what may be sufficient, deficient, or toxic, but different crops grow optimally at different pHs. Foth and Ellis (1996) present data from a 1938 Ohio agronomic experiment stations study of various crops and their relative yield at pHs from 4.7 to 7.5. In the table, corn, wheat, alfalfa, clover, and soybeans had 100 percent relative yield at pH 6.8. At pH 5.7, corn, wheat, and soybeans produced a relative yield of 83, 89, and 80 percent. Adams and Pearson (1967) observed highest soil pH at which a lime response was seen is 5.7 for corn, 5.8 for cotton, 5.7 for sorghum, 5.7 for peanuts, and 6.0 for soybeans. Oats were not seen to respond to lime at pH less than 5 and coffee at pH less than 4.2. Hill et al. (2009) found a relative yield response of 1 to 3% increase when lime was applied to corn and soybeans with a soil pH under 6.4.

Soil Testing Methods to Estimate Lime Requirements

When a farmer wants to raise the soil pH, the first question asked is target pH for that crop, and the second is how much lime to add. Time consuming methods of estimating a lime recommendation are lab or greenhouse incubations with increasing rates of $Ca(OH)_2$ or $CaCO_3$ and reading their resultant pH. Farmers need a rapid soil test that can be ran by a university or private lab. Woodruff used the concept of adding a chemically buffered solution to a soil and measuring the ability of the soil to lower the solutions pH. This concept has been built upon by other researchers for their regions.

Woodruff

Woodruff (1947) first proposed the concept of using a pH buffered chemical to react with an acid soils and, and measure the ability of the soil to lower the buffered chemical's pH. He explained that the buffered chemical pH change should be proportional to the exchangeable hydrogen in the soil. Woodruff proposed four characteristics a buffered solution should exhibit for estimating lime requirements. First, the buffered solution must react in a linear fashion to the addition of protons, second, the buffer must react in a speedy manner, third, it must be able to predict lime needs over a wide range of soil characteristics, and finally, the buffer reading must be easily translatable to a lime recommendation.

Woodruff comprised his buffer of Para-nitrophenol, calcium acetate, and sodium hydroxide (NaOH). The buffer's pH was then brought to pH 7 with addition of NaOH. When titrated with protons the change in the Woodruff buffer pH is linear between pH 6 and 7.

To estimate lime requirements of soils, Woodruff added KCl and NaOH to soils, in amounts to create a soil pH below and above 7. The unknown number of soils were shaken, and allowed to stand for two hours, and the pH of the two treatments were read. The points were graphed and the amount of base interpolated to bring the soil to pH was calculated. Soil acidity and change in buffer's pH was plotted with a good correlation. Woodruff concluded that the depression in buffered chemicals pH and acidity measured by the NaOH titrations were close enough to reliably predict lime recommendations to a target pH 7.

For a laboratory to make recommendations with Woodruff's buffer requires the use of a "soil limemeter" calibrated to read the change in buffer pH and it reads in 1000's lbs of lime per acre. One might be able to estimate Woodruffs calibration as he did publish a graph of buffer pH change after reacting with soil and the amount of exchangeable acidity in a soil but he does not provide a linear equation for it.

New Woodruff

Research by Mclean et al. (1958) found that the Woodruff's buffer underestimated the lime need of Ohio soils with free aluminum present. Brown and Cisco (1984) published work using a modified Woodruff buffer, later developed but not published by Woodruff, to better account for the free aluminum. To examine the new Woodruff buffer a titration and incubation study were performed. In the titration study 75 Missouri soils were used with a 1:1 soil: 0.01 M $CaCl_2$ pH values from 3.8 to 5.9. Six rates of $Ca(OH)_2$-$CaCl_2$ were added to 10 grams sub samples in 100 mL bottles. Lime rates were determined by measurement of the soil's new Woodruff buffer pH and how much lime is estimated to raise the soil pH to 8.0. Amounts of lime needed to reach pH 8 were divided by five and each increment was added to the soil. After apportioned lime rates were added, the bottle was filled to 80 mL volume with 0.01 M $CaCl_2$ solution. Bottles were shaken for 1 hr, allowed to stand for 24 hrs, shaken for 10 min and then supernatant pH read.

Brown and Cisco (1984) observed that original Woodruff buffer greatly underestimate lime requirements determined by titration with buffer lime requirement = 0.65 x lime rate determined by titration - 0.02 (r^2= 0.95). A better linear relationship was observed between the new Woodruff buffer lime requirements and the bottled titrations, with new Woodruff lime requirement = 1.16 x lime rate determined by titration -0.63 with an r^2 = 0.95.

Brown and Cisco (1984) also used fourteen soils in a greenhouse study where they applied 0, 5, 10, 15, 20, and 15 metric tons lime ha^{-1} assuming 17.8 cm treated depth, to 2.5 kg of soil. Soil was wet to approximate field capacity and sealed for three weeks, soybeans were planted in the pots, harvested 45 days after planting, and soybeans replanted and harvested 45 days after planting. Results from their incubation showed that new Woodruff lime recommendations = 1.16 x lime rate determined by incubation – 1.72 with an r2=0.88. This shows that the titration and incubation lime rate comparisons to the new Woodruff buffer are similar and that the new Woodruff is a better predictor of lime needs than the original buffer. Brown and Cisco, (1984) stress that this buffer should not be used on Ultisols or Oxisols. For laboratories to use the new Woodruff buffer they published the lime requirements formula of: Lime required ($cmol_c\ kg^{-1}$) = 10 x (initial buffer pH at 7 – buffer pH after reacting with the soil)

Shoemaker-McLean-Pratt

Shoemaker, Mclean, and Pratt (SMP) developed a buffer that was less resistant to pH change than Woodruff, and able to react with large amounts of aluminum (Shoemaker et al., 1961). They stated that it has a faster response to soil acidity, making it more accurate than Woodruff. Shoemaker et al. (1961) used fourteen Ohio soils in a seventeen month incubation study with 0, 4, 9, 13, 18, 22, 27, and 38 Mg $CaCO_3$ ha^{-1} applied. Relationship between fourteen incubated samples and lime requirement estimated by SMP is $r^2 = 0.97$. They also examine 100 soils, with lime requirements spanning 8.96 to > 33.6 Mg ha^{-1}, by comparing lime requirements estimated by $Ca(OH)_2$ soil titrations to SMP buffer values. They observed a tight relationship of $r^2 = 0.93$ and recommended Ohio State University Soil Testing Laboratory to adopt the procedure. They do caution that lime requirement error increases as recommended lime rates decrease; because of this Shoemaker et al. (1961) recommend a minimum application of 4.5 kg ha^{-1} for non-sandy soils and 2.2 kg ha^{-1} for sandy soils. They also provide a table of buffer pH values and lime recommendations for a target pH of 6.0, 6.4, and 6.8.

Target pH 6.0 : Lime recommendation (Mg ha^{-1}) = -0.11 (buffer pH) + 6.93
Target pH 6.4 : Lime recommendation (Mg ha^{-1}) = -0.09 (buffer pH) + 6.94
Target pH 6.8 : Lime recommendation (Mg ha^{-1}) = -0.08 (buffer pH) + 6.93

Adams- Evans buffer

Woodruff's buffer is not as effective on soils with low cation exchange capacity (CEC) Adams and Evans (1962). Because of this, Adams and Evans (1962) developed a buffer for the Red-Yellow Podzolic soils (Ultisols) of Alabama which have low CEC and low lime requirements. Adams and Evans (1962) evaluated their buffer by comparing the soil acidity measured by 1 N NH4OAc and soil pH (1:1 soil:water) on 348 soils, with a pH range between 4.1 to 6.5 and CEC between 0.8 to 13.0 meq per 100 g soil. Adams-Evans buffer and measureable soil acidity had a linear relationship of NH4OAc acidity = buffer acidity – 0.33 with a correlation of r=0.94. They explained that this close relationship shows that resultant buffer pH after reaction with soil is a good predictor of exchangeable acidity. They then examined the pH and base unsaturation, which is the subtraction of total bases from CEC. Soil pH was observed to produce a curvilinear relationship to base unsaturation. From these observations Adams and Evans formulated that the amount of acid to be neutralized was equal to (exchangeable acidity/ initial base unsaturation) x desired change in base saturation.

To further support their observations, an incubation study was performed on four Decatur silty clay loams, four Magnolia fine sandy loams, and six Hartselle fine sandy loams each with a range in soil pHs all below 6.1. $Ca(OH)_2$ was added at varying rates and allowed to react for four weeks. The amount of lime required to change the pH to 6.5 in the incubation study was slightly higher than the estimated Adams-Evans lime recommendation. They explained that this may be due to incomplete reaction of the lime after four weeks or that the buffer did not measure all of the soil's acidity. The differences were not great enough on an agronomic scale to prevent the use of the Adams-Evans buffer for lime recommendations on Ultisols. Recommendation made using the Adams-Evans buffer takes into consideration initial soil:water pH as well as the buffer pH. This is a difference from other buffers as they only rely on the buffer pH value for a lime recommendation.

Mehlich

Mehlich (1976) developed a buffered chemical buffer solution to estimate lime requirements on North Carolina mineral and organic soils. He used 61 soils from across geologic provinces of North Carolina, twelve soils from ten Southeastern U.S. states, and eighteen soils from Amazonia, and Columbia. He also tested his buffer against 100 Histosols from North Carolina ranging in organic matter from 20 to 90% by loss on ignition. Mehlich converted buffer pH (BpH) values to buffer pH acidity (AC) values by equation 1-6.

Equation 1-6. Estimate acidity with Mehlich Buffer

$$(AC)\ CaCO_3\ meq / 100\ cm^3\ soil = (6.6 - soil{:}buffer\ pH)/0.25$$

Mehlich found that unbuffered salt exchangeable acidity (ACe) correlated well (r=0.966) to the buffer pH acidity of the 91 mineral soils examined giving a relationship of (ACe) = -0.54 + 0.96 AC. Mehlich gave the range of (ACe) in the soils studied as 29% between 1.9 to 4.9, 53% between 5 to 10, and 18% greater than 10 meq/100 g of soil. Correlation of buffer pH acidity to unbuffered salt exchangeable acidity was R = 0.956 for Histosols with a linear relationship of -7.4 +1.6 AC. Mehlich proposes a lime requirement formula for mineral soils less than 10% OM and a soil pH target of 5.8 as

Equation 1-7. Mehlich's initial equation to estimate lime requirements.

$$meq\ CaCO_3\ 100\ cm^{-3}\ soils = 0.1\,(AC)^2 + (AC)$$

For crops less tolerant of acid soils the lime requirement for 5.8 should be multiplied by 1.5.

Mehlich checked his buffer by examining the yield of barley with increasing rates of applied lime. Maximum relative yield occurred within 0.2 meq $CaCO_3$ / 100 g soil from the calculated lime requirement for the Norfolk, Dyke, and Haynesville soils. On a White Store soil calculated lime requirement was 7.9 meq $CaCO_3$ 100 g^{-1} soil, with maximum observed yield occurring at 12.8 meq 100 cm^{-3}, but optimal yield may have occurred at a rate lower than that.

Mehlich later modified his equation to include initial soil pH and target soil pH (David Hardy, North Carolina Dept. of Ag, personal communication) (Equation 3.1).

Equation 1-8. Mehlich's modified equation to estimate lime requirements.

[(Buffer pH – soil:buffer pH) / 0.25] x [(target pH – soil pH)/(buffer pH – soil pH)] x 2.2 = Mg lime ha^{-1}

Green Buffers

Most buffered chemicals for lime recommendations were created before Environmental Protection Agency regulations on the disposal of hazardous materials. Many of these buffers contain materials now deemed hazardous. This poses a risk to lab personnel as well as great expense in disposal. Many of the hazardous chemicals have been replaced by non-toxic chemicals.

Adams-Evans buffer uses toxic para-nitrophenol which Huluka (2005) successfully replaced with KH_2PO_4. Moore and Sikora (2007) observed variability between the original Adams-Evans and the Huluka formulated Adams-Evans, and wanted to design a better non-hazardous buffer to mimic Adams-Evans. Moore and Sikora (2007) used 222 South Carolina soils from Piedmont, Sandhills, and Coastal Plains. These soils were usually of coarse texture, a CEC below 13 cmolc kg-1 soil, with a 1:1 soil:water pH ranging from 4.6 to 7.1. Moore-Sikora buffer produced a linear relationship with Adams-Evans with Moore-Sikora pH = Adams Evans pH – 0.55 with an r2 of 0.99. This tight relationship made the Moore-Sikora buffer the preferred lime recommendation buffer for Clemson University.

The SMP buffer contains Para-nitrophenol as well as chromium, both now classified as hazardous material. Sikora (2006) formulated a new buffer with "triethanolaomine, imidazole, MES, and acetic acid" to mimic the SMP buffer. To confirm a close relationship between the original SMP and the Sikora mimic, 347 soils sent to the Kentucky soil testing laboratories in

Lexington, KY and Princton, KY, and 87 soils obtained from around the United States and provided by the North American Proficiency Testing (NAPT) program were used. Kentucky soils provided an r^2 between the Sikora and SMP buffers of 0.974 and a linear relationship of Sikora pH = 1.03 x SMP pH – 0.216. Sikora also correlated well over a range of non-Kentucky soils with an r2 of 0.967 and a relationship of Sikora pH = 1.01 x SMP pH -0.035.

A concern of the Sikora buffer was its shelf life. Sikora (2007) points out that chromium in SMP prevents microbial growth allowing for a long shelf life. Sikora (2007) explains that the Mehlich buffer relied on barium to control halophillic bacteria that could feed on C, N, and P present in the Mehlich buffer's chemicals. Sikora's buffer supplies C and N to microbes but not P. Its' lack of P is deemed responsible for a shelf life of 150 days (Sikora, 2007).

Hoskins and Erich (2008) proposed a modification to the Mehlich buffer were barium is replaced with calcium. This replacement is simple because $CaCl_2$ readily dissolves, does not affect the buffers pH, and is mostly used to exchange with protons on the soil surface placing them in soil solution (Hoskins and Erich, 2008). They explain that microbial growth in the modified Mehlich should not be a problem if a new batch is made frequently. Hoskins and Erich (2008) did not publish their comparison of the original Mehlich to their modification but said that they "exhibited identical buffering characteristics."

University of Georgia soil testing laboratory opted to avoid hazardous material in buffers by switching to a new method entirely. Liu et al., (2005) developed a soil test procedure in which the initial soil pH and pH following a one point addition of base would be used to extrapolate how much lime would be needed to reach pH 6.5. Using fourteen soils, initial pH was measured by 1:1 soil:DI Water or 0.01M $CaCl_2$. Additions of either 1 mL or 3 mL of 0.022M $Ca(OH)_2$ were added to soils and the resultant pH measured. From this data they analyzed the accuracy of extrapolating from initial pH and pH after 3 mL of 0.022M $Ca(OH)_2$ is added. Results from the titration were compared to a lab incubation in which 30 g of soil were mixed with 30 mL of water mixed, covered, and allowed to sit for four days. Soil pH was measured each day until completion. Liu et al. (2005) concluded that lime requirements made with 0.01M $CaCl_2$ are better correlated to the three day incubation than DI water. They also concluded that use of initial soil pH and addition of 3 mL of 0.022 M $Ca(OH)_2$, in 0.01M $CaCl_2$ solution extrapolates estimated lime requirement well when compared to multiple additions of base. One assumption of this test is that a three day saturated incubation with $Ca(OH)_2$ was long enough to react with all the soil acidity.

The titration method has been observed by Godsey et al., (2007) to underestimate lime requirements on Kansas soils. Godey et al., (2007) observed that the linear relationship between a 60 day incubation and a $Ca(OH)_2$ titration lime requirement estimation to pH 6.8 correlates well, $r^2 = 0.95$, but that titration estimates only 45 percent of the observe lime requirement by incubation. Godsey et al., (2007) speculate that the different results between the studies may be due to the fact that the soils studied are different. Liu et al., (2007) studied Georgia soils with lower CEC and clay contents than Kansas soils. Godsey et al., (2007) also speculate that the different incubation times, 3 days for Liu et al., (2005) and 60 days for Godsey et al., (2007), may have played a role.

Summary

Fertilizer recommendations are based upon proper soil samples, extracts, correlation/calibration data, yield goal, and application method. Taking at least ten cores per sample is crucial for accurately representing an area of concern. Sampling to the correct depth for mobile and immobile nutrient prevents diluting of nutrients or underestimation of those available. Understanding the relationship between extracted nutrients and yield is important for proper interpretation. Critical values will differ by crop, extract, and by method of calculation. Two common ways laboratories provide fertilizer recommendations are sufficiency or build-maintain. Sufficiency recommendations are intended to optimize yield in the current year with low fertilizer cost. Build-maintain recommendations rely on soil nutrient buffering capacity, crop removal, and critical value to estimate how much fertilizer is needed to build a soil's nutrient level. Higher yield goals tend to receive higher fertilizer recommendations. For corn and wheat, banding fertilizer has been shown to require lower total applications compared to broadcasting.

Mineralization of N makes OM content a valuable factor in N fertilizer recommendations. The three ways commercial laboratories may estimate OM are; WB, DC, and LOI. Walkley-Black measures EOC and assumes a C recovery factor and C fraction in OM. The C recovery fraction will vary from sample to sample. The most accurate assessment of TC is by DC. To obtain TOC one must pre-treat calcareous samples with acid before analysis. Estimation of OM from DC is achieved by assuming a percent C in OM. Loss on ignition indirectly measures OM by measuring weight loss after drying and igniting the sample. Laboratories prefer LOI as it does not have hazardous materials, like WB, and is faster than DC. Values obtained by LOI must be correlated to WB or DC values for soils in a similar region to translate between the two.

Soil pH is one of the most important aspects to soil fertility. Different crops require different target pHs. Soils will also differ in their ability to resist pH change with liming. Estimating how much lime is required to raise a soil's pH may be quickly done with buffered chemicals. These chemicals have been developed for various soils and regions. Modifications have been made to many of the original buffered chemicals because they contained hazardous materials. Buffers are evaluated using laboratory incubation studies in which various amount of lime are added to soils and the amount of lime require to reach a desired pH correlated to the soil's BpH value. The lower a soil's BpH the more lime required to raise its pH.

The KSU Soil Testing Laboratory routinely suggest farms to analyze 0-15 cm samples for pH, P, and K for all intended crops. It is suggested to test zinc on fields going to soybean, corn, or grain-sorghum. For non-legume row crops it is suggested to test SOM, to estimate how much N may come from SOM mineralization. We suggest a 0-15 cm sample depth for P, K, and Zn because they are relatively immobile nutrients and a fair amount of their availability in the soil may be captured in the surface. It is also assumed that most of the SOM mineralization will occur in the top 15 cm. If a farmer does not choose to test for SOM, the laboratory will use the Kansas SOM average of 2 percent in the N fertilizer equation. A 0-15 cm sample depth is not entirely appropriate for pH in no-tillage systems because the lime will not work its way that deep. A 0-7 cm sample would be more appropriate in this case, but farmers may be resistant to having to taking and keeping track of three samples, a 0-7, 0-15, and 0-60 cm, for the same area. The results from a 0-7 and 0-15 cm pH may also not be different enough to warrant explicitly asking for a 0-7 cm sample on no-tillage fields.

It is recommended to take a 0-60 cm sample for nitrate, on non-legume row crops, sulfate, and chloride. Nitrate is the most common subsoil nutrient tested for as N is usually the most liming nutrient. If a farmer does not chose to test for sub-soil nitrate, the laboratory will use default value in the N fertilizer calculation of 34 kg N ha^{-1} in the soil profile. This value is probably lower than the average residual amount of nitrate in Kansas, but it is better from a recommendation stand point to slightly overestimate N needs than to under estimate. This is because farmers want to ensure that all nutrients are not limiting and they will remember a laboratory that limited their yield and probably not use them in the future. Sulfur deficiencies have been increasingly observed in Kansas as sulfur from rainfall deposition has dropped with cleaner emissions standards. Chloride is recommended only for wheat, corn, and grain sorghum.

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Chapter 2 - Methods to estimate soil organic matter: Walkley-Black, loss on ignition, and dry combustion

Abstract

Soil organic matter (SOM) measurements are important for nitrogen (N) fertilizer recommendations, and herbicide application rates. Soil testing laboratories may estimate SOM by measuring easily oxidizable carbon (EOC) with Walkley-Black (WB), total organic C (OC) with dry combustion (DC), or weight loss after ignition with loss-on-ignition (LOI). Objectives of this study were to compare WB, DC SOM, and LOI estimates for Kansas soils and evaluate method variances. Methods were compared using 98 soil samples from Eastern Kansas selected for a range of SOM, texture, and pH. Comparison of WB with sample scooping versus weighing was also performed. Regression of gravimetric WB to LOI produces a linear equation WB = 0.89 (LOI) - 0.23 with an r^2 of 0.97. Relationship between LOI and DC OC give a linear equation of LOI = 1.69 (DC OC) + 0.39 with an r^2 of 0.98. Gravimetric WB lends a regression to DC OC of WB = 1.53 (DC OC) + 0.08, with an r^2 of 0.98. Standard deviations were highest with volumetric WB, followed by LOI, gravimetric WB, and DC (0.24, 0.17, 0.13, and 0.04 percent, respectively). Recovery of total C using WB ranged from 55 to 80 percent, averaging 76 percent.

Introduction

Measuring soil organic matter (SOM) accurately and precisely is important in nitrogen (N) fertilizer recommendations, herbicide application rates, and assessing soil quality. The University of Missouri credits SOM with providing 11, 22, and 45 kg N ha^{-1} to summer crops on clayey, loamy, and sandy soils, respectively (Buchholz, 1983). Kansas State University and Colorado State University estimate that that for each percent SOM, 22 and 16 kg N ha^{-1}, respectively, will be provided to summer crops (Leikam et al., 2003; Davis and Westfall, 2009). Weber et al. (1987) observed that an increase in OM increased the amount of alachlor, butralin, metolachlor, metribuzin, and trifluralin needed for 80 percent weed control. Sikora and Scott

(1996) noted that SOM speeds soil warming (Stott and Martin, 1990), increases water holding capacity, and decreases runoff (Stevenson, 1994). Estimation of SOM may be made by Walkley-Black (WB), loss-on-ignition (LOI), or dry combustion (DC). These methods estimate OM differently, and have distinct advantages and disadvantages.

Dry combustion measures total C (TC). Soil is combusted at high temperatures releasing CO_2 where its concentration is measured with an infrared cell. While this method is more accurate and precise, than WB and LOI, its results turnaround time and cost are prohibitive to farmers. Small quantities of sample are needed for dry combustion instruments which require samples to be ground to a fine powder using a mortar and pestle, ensuring a homogeneous sample. Exact weights must also be recorded to calculate total C. Because TC is measured, calcareous soils must be treated with acid before analysis to remove carbonate C, leaving organic C (OC). Once OC percent is measured it is multiplied by 1.72 (Van Bemmelen factor) to estimate SOM percent (Nelson and Sommers, 1975). These steps increase labor cost and time spent per sample, which are not favorable to commercial soil testing laboratories.

Easily oxidized carbon (EOC) is measure by WB. Analyzing SOM by WB presents concerns for soil testing laboratories because of hazardous waste generation and disposal, result variability, and fluctuation in TC recovery. Walkley and Black (1934) modified Degtareff's (1930) method of measuring EOC by only using potassium dichromate and sulfuric acid. They also adopted Schollenbereger's (1926) method of back titrating with ferrous ammonium sulfate to calculate how much C was oxidized. These alterations decrease time required per sample but have increased result variability (Combs and Nathan, 1998). Graham (1948) found that chromic acid changes color proportionally to the amount left unreacted and may be measured with a spectrometer. Combs and Nathan (1998) report that the standard deviation of 25 samples increased from 0.16 percent when read by titration to 0.65 percent when read colorimetrically. To speed up turnaround time for farmer samples many soil testing laboratories rely on scooping volumes of soil as prescribed by Peck (1998). Scooping sample weight can produce inconsistent results. Combs and Nathan (1998) report that when read colorimetrically, weighing samples gives a standard deviation of 0.53 percent compared to scooping of 0.70 percent . To reduce variability among replications, samples may be weighed and reported on a gravimetric basis. A ground soil's volume weight, or sample density, may be used to convert a scooped soil's result to a weighed (Mehlich, 1973).

Recovery percentages of total OC vary when using WB. Walkley-Black (1934) did not adopt Schollenberger's (1926) procedure of heating the sample to 175^{o}C. Without external heat applied WB has been observed to recover 44 to 92 percent of soil C (Nelson and Sommers, 1975; Bremmer and Jenkins, 1960). Walkley-Black (1934) observed C recoveries ranging from 60 to 80 percent, with an average of 76 percent suggesting a correction factor of 1.32 to obtain total soil OC. Once total OC has been calculated OM may be estimated by multiplying total OC by the Van Bemmelen factor of 1.72 (Nelson and Sommers, 1982) (Equation 2-1). This conversion factor has been observed to range from 1.9 to 2.2 on surface mineral soils (Broadbent, 1953; De Leenheer et al., 1957, Howard, 1965; and Loftus, 1966).

Equation 2-1. Estimation of SOM by WB.

Walkely-Black percent organic matter = (easily oxidizable carbon percent x 1.32) x 1.72 x100

Loss-on-ignition measures organic matter by measuring weight before and after low temperature combustion (Equation 2-2). Advantages of LOI for commercial soil testing laboratories are quick turnaround time, affordability, and lack of hazardous waste. Analysis by LOI does not directly measure OC or EOC, but has been shown to be highly correlated to both DC (Table 2-1) and WB (Table 2-2).

Equation 2-2. LOI organic matter equation.

$$\text{LOI Percent Organic Matter} = \frac{[(\text{Weight oven dried soil}) - (\text{weight ignited soil})]}{(\text{Weight oven dried soil})} \times 100$$

Table A-1. Past studies heating times, and temperatures of loss on ignition, and its relationship to dry combustion.

Reference	Area	Temperature (ºC)	Time (hr)	R^2	n
Goldin (1987)	WA, USA; BC, Canada	600	6	0.86	60
Konen et al. (2002)	MLRA 75 (NE & KS)	360	2	0.94	21
Konen et al. (2002)	MLRA 95 (WI)	360	2	0.98	28
Konen et al. (2002)	MLRA 108 (IA)	360	2	0.97	129
Konen et al. (2002)	MLRA 103 (IL)	360	2	0.98	68

Table A-2. Past studies heating times, and temperatures of loss on ignition, and its relationship to Walkley-Black.

Reference	Area	Temperature (ºC)	Time (hr)	R^2	n
Ball (1964)	Wales, UK	375	16	--	67
Davies (1974)	Wales, UK	430	24	0.98	17
Rhodes et al. (1981)	Sierra Leone	350	7	0.99	10
Storer (1984)	Canada and 19 States	500	4	0.98	215
Storer (1984)	Canada and 19 States	500	4	0.87	210
Ben-Dor and Banin (1989)	Israel	400	8	0.97	91
Schulte et al. (1991)	Wisconsin	360	2	0.9	316
Schulte et al. (1991)	Wisconsin	360	2	0.97	356

Ben-Dor and Banin (1989) point out that free and structural water in soil minerals may interfere with LOI results as soil minerals release water at certain temperatures (Table 2-3). Because of this, samples are dried before ignition at 105 to 150^{o} C, and then weighed, before ignition. Ignition temperature is also capped at below 450^{o} C to prevent dehydroxylation of phyllosilicates and decarboxylation of carbonates (Ben-Dor and Banin, 1989).

Table A-3. Temperature at which selected soil minerals lose weight. Modified from Ben-Dor and Banin, (1989).

Mineral	^{o}C
Phyllosilicates	100-200
Gypsum	100-200
Palygorskite	200-300
Halloysite	200-300
Hydrated iron-oxides	250-300
Quartz	400
Feldspar	400
Dehydroxylation of phyllosilicates minerals	450-650
Decarboxylation of carbonate	750-900

Studying method variability will assist in knowing tolerance for error when making N fertilizer recommendations or plotting C and SOM trends over time. Objectives of this study are to compare DC, WB, and LOI for estimating SOM, and evaluate method variability.

Methods and Materials

Soils

Ninety-eight soils from eastern Kansas were selected for a range in SOM, texture, and pH. Samples were dried at 60^{o} C for 48 hours, ground (Dino grinder ® Florida) and sieved with a 2 mm screen. Soil pH was measured using 8.5 cm^{3} of soil in 10 mL water, in order to identify soils with possible carbonates. Samples were analyzed in three independent repetitions using DC, LOI and WB.

Walkley-Black

Samples were treated using the heat of dilution WB procedure by Combs and Nathan (1998). A 0.85 cm^3 scoop or weighed 1 g of soil was place in a 200 mL glass flask, 10 mL of potassium dichromate (0.17 M KCr_2O_7) and 20 mL of concentrated sulfuric acid (96 % wt/wt) were added. Samples were swirled to ensure mixing and let sit for 30 minutes. Flasks were then filled to 185 mL with deionized water, swirled, and let sit for 20 minutes. Samples were swirled again before filtering (Ahlstrom 642). Sample absorbance was read on a Brinkmann 910 colorimeter at 620 nm. A standard curve of 0, 0.5, 1, 1.5, and 2 g of a known 2 percent SOM soil (North American Proficiency Testing NAPT sample 2006-108) was used. Eighty of the 98 samples were also subjected to an EOC standard curve constructed from 0, 0.05, 0.1, 0.2, 0.4 and 0.6 g of table sugar. Carbon recovery from WB with the soil standard curve was estimated using the assumptions of 76% recovery and 58% C in SOM. Calculated carbon measured by WB was compared to DC OC percent. Scoop volume weight was measured as prescribed by Mehlich (1973).

Dry Combustion

Samples were mortar and pestled, and weighed to 0.35 g. The weight was recorded to ten thousandths of a gram. In nickel foil, samples were loaded into a carousel for analysis on a LECO TruSpec ® CN (St. Joseph, MI). Before sample analysis at least five blanks are analyzed, machine adjusted for atmospheric conditions, three check standards were analyzed and a one point calibration for drift was performed. Samples were combusted for 8 min at 950^{o} C. Samples having a pH > 7.1 were analyzed with and without 1 M phosphoric acid additions to examine carbonate C effects. Phosphoric acid was added drop wise to weighed samples in nickel foil, until no effervesce was visible.

Loss-on-Ignition

Ten mL Pyrex beakers were placed on an analytical balance (Precisa 180A) and the mass recorded to ten thousandths of a gram. One gram of soil was placed into a beaker. Samples were then placed in an oven (Fisher Scientific Isotemp) at 150^{o} C for 2 hours. After cooling for 15 minutes, they were weighed. Soils were placed in a preheated muffle furnace (Thermolyne type

30400) at 400^o C for 3 hours. Samples were cooled to 150^o C for 1 hour, allowed to cool out of the oven for 15 minutes, and their final weight was recorded.

Oven variability was examined by placing samples from one soil across a holding tray, 4 samples in front, 4 samples in the middle and 4 samples in the back. 4 samples were also placed on the left, center, and right of the tray. Three trays were used on the bottom, middle, and top shelves of the muffle furnace. Replications were ran once a day for four separate days, as one sample can only be placed in a specific part of the furnace for each run. The drying time for this evaluation was 105^{o}C instead of 150^{o}C. The weighing time was not exactly 15 minutes after being removed from the cooling oven but was approximately 15 minutes once removed. PROC GLM in SAS (Cary, NC) was used to calculate ANOVA results for individual variables and their interactions.

Effects of atmospheric moisture on samples once removed from an oven at 150^{o}C were examined with five samples and an empty beaker. The weight of the samples and empty beaker was measure, 1, 2, 4, 8, 16, 32, and 64 minutes after removal.

Repetitions for each soil were averaged by method and compared with paired T-Test and PROC REG using SAS 9.2 (Cary, NC). The mean standard deviation for the methods was calculated by first finding each sample's standard deviation from their three replications and then averaging all the samples standard deviation.

Results and discussion

Comparisons

Relationship between LOI and DC TC provides an r^2 of 0.96 (Figure 2-1) but improves, when soils with a pH > 7.1 are acid treated, to 0.98 (Figure 2-2). This supports the statement by Ben-Dor and Banin (1989) that a 400^o C burn during LOI does not decarboxylate carbonate C from soils with free carbonate. It also stresses that LOI may be used as a proxy for estimating soil OC, not TC, on Kansas soils.

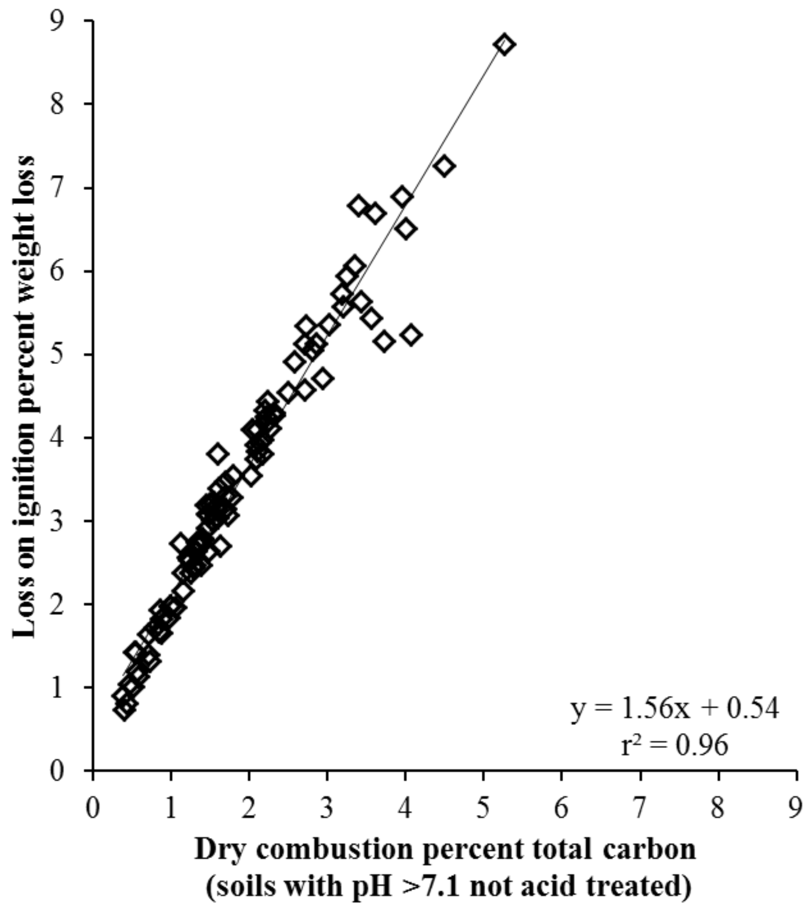

Figure 2-1. Comparison of sample mean values, from three replications, of 98 soils for loss on ignition percent weight loss to dry combustion percent C when soils with a pH >7.1 were not acid treated.

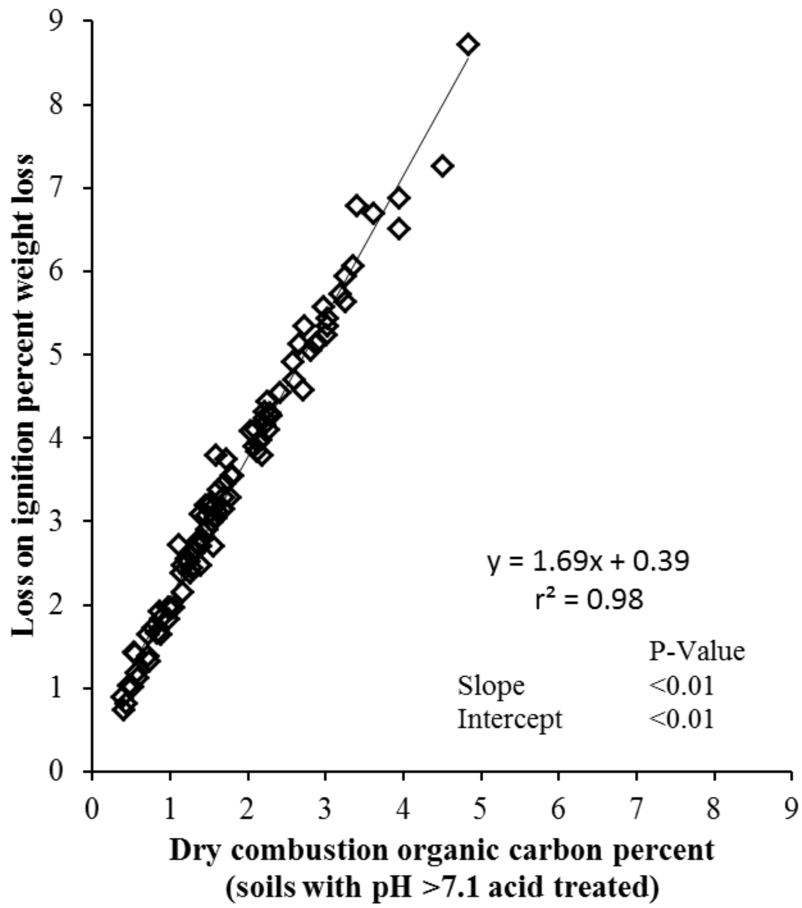

Figure 2-2. Comparison of sample mean values, from three replications, of 98 soils for loss on ignition percent weight loss to dry combustion percent C when soils with a pH >7.1 were acid treated.

Table A-1. Predicted dry combustion organic carbon (DC OC) values and Walkley-Black (WB) percent soil organic matter (SOM) at specific loss on ignition (LOI) values.

LOI value percent weight loss	DC OC	WB SOM
	----------- predicted value ------------	
	---------------- Percent ----------------	
1	0.39	0.66
2	0.97	1.56
3	1.55	2.45
4	2.13	3.35
5	2.71	4.24
6	3.29	5.14
7	3.87	6.03

Linear regression between LOI and DC OC provided a strong r^2 of 0.98, and relationship of LOI percent = (DC OC percent x 1.69) +0.39 (Figure 2-2). The relationship between LOI and WB SOM percent provided a strong r^2 of 0.97 and linear relationship of WB SOM percent = (0.89 x LOI percent) – 0.23 (Figure 2-3). Estimated DC OC and WB SOM percent values from LOI are presented in table 2-4, using the linear relationships observed. As OC percent fractions of SOM have been observed to vary from 1.72 to 2.2 (Nelson and Sommers, 1982) one will not know which method gives the best actual SOM percent estimate unless SOM analysis is directly is performed on these soils.

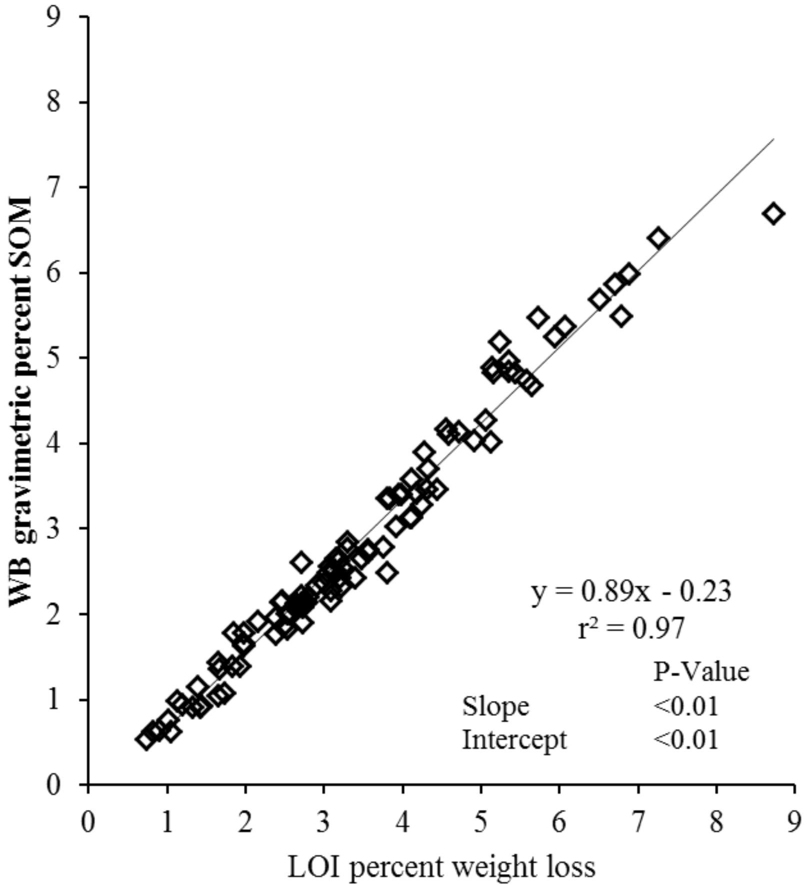

Figure 2-3. Comparison of sample mean values, from three replications, of 98 soils for Walkley-Black percent SOM (wt/wt) to loss on ignition percent weight loss.

While reliable comparisons from one method to the other allow conversions from one test value to another, the understanding of how that value came to be is also important. When looking at the average values given from the 98 samples among the methods it is clear that farmers and researcher who receive values from a laboratory need to know how that value was obtained. Figure 2-5 shows how methods result in different reported values.

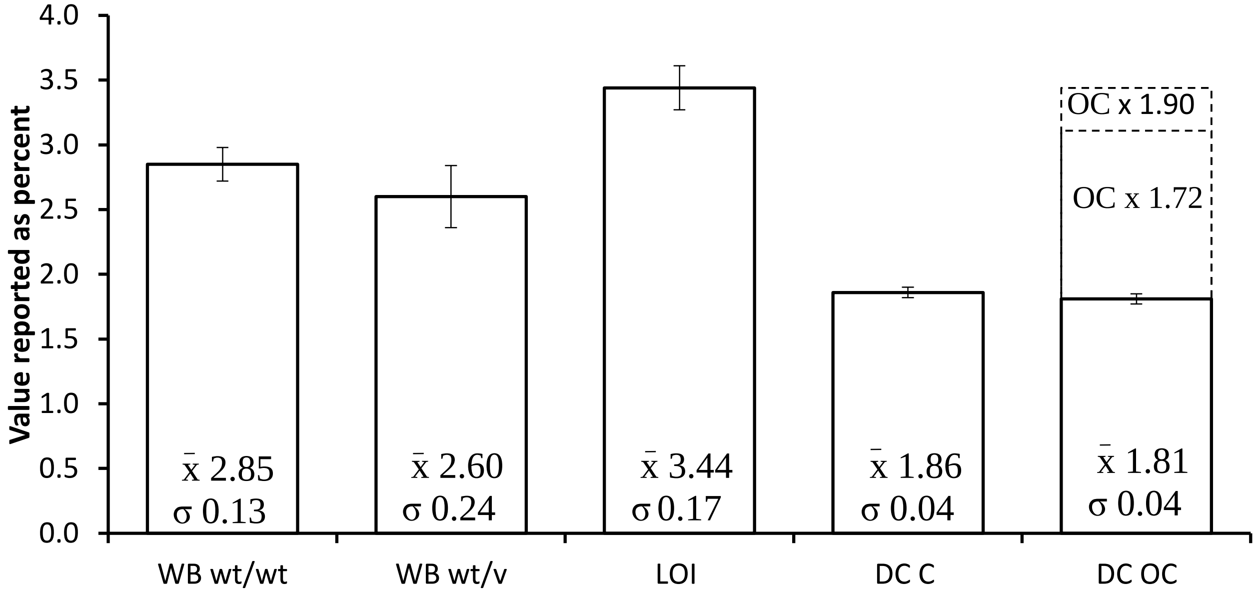

Figure 2-4. Average of three repetitions from 79 Kansas soils using Walkley-Black (WB) weighed and scooped loss on ignition (LOI), dry combustion total carbon (DC C), and DC organic C (DC OC). Standard deviation presented is the average standard deviation of the 79 samples by method. Dashed lines show DC OC multiplied by 1.72 and 1.90.

On a gravimetric basis, WB gives lower OM estimations than LOI (P-value value < 0.001) and DC OC x 1.72 (P-value < 0.001). Gravimetric WB being lower than DC OC x 1.72 may be explained by varying rates of C recovery from Walkley and Black's (1934) suggested 76 percent. The North American Proficiency Testing (NAPT) reference soil (year 2006 - soil #108) which constructed the standard curve had a C recovery rate of 70% which could artificially lower the OM values. Measured soil C was reverse calculated from WB OM percent using assumptions of 76 percent C recovery (Walkley and Black, 1934) and 58 percent C in soil OM (Nelson and Sommers, 1982). Once calculated, percent C recovery ranged from 55 to 80, with an average of 68 (Figure 2-6).

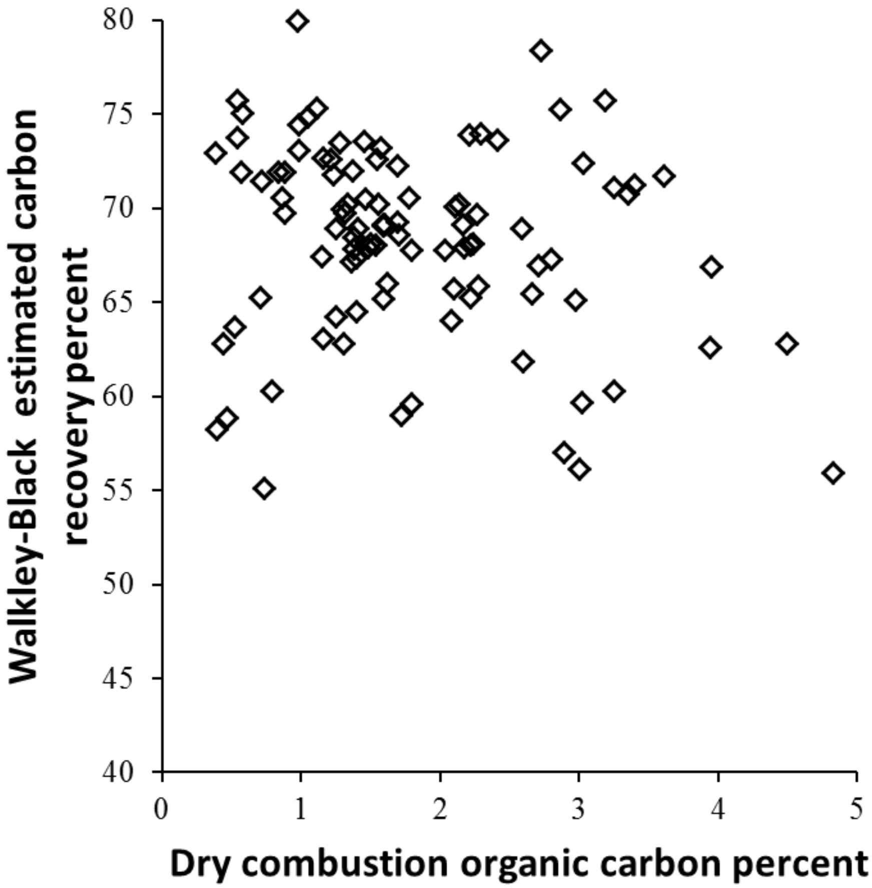

Figure 2-5. Calculated Walkley-Black (WB) recovery percent from 98 Kansas soils. Recovery percent was calculated from dividing reported WB soil organic matter percent, using NAPT reference soil as standard curve, by assumed carbon (C) recovery of 76 percent and dividing by assuming soil organic matter is 58 percent C.

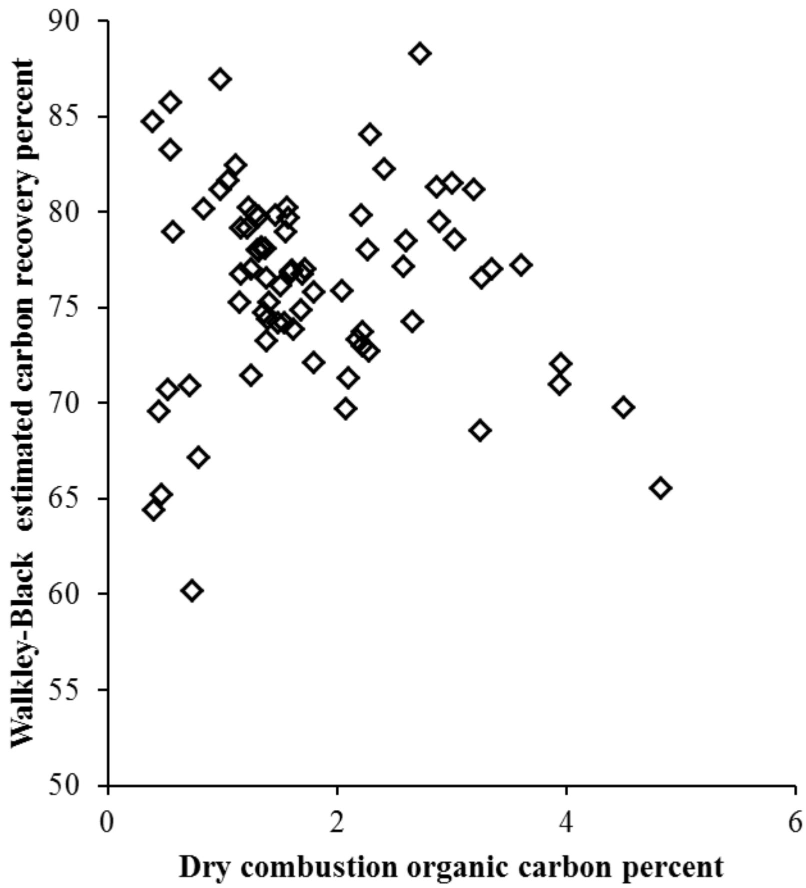

Figure 2-6. Measured Walkley-Black (WB) recovery carbon (C) percent from 79 Kansas soils. Recovery percent was arrived from measuring easily oxidizable C by a sugar standard curve and diving by dry combustion organic C.

When a sugar standard curve is applied to 79 of the 97 soils used, and recovery calculated by EOC divided by DC total C, recovery matches what was originally observed by Walkley and Black (1934) (Figure 2-7). Average WB EOC of the 79 samples was 1.37 percent by weight. When multiplied by (1 / 0.76) total OC is estimated to be 1.80 percent, which is the same average given by DC OC (Figure 2-8).

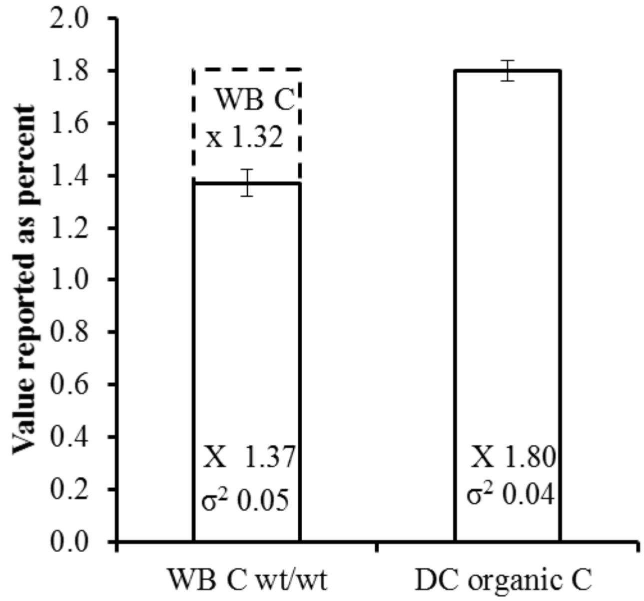

Figure 2-7. Average of three repetitions from 79 Kansas soils using Walkley-Black easily oxidizable carbon percent to dry combustion organic carbon. Standard deviation presented is the average standard deviation of the 79 samples by method. Dashed lines show Walkley-Black EOC multiplied by a total carbon recovery rate of 76 percent to achieve total organic carbon.

Scooping a sample for WB produces a lower value and a higher replication standard deviation than when weighing. Lower reported SOM percent is attributed to unit's associated with the number. Scooping produces a number based on weight of SOM to volume of soil. Weighing a sample produces a SOM value on a weight to weight basis. Average volumetric results being lower than gravimetric may be explained by the average 0.85 cm^3 volume scoop weight of samples analyzed being 0.92 g and ranging from 0.77 to 1.2 g. When a soil's volume scoop weight is accounted and scooping results adjusted on a weight/weight basis, scooping does not give a different value than when weighing (P-value, 0.33). Commercial soil testing laboratories scoop soil samples to speed up turnaround time and reduce costs, and report SOM as a percent but it may not always be clear to the farmer or researcher if the percent is on a SOM weight to soil volume basis or an SOM weight to soil weight basis. When reporting on a percentage basis it is important to be specific if the percentages are based on mass, volume, or combination.

Table 2-4 shows that a scooped WB sample has highest average standard deviation, 0.24, of any of the methods. This is likely due to slight variability in a soil's scoop weight. Evidence supporting this assumption may be found in the variability of scoop weights and in comparison to WB OM variability once the samples are weighed to 1.00 gram. Average 0.85 cm^3 scoop weight standard deviation from 98 soils was 0.024 g cm^{-3}.

Average sample standard deviation for LOI was 0.17, which was higher than both DC and a weighed WB sample. Average LOI sample standard deviation is lower than a scooped WB sample. Laboratory implementation of LOI for farmers will give better reproducibility than is currently achieved.

Variability in LOI is assumed to be from uneven heating in muffle furnace as well as sample moisture absorption once removed from the drying oven. Table 2-5 shows that the replication, shelf, front to back, and interaction between front to back and shelf provided significantly different results. Tables 2-6 shows that a significant difference was observed for the mean value obtained for each replication ran on four separate days. Table 2-7 gives the various position values among placement in the back or on the top rack of the muffle furnace gives different results. Figure 2-8 shows that beakers gain weight from atmospheric moisture up to about 10 minutes after being removed from the over. Soils rapidly collect moist for about 10 minutes after being removed from the over, but then the moisture accumulation rate slows. The samples were not measured over a long enough period of time to observe a plateau.

Table A-2. ANOVA results for replication and sample position in muffle furnace. One replication per day was used as positions could only be occupied once per run. Results from a 1 g samples, Dried at 105ºC for 2 hours, ignited at 400ºC for 3 hours, and weighed about 15 minutes after cooling to 150ºC.

Placement	P-value
Replication	<0.01
Shelf	<0.01
Left to right	0.77
Front to back	<0.01
Shelf x left to right	0.55
Shelf x front to back	0.03
Left to right x front to back	0.94
Shelf x left to right x front to back	0.96

Table A-3. Average Weight loss percent observed with each replication. One replication per day was used as positions could only be occupied once per run. Results from a 1 g samples, Dried at 105^oC for 2 hours, ignited at 400^oC for 3 hours, and weighed about 15 minutes after cooling to 150^oC.

Replication	Weight loss percent
1	3.33B†
2	3.27C
3	3.21D
4	3.40A

† Letters signify differences at α=0.05 level using PROC GLM

Table A-4. Describes muffle furnace placement effect on loss on ignition values. Positions were analyzed once a day for four separate days to build replications. Results from a 1 g samples, Dried at 105^oC for 2 hours, ignited at 400^oC for 3 hours, and weighed about 15 minutes after cooling to 150^oC.

	Depth in muffle furnace		
	Front	Middle	Back
Shelf	Weight Loss Percent		
Top	3.42 A†	3.39 AB	3.36 AB
Middle	3.26 D	3.26 D	3.20 E
Bottom	3.30 DC	3.35 BC	3.17 E

†Letters signify differences at α=0.05 level using PROC GLM

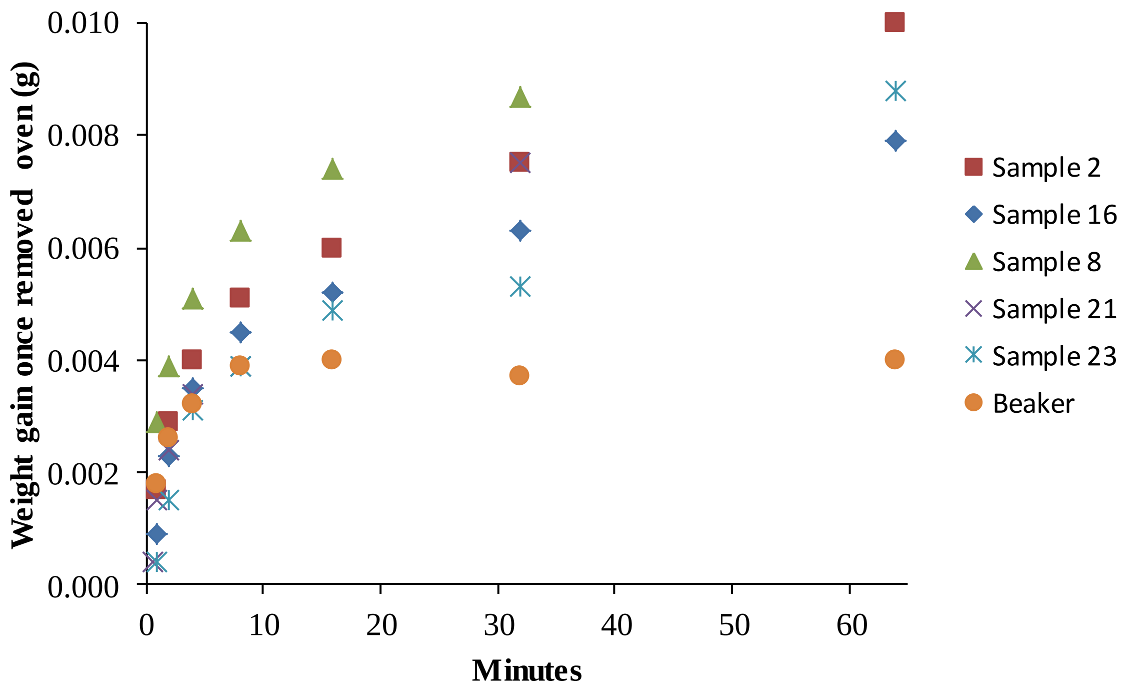

Figure 2-8. Measured weight gain of five, 1 g soil samples and an empty beaker 0.5, 1, 2, 4, 8, 16, 32, and 64 minutes after removal from a 150° C drying oven.

Implications

It is important that users of a soil testing lab understand how soil OM is estimated as well as any conversions calculated to arrive at a reported OM percent. Understanding what the number means is important in some herbicide applications and in making N fertilizer recommendations. Farmers who use LOI for N credits instead of WB will have a lower N fertilizer recommendation in states that credit OM with supplying N. Differences between recommendations made with LOI or WB weighed, however do not differ greatly when looking at field applications, but do when compared to WB scooped. Table 2-8 shows the amount of N credited for summer crops from WB and LOI using Kansas State University recommendations (Leikam et al., 2003).

Table A-1. Predicted WB gravimetric, volumetric, and LOI values at specified DC OC x 1.72 values. Predictions were made from regression of 98 soils to each method. Their N credit difference from DC OC x 1.72 for summer crops in Kansas, assuming each percent SOM supplies 22 kg N ha^{-1}.

DC OC x 1.72	Predicted value			N contribution difference from DC SOM		
	WB wt/v	WB wt/wt	LOI	WB wt/v	WB wt/wt	LOI
------------------- percent SOM-----------------				------------------- kg N ha^{-1} ---------------		
1	0.9	1.0	1.4	-1.8	-0.3	8.7
2	2.3	1.9	2.4	6.2	-2.8	8.3
3	3.6	2.8	3.4	14.3	-5.2	7.9
4	5.0	3.7	4.3	22.4	-7.6	7.6
5	6.4	4.6	5.3	30.5	-10.0	7.2

Differences in SOM N credits are small among DC OC x 1.72, WB gravimetric, and LOI. The largest difference is observed between WB on a volumetric basis and other methods, but with most agronomic Kansas soils ranging in WB volumetric SOM from 1 to 3 percent, most SOM credits made by WB on a volumetric basis will be between -1.8 kg ha^{-1} too low and 14.3 kg ha^{-1} too high.

Knowledge of how SOM measurements differ is also important for assessing soil quality. For total organic C it would be best advised to use DC and acid treat soils with free carbonates. for EOC, WB would the best method to use. It would also be stressed that a standard curve should be constructed from an EOC source such as sugar, instead of a reference soil. If direct measurements of TC, OC, or EOC are not needed, then LOI would be a cheap and fast alternative.

Understanding the variability/standard error associated with these methods may help to understand if differences are real or not. When looking at OC or SOM trends over time this variability could either mask real changes or show changes that are not actually real. Variability differences among methods should be a driver for which method is needed to accurately detect changes. If small changes are to be detected, +/- 0.08 percent OC with 95 percent confidence, DC would be the preferred method. Farmers using WB or LOI who monitor SOM year to year would need to keep in mind that the confidence limits of gravimetric WB could be +/- 0.26 percent, and LOI could be +/- 0.34 percent, with 95 percent confidence.

It has been argued that results from these methods should be reported without any conversion factors (Nelson and Sommers, 1982). This would be beneficial to farmers and researchers as transparency of the method used to make N, herbicide rates, or assessing soil quality would be inherently reported in the unit of measure.

Conclusions

Relationships exist among the methods for one to estimate how values will change from analysis to analysis. Soil OM credits used in N fertilizer recommendations from Kansas State University are not greatly affected from method to method. Understanding what different methods actually measure and the assumptions used in further estimating SOM is important. Using LOI lowers costs and turnaround time to both farmers and researchers, while allowing for an estimate of WB SOM or DC OC from a LOI value. Easily oxidizable C is measured by WB, which may be of a specific use to a researcher. It would be suggested to soil testing laboratories to not use reference soils as a SOM standard curve, but a standard curve constructed from sugar, or other EOC sources instead. When high levels of precision are required to measure small changes in soil total or organic C, it is best to use DC. While converting WB EOC and DC OC to SOM values is commonly done, reporting the raw values without any conversions to users will remove any assumptions that may not be accurate for a particular soil.

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Chapter 3 - Evaluation of lime rate, moisture, and time on lime incubations and using various buffers to estimate lime requirements

Abstract

Buffers are used by commercial soil testing laboratories to estimate the lime requirements of acid soils. A room temperature incubation study was performed to evaluate incubation soil moisture content, length of incubation time, and to compare the Shoemaker-McLean-Pratt (SMP), Sikora, and modified-Mehlich buffers. Three lime rates (0, 1.1, and 2.2 Mg ha^{-1}) were added as a $Ca(OH)_2$ of varying moisture content slurry to 50 g of Belvue loam and Smolan silty clay loam soils creating 10, 20, 30, and 40% gravimetric moisture content, with three replications, incubated for 28 and 50 days. A similar un-replicated study was performed on 25 eastern Kansas soils with a pH <5.8, using 10 g of soil, incubated for 56 days. Additionally, five lime rates (0, 2.2, 4.5, 9.0, and 18 Mg ha^{-1}) were added to 10 g of 37 eastern Kansas soils with a pH <5.8. Soils were brought to 20% gravimetric moisture, allowed to dry, and brought back to 20% moisture on eight occasions. Smolan and Belvue soils with moisture contents of 30 and 40 percent and 40 percent, respectively, gave higher final pHs than 10 percent moisture for all lime rates. Final pH difference found between 0 and 2.2 Mg ha^{-1} was 1.5, 1.7, and 1.9 pH units at 15, 30, and 45 percent moisture contents. Buffer pH values alone provide weaker correlations to observed lime requirements, compared to both buffer and soil pH. The Mehlich buffer provided the lowest r^2 of calculated versus observed lime requirements to pH target 6.0 and 6.6, 0.89 and 0.60, respectively. Sikora and SMP provided an r^2 of calculated lime requirements to observed pH targets 6.0 and 6.6 of 0.93 and 0.86, and 0.92 and 0.85, respectively.

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Introduction

Proper soil pH is critical for optimum crop yields. Acid soils are ameliorated to various target soil pHs determined by crop sensitivity to soil pH and aluminum toxicity. Lime requirements are normally estimated with pH buffered solutions. These buffers are calibrated against soil pH changes with incremental lime additions observed in laboratory incubations. Incubation studies have varied in the length of time they allow the lime to react with the soil, and are normally conducted at one moisture content.

Appropriately increasing soil pH is important for crop yields. Hill et al. (2009) found a relative yield response of 1 to 3 percent increase when lime was applied to corn and soybeans with a soil pH under 6.4. Optimum soil pH observed for corn, cotton, sorghum, and peanuts is 5.7, 5.8, 5.7, and 5.7, respectively (Adams and Pearson, 1967). Alfalfa and sweet clover have optimal growth at pH 6.8 (Foth and Ellis, 1994). Crop differences thus require farmers to lime soil to different target pHs.

When farmers receive lime recommendation from laboratories, rates are normalized using calcium carbonate equivalent (CCE) and fineness. This is to allow farmers to buy various grades of lime but apply rates properly. Lime rates are normalized by physical and chemical properties. By Kansas standards, lime particles greater than 2.38 mm, between 2.38 and 0.25 mm, and less than 0.25 mm are given a fineness rating of 0, 50, and 100 percent effective. A lime's CCE is found by comparing the amount of carbon dioxide gas produced after adding acid to the sample and to pure calcium carbonate. A CCE score is the amount of carbon dioxide gas produced by the sample divided by the amount of carbon dioxide gas produced by the pure check.

Woodruff (1947) first proposed the idea that soil exchangeable hydrogen could be measured with a pH buffered chemical. Woodruff suggested that a buffered solution must react in a linear fashion to increasing soil acidity, must react timely, must be viable across many soil characteristics, and measurements must be easily interpreted for lime recommendations. Woodruff's buffer was designed for acidic Missouri's soils. Others using Woodruff's principles also developed buffers for their soils. Shoemaker, Mclean and Pratt (SMP) designed a buffer for high CEC Ohio soils (Shoemaker et al., 1961) and Mehlich designed his buffer for lower CEC Southeastern US soils (Mehlich, 1976)

Early developed buffers used hazardous materials. Mimics and modifications have been made to original buffers removing hazardous materials. The SMP buffer contains Para-nitrophenol as well as chromium. Sikora (2006) formulated a SMP mimic buffer with "triethanolaomine, imidazole, MES (2-(*N*-morpholino)ethanesulfonic acid), and acetic acid". Mehlich's buffer contained barium chloride. Hoskins and Erich (2008) modified Mehlich's buffer by substituting calcium chloride for the barium chloride on calcium to barium molar basis.

A soil's lime requirement is estimated using a buffer by comparing a soil and buffer mixtures pH to the results from laboratory incubation studies where lime has been added either in incremental rates or as a factor of one buffer's estimation. Soils are normally kept at "field capacity" during the incubation period. Shoemaker et al. (1961) applied eight rates 0, 4, 9, 13, 18, 22, 27, and 38 Mg $CaCO_3$ ha^{-1} to fourteen Ohio soils at field capacity and allowed them to react for seventeen months. Mehlich (1971) examined his buffer's ability to predict lime requirements from soil remaining after four North Carolina soils had various amounts of lime were added in a greenhouse study. Wolf et al. (2008) compared SMP and Mehlich buffers by incubating 22 Pennsylvania soils. Lime rates were added at 0, 1/3, 2/3, 1, and 4/3 of SMP lime requirement estimation. Wolf et al. (2008) determined field capacity by adding 5 mL of water to 50 g of soil in a beaker, allowing to sit overnight, and measuring soil moisture at the top of the beaker. Soils were mixed and rewet every three weeks for three months. Godsey et al. (2007) also compared SMP and Mehlich buffers using a 60 day incubation at field capacity on 97 Kansas Soils. Lime rates were applied by SMP lime requirement estimations to target pHs 5.5, 6.0, and 6.8.

Buffer lime requirement equations are calculated from incubation studies. Two ways to calculate lime requirements are fitting a regression between a soil's buffer pH to observed lime requirements or by including soil pH, buffer pH, and target pH in an equation. Woodruff and SMP buffers were originally designed to estimate lime needs by only examining buffer pH and observed lime needs. Mehlich originally proposed a lime requirement estimation equation using buffer pH alone (Mehlich, 1976) but later modified his equation to include initial soil pH and target soil pH (David Hardy, North Carolina Dept. of Ag, personal communication) (Equation 3.1).

Equation 3.1. Mehlich's modified lime requirement equation:

$$[(\text{Buffer pH} - \text{soil:buffer pH}) / 0.25] \times [(\text{target pH} - \text{soil pH})/(\text{buffer pH} - \text{soil pH})] \times 2.2 = \text{Mg lime ha}^{-1}$$

The need to remove hazardous materials from the laboratory prompts the evaluation of Sikora and Modified-Mehlich buffers as a replacement. Understating the effects of moisture on laboratory lime incubation, and reaction time will be valuable for future studies. Objectives of this study are to observe moisture, lime rate, and incubation time on soil pH and to compare SMP, Sikora, and Modified Mehlich buffers ability to predict observed soil lime requirements.

Methods and Materials

A Belvue sandy loam soil (Coarse-silty, mixed, superactive, nonacid, mesic Typic Udifluvent) and a Smolan loam soil (Fine, smectitic, mesic Pachic Argiustoll) with 48 and 10 percent sand, respectively, were subjected to multiple lime rates and moisture contents for a laboratory incubation study. Fifty g of soil was added to a specimen cup. Three lime rates of 0, 2.2 and 4.5 Mg ECC ha^{-1}, were added as a $Ca(OH)_2$ slurry. Slurry volume was adjusted to create four gravimetric moisture contents of 10, 20, 30, and 40 percent. Soil and lime were mixed well, and covered with punctured saran wrap. Moisture content was brought back to its respective level every three days, by weighing the cup, and moist soil, and adding deionozed water drop wise to bring the sample to the pre-determined moisture content. Soil pH changes were observed 28 and 50 days after application. Soil pH was measure by adding deionozed water creating a 1:1 soil:water slurry by weight, mixing well, waiting 10 minutes, and mixing right before measuring. This study used three replications. Data was analyzed with Proc GLM in SAS 9.2 (Cary, NC) and mean separations were done using the Tukey Test and $\alpha = 0.05$. Saturation percentage of the soils was estimated by mixing deionized water to 25 g of soil until a thin film of water appeared on the surface, and no water drained from the sample when turned at a 90^o angle.

A second un-replicated study using nineteen Kansas soils brought into Kansas State Soil Testing Laboratory by farmers and gardeners was completed examining the effect of lime rate and moisture content on soil pH. Ten g of soil was added to an 89 cm^3 plastic shot glass. Three lime rates of 0, 3.4 and 6.7 Mg ECC ha^{-1} were added to 10 g of soil as various volumes of a $Ca(OH)_2$ slurry creating 15, 30, and 45 percent gravimetric water contents. Samples were covered with punctured Saran wrap. Moisture content was brought to its original level every three days by bringing moist soil and cup to original weight by adding deionozed water drop wise. The difference between no lime and 2.2 Mg ECC ha^{-1} was calculated for each sample and moisture content. Change in pH across moisture levels was compared using a paired t-test.

To compare buffer pHs, 10 g of 37 Kansas different soils were added to an 89 cm^3 plastic shot glass and subjected to 5 lime rates of 0, 2.2, 4.5, 9.0, and 18.0 Mg ECC lime ha^{-1}. Soils were brought to 20 percent gravimetric content over eight wet and dry cycles, at least one week in length. Final soil pH was measured by adding deionozed water creating a 1:1 soil:water solution, mixing, waiting 10 minutes, and stirring again before reading. Soil buffer pH was measured with Sikora, SMP, and modified-Mehlich using a 1:1:1, 1:2:1, and 1:1:1 soil:water:buffer solution, respectively. Samples were mixed with deionozed water, allowed to sit for 10 minutes, stirred, buffer added, stirred, allowed to sit for 20 minutes, stirred, allowed to sit for 20 minutes, stirred and pH measured. Soil buffer pHs were regressed to observed lime incubation needs to pHs 6.0, 6.3, and 6.6, for all initial soil pH categories combined, for linear and quadratic models using PROC REG in SAS 9.2 (Cary, NC). Lines presented in these graph are the statically significant relationship at α=0.05. Soils were broken into three catagories of initial pHs of 4.2 to 5.0, 5.0 to 5.5 and 5.5 to 5.8. Soil buffer pHs for individual intial soil pH categories were regressed to observed lime incubation needs to pHs 6.0, 6.3, and 6.6, for linear and quadratic models using PROC REG in SAS 9.2 (Cary, NC). Lime requirement estimation for all buffers was calculated using Mehlich's equation replacing SMP and SIkora initial buffer pH value in pace of the Mehlich buffer's initial pH of 6.6. Observed minus calculated lime need was also plotted to assess accuracy.

Results and Discussion

Incubation moisture content and length of time incubated

No difference due to incubation time in soil pH was observed after incubating soils with lime added for 28 and 50 days for both Belvue and Smolan soils (Table 3-1). This shows that when finely divided reagent grade lime is added as a slurry, 28 days is sufficient to observe soil pH changes. Results from both the 28 and 50 day incubations were combined in further analyses. Moisture, lime rate and their interaction were significant for both soils. Across all lime rates, increasing soil moisture increased final pH.

Table A-1. Belvue and Smolan ANOVA results for measuring final pH 28 and 50 days after liming (Time), moisture contents (M) of 10, 20, 30, and 40 percent, and lime rates (L) 0, 1.1, and 2.2 Mg ha^{-1}

Variable	Belvue	Smolan
	------------ **Pr>F**	---------
Time	0.290	0.670
M	0.001	0.001
L	0.001	0.001
M x L	0.001	0.001

No final pH difference between 10, 20, and 30 percent moisture was observed within individual lime rates on the Smolan soil. However, final pH at 40 percent moisture was higher than all lower moisture contents across all lime rates (Figure 3-1). Final pH for the Belvue soil at 30 and 40 percent moisture was greater than 10 percent moisture for all lime rates. Final pH at 20 percent showed inconsistent results as it is equal, less than, and greater than 10 percent moisture at 0, 1.1, and 2.2 Mg ha^{-1} lime rates, respectively (Figure 3-2). Differences observed between soils may be attributed to soil texture and their saturated moisture content. Belvue and Smolan are 48 and 10 percent sand, respectively. Smolan and Belvue soil saturation percentages were measured at 46 and 28 percent moisture content, respectively.

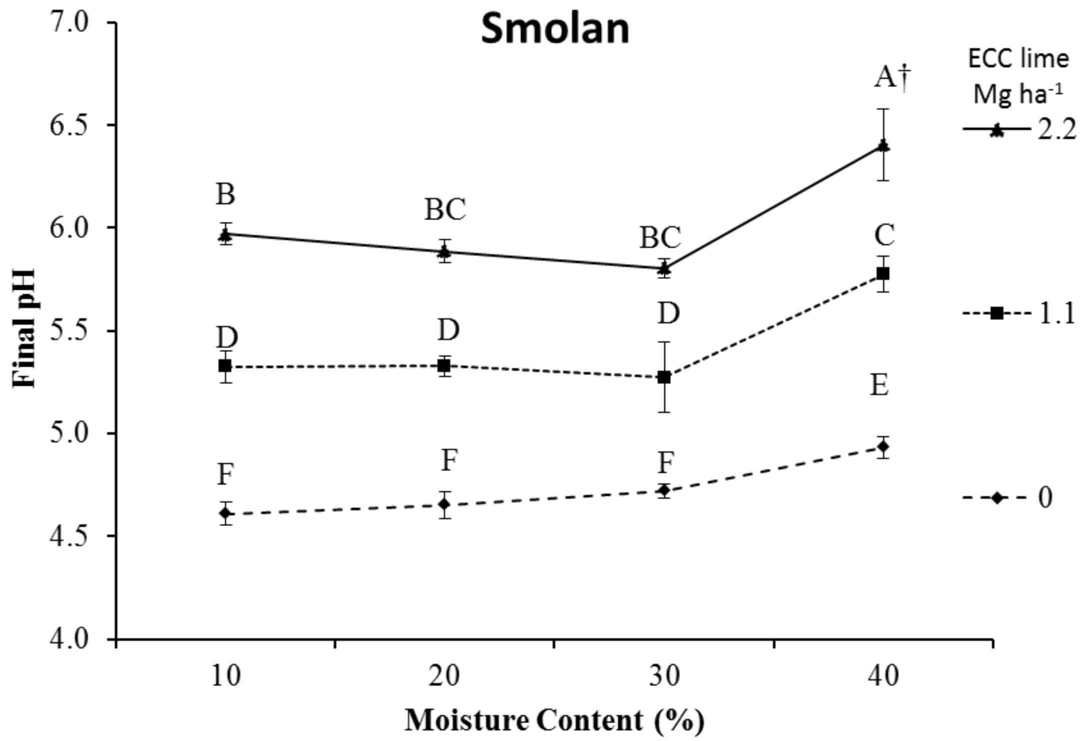

Figure 3-1. Final pH of a Smolan soil with lime rates of 0, 1.1, and 2.2 Mg ha^{-1}, and moisture contents of 10, 20, 30, and 40 percent gravimetric using combined replications from 28 and 50 day incubations. †indicates letter differ at $\alpha = 0.05$ using PROC GLM - Tukey analysis with SAS 9.2. Minimum significant difference was 0.18 pH units.

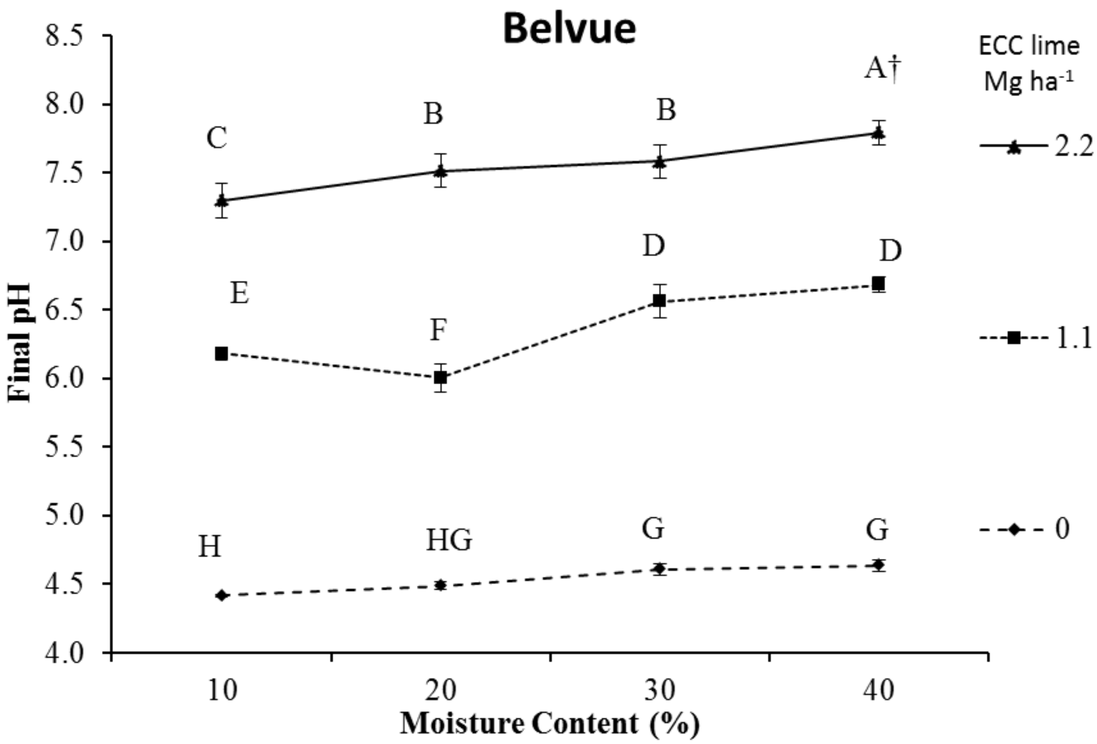

Figure 3-2. Final pH of a Belvue soil with lime rates of 0, 1.1, and 2.2 Mg ha^{-1}, and moisture contents of 10, 20, 30, and 40 percent gravimetric using combined replications from 28 and 50 day incubations. †indicates letter differ at $\alpha = 0.05$ using PROC GLM - Tukey analysis with SAS 9.2. Minimum significant difference was 0.17 pH units.

High gravimetric moisture contents were also observed to give higher final pH values on the second study using nineteen soils as the average differece between no lime and 6.7 Mg ha^{-1} of lime at 15 percent moisture is 0.2 and 0.4 pH units lower than soils kept at 30 and 45 percent moisture. (Table 3-2).

Table A-2. Average final pH difference between 0 and 2.2 Mg ha^{-1} lime for 19 Kansas soils.

Gravimetric moisture content		
15	**30**	**45**
Final pH difference between 0 and 2.2 Mg ECC ha^{-1}		
1.5 C†	1.7 B	1.9 A

†Letters, within row, signify statistical difference using a paired t-test with α = 0.05.
Excludes sample ID 6780 with 10 % organic matter

Buffer comparisons

Direct comparison of the buffer pH values obtained from the tested buffers using 37 Kansas soils show a strong correlation, though individual buffer values did differ. The Sikora and SMP buffers correlated well and give similar values (Figure 3-3). The Modifed-Mehlich correlates well to both SMP (Figure 3-4) and Sikora (Figure 3-5) but gives lower buffer pH values.

Sikora and SMP values were expected to be similar as the Sikora buffer is designed to mimic SMP. However while the Sikora buffer pH was slightly lower than SMP, the slope of the comparison was near 1:1. Thus the results between the two are similar. These results are also similar to those observed by the developer of the Sikora Buffer. Sikora (2006) showed a relationship between Sikora and SMP on 255 Kentucky soils as Sikora = 1.03 SMP - 0.22. Absence of a 1:1 relationship between Sikora and SMP has been observed by Hill et al. (2009) as they found a relationship between Sikora and SMP, on 1,252 Iowa soils, as Sikora = 0.88 SMP + 0.77. A possible explanation as to why this study observed SMP value to be constantly slightly higher than the Sikora values may be due to procedure alterations to fit within a pH robot's constraints of stirring, instead of shaking, and measuring up to 40 minutes after mixing, instead of immediately after. Sikora (2006) suggests samples to be shaken for 10 minutes and pH measured immediately after. Many commercial laboratories use pH robots to measure soil and buffer pH. Robots stir soil and buffer together over multiple instances, usually one or two samples at a time, making an immediate reading after every sample untimely.

Modifed-Mehlich giving different results from both SMP and Sikora is expected as they measure and react with soil acidity differently. Modified Mehlich buffer measures acidity mostly from soil aluminum (Wolf et al., 2008) while SMP measures acidity from protons (Shoemaker et al., 1961). Hoskins and Erich (2008) show the slope between buffer pH and meq of acid added to Modifed-Mehlich, Sikora, and SMP is -5.0, -2.4, and -2.4, respectively. This means that Modified-Mehlich buffer pH will be lowered more by an equal amount of protons added to SMP or Sikora. This is logical as the Mehlich buffer was developed to be used on low CEC Southeastern US soils comprised predominantly of 1:1 clays, while the SMP was designed for use on higher CEC Midwestern US soils comprised predominantly of 2:1 clays. Soils higher in CEC will have more protons than a lower CEC soil at a given pH. Exchange sites on 1:1 clays are pH dependent, while 2:1 clays have both permanent and pH dependent exchange sites.

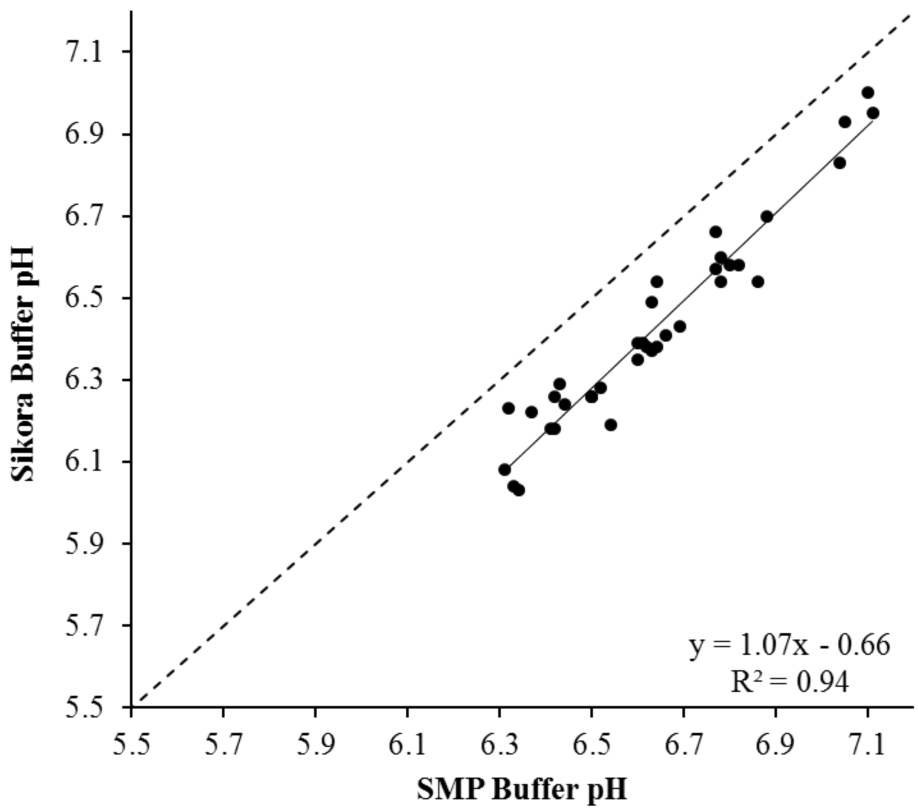

Figure 3-3. Comparison of Sikora and Shoemaker-McLean-Pratt (SMP) buffers for 37 Kansas soils, using 10 g of soil to 10 mL of deionized water, stirring, waiting 10 minutes, adding 20 mL of SMP or 10 mL of Sikora, stirring, waiting 20 minutes, stirring, waiting 20 minutes, stirring and reading buffer pH.

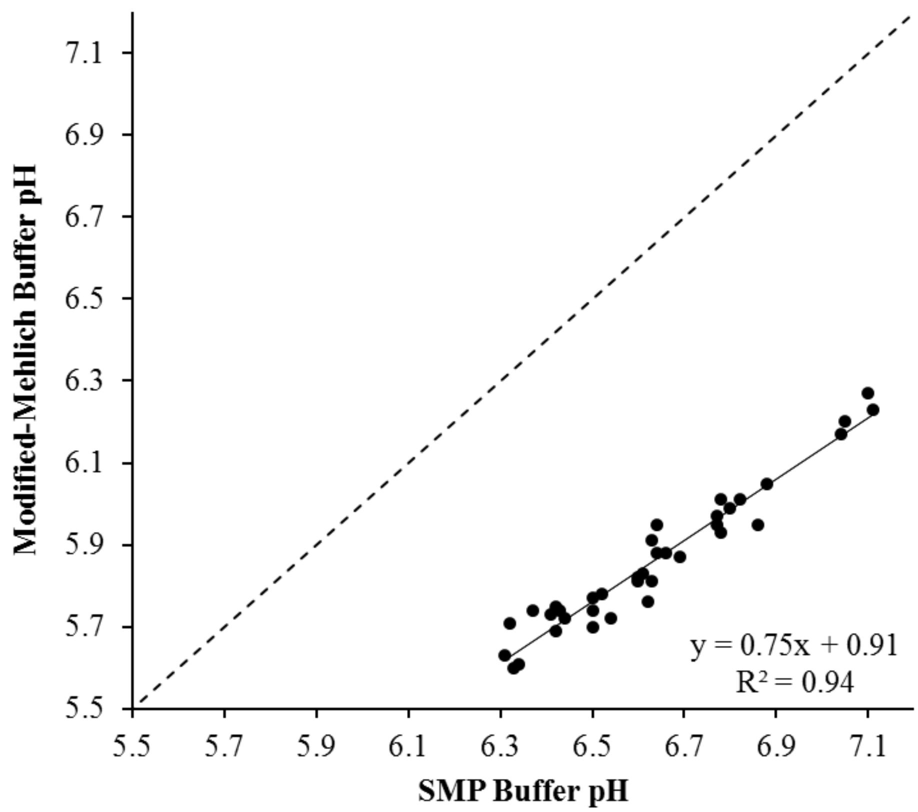

Figure 3-4. Comparison of modified-Mehlich and Shoemaker-McLean-Pratt (SMP) buffers for 37 Kansas soils, using 10 g of soil to 10 mL of deionized water, stirring, waiting 10 minutes, adding 20 mL of SMP or 10 mL of modified-Mehlich, stirring, waiting 20 minutes, stirring, waiting 20 minutes, stirring and reading buffer pH.

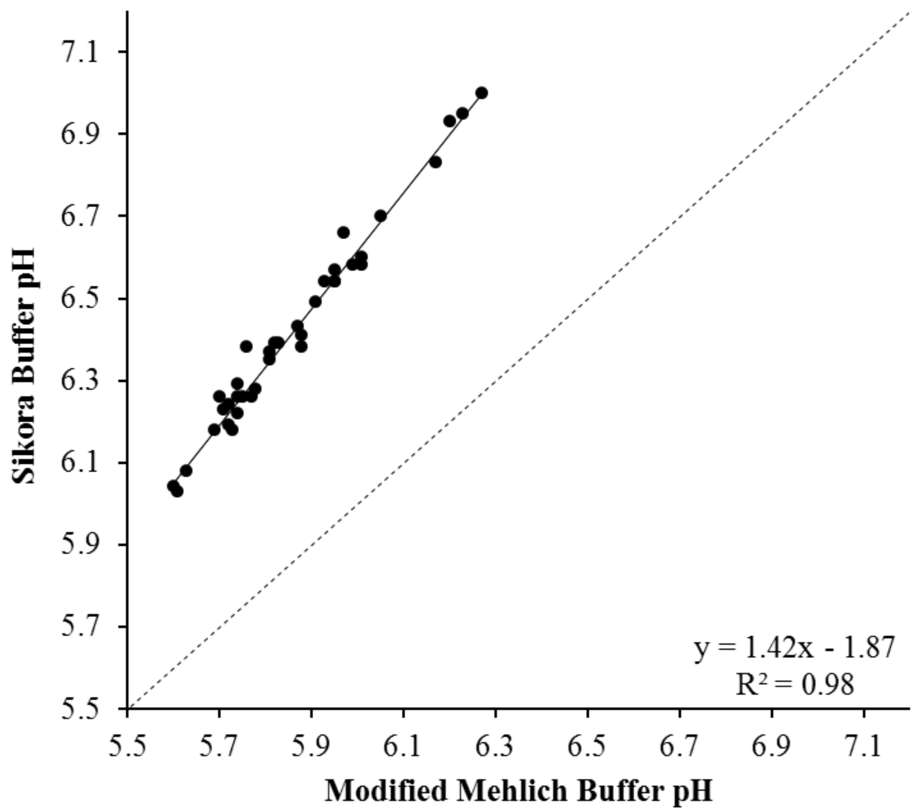

Figure 3-5. Comparison of modified-Mehlich and Sikora buffers for 37 Kansas soils, using 10 g of soil to 10 mL of deionized water, stirring, waiting 10 minutes, adding 10 mL of modified-Mehlich or 10 mL of Sikora, stirring, waiting 20 minutes, stirring, waiting 20 minutes, stirring and reading buffer pH.

Buffer pH regression to lime requirements

All buffers exhibited significant linear relationships between a soil's buffer pH value and lime requirements to target pHs 6.0 and 6.3, and quadratic to target pH 6.6 (Figures 3-4 to 3-14). A possible explanation for this may be that buffers are not sensitive enough to measure small lime needs. Evidence to support this exist in the correlation coefficients increasing for each buffer as target pHs increase. Curvilinear response between Mehlich and SMP to a high pH target is similar to that observed by Godsey et al. (2008), but differ from Wolf et al. (2008) as they found a linear response to pH target 6.5. Godsey et al. (2008) also reported a curvilinear response to pH target 5.5 and 6.0 while we observed a linear response. Differences in soil buffer value relationships to lime requirements may be due to the initial pH of the selected soils.

Initial soil pH also shows a significant linear relationship to lime requirements to pH targets 6.0 (Figure 3-15), 6.3 (Figure 3-16), and 6.6 (Figure 3-17) (P-values <0.001, <0.001, and <0.001, respectively). To explore regression responses of soils by initial pH, soils were grouped into pH ranges of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8 and their buffer pH value regressed against lime requirements to pH 6.0, 6.3, and 6.6. Soils with an initial pH less than 5.0 give a linear relationship (P-value <0.001) to all pH target levels for modified-Mehlich (Table 3-3), SMP (Table 3-4) and Sikora (Table 3-5). These soils had the best coefficient of determination and lowest root mean square error compared to the higher soil pH groups, for all buffers and target pHs except for Mehlich buffer to target 6.6, and for Sikora buffer to targets 6.3 and 6.6. Soils with a pH between 5.0 and 5.0 showed a linear response to pH target 6.0 for SMP and Sikora buffers. A quadratic response to pH targets 6.3 and 6.6 for SMP and Sikora, and all pH targets with modified-Mehlich. Soils higher than 5.5 give no relationship to lime requirements to achieve pH 6 with Mehlich, SMP, and Sikora buffers (P-values 0.21, 0.20, and 0.23, respectively) or to pH 6.3 (P-values 0.07, 0.07, and 0.08, respectively). Linear relationships are observed to target pH 6.6 for Mehlich and SMP buffers (P-values 0.04 and 0.04, respectively), and curvilinear using Sikora (P-value 0.05).

Our results show that, in Kansas, use of buffer pH alone is not the best approach to making lime recommendations. Better coefficients of determination were observed with soil pH regression to lime requirements for pH 6.0 and 6.3 than with all buffers. Mehlich formulated an equation to include current soil pH, and, target pH, and buffer pH. This equation provides a strong correlation to lime requirements for all buffers and pH targets.

Sikora provided the highest coefficient of determination to all observed lime requirements with r^2 of 0.93, 0.90, and 0.86 to pH targets 6.0 (Figure 3-18), 6.3 (Figure 3-19), and 6.6 (Figure 3-20), respectively. Sikora overestimates lime requirements for pH targets 6.0 (Figure 3-21), 6.3 (Figure 3-22), and 6.6 (Figure 3-23) for lime requirements less than 6.0, 7.1, and 9.0 Mg ha^{-1}, respectively. Sikora ranged in residuals from calculated lime requirements minus observed with -1.73 to 0.77, -2.10 to 1.03, and -2.66 to 1.31 Mg ha^{-1} for pH targets 6.0, 6.3, and 6.6, respectively. The sum of the absolute value of the residuals is larger than modified-Mehlich, but smaller than SMP with sums of 29.7, 37.0, and 40.5 for targets 6.0, 6.3, and 6.6, respectively.

The SMP buffer provided strong coefficients of determination of 0.92, 0.89, and 0.85 were observed to pH targets 6.0 (Figure 3-24), 6.3 (Figure 3-25), and 6.6 (Figure 3-26), respectively. The SMP buffer overestimated lime needs for targets 6.0 (Figure 3-27), 6.3 (Figure 3-28), and 6.6 (Figure 3-29) for lime requirements less than 5.0, 6.5, and 8.0 Mg ha^{-1}, respectively. The SMP ranged in residuals from calculated lime requirements minus observed with –1.33 to 1.15, -1.66 to 1.53, and -1.86 to 1.98 Mg ha^{-1} for pH targets 6.0, 6.3, and 6.6, respectively. While the ranges to pH targets 6.0 and 6.3 are larger than observed in modified-Mehlich and Sikora, the sum of the absolute value of the residuals is the smallest for all pH targets with 19.3, 23.7, and 25.9 Mg ha^{-1}, for targets 6.0, 6.3, and 6.6, respectively.

Weakest coefficients of determination between lime calculated and required was observed by modified-Mehlich with $r^2 = 0.89$, 0.77, and 0.60 for pH targets 6.0 (Figure 3-30), 6.3 (Figure 3-31), and 6.6 (Figure 3-32), respectively. Modified-Mehlich overestimates lime needs to pH target 6.0 (Figure 3-33), 6.3 (Figure 3-34), and 6.6 (Figure 3-35) at lime requirements less than 5.1, 6.5, and 8.0 Mg ha^{-1}, respectively. Smallest deviations of observed minus calculated lime requirements to target pH 6.0 were given with modified-Mehlich ranging from -1.69 to 0.69 Mg ha^{-1}. Deviations to target pHs 6.3 and 6.6 were the largest of all buffers with calculations ranging from -3.01 to 1.14 under and -4.23 to 1.77 Mg ha^{-1}, respectively. The sum of the absolute value of residuals was the largest using modified-Mehlich with sums of 31.7, 42.9, and 52.1 for targets 6.0, 6.3, and 6.6, respectively.

From this data it would be suggested that one uses Sikora's buffer and Mehlich's equation. Sikora's buffer also allows one to estimate lime requirements for higher pH targets, unlike modified-Mehlich. Even though SMP was best at predicting lime requirements, Sikora's buffer does not have hazardous materials. Sikora's overestimation may be adjusted for by using the linear regression between calculated and observed lime needs. This adjustment mathematically forces the relationship between the Sikora estimated lime requirement and observed incubation lime requirement to be 1:1 with an intercept of 0 to pH targets 6.0 (Figure 3-36), 6.3 (Figure 3-37), and 6.6 (Figure 3-38). This adjustment also improves Sikora buffer's ability to estimate lime requirements as once made, all but one, three, and six of the 37 observations deviate by larger than 1 Mg ha^{-1} for targets 6.0 (Figure 3-39), 6.3 (Figure 3-40), and 6.6 (Figure 3-41), respectively.

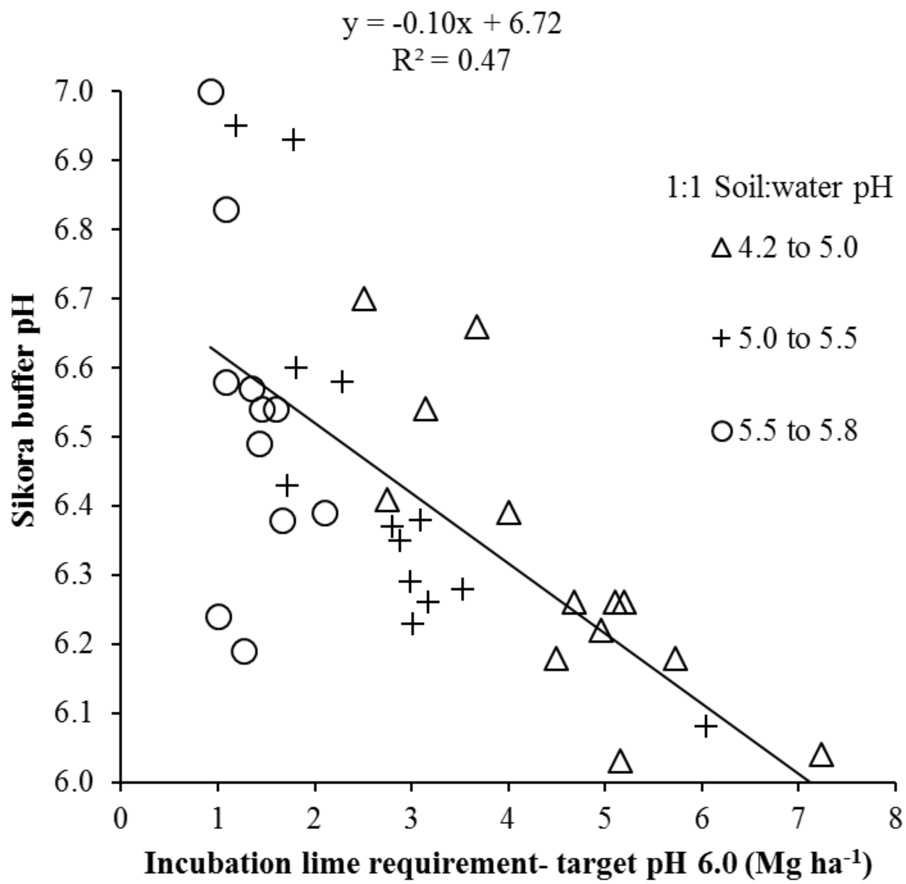

Figure 3-6. Regression of Sikora buffer pH values to incubated lime requirements to pH 6.0, Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

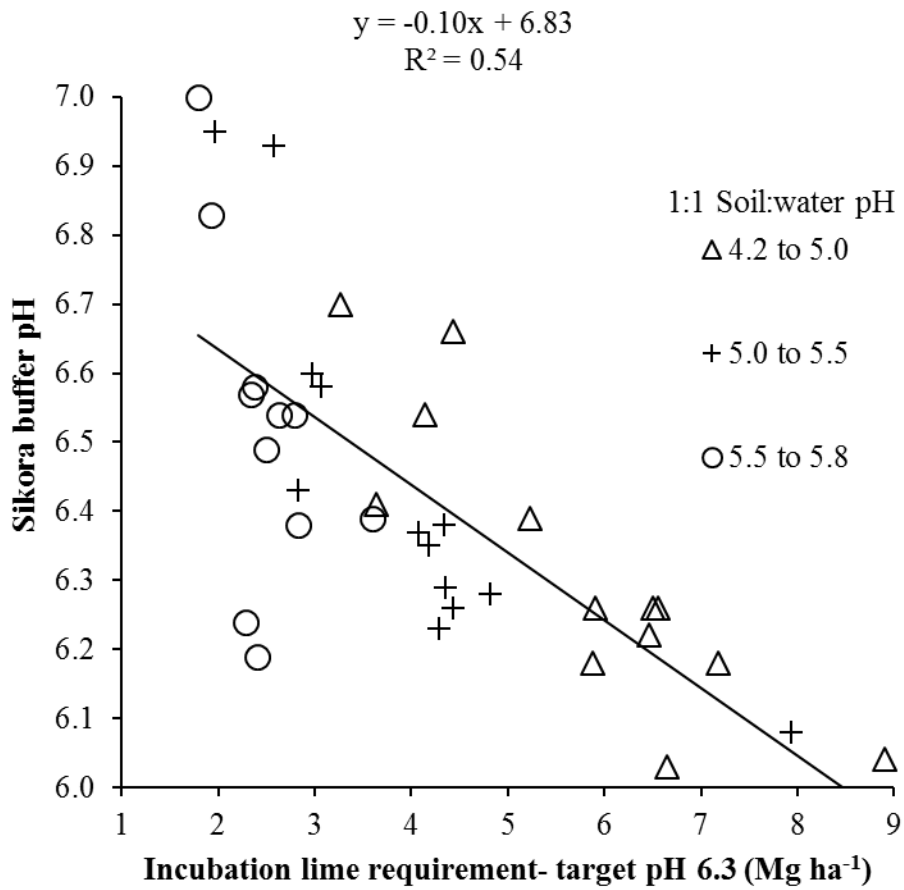

Figure 3-7. Regression of Sikora buffer pH values to incubated lime requirements to pH 6.3. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

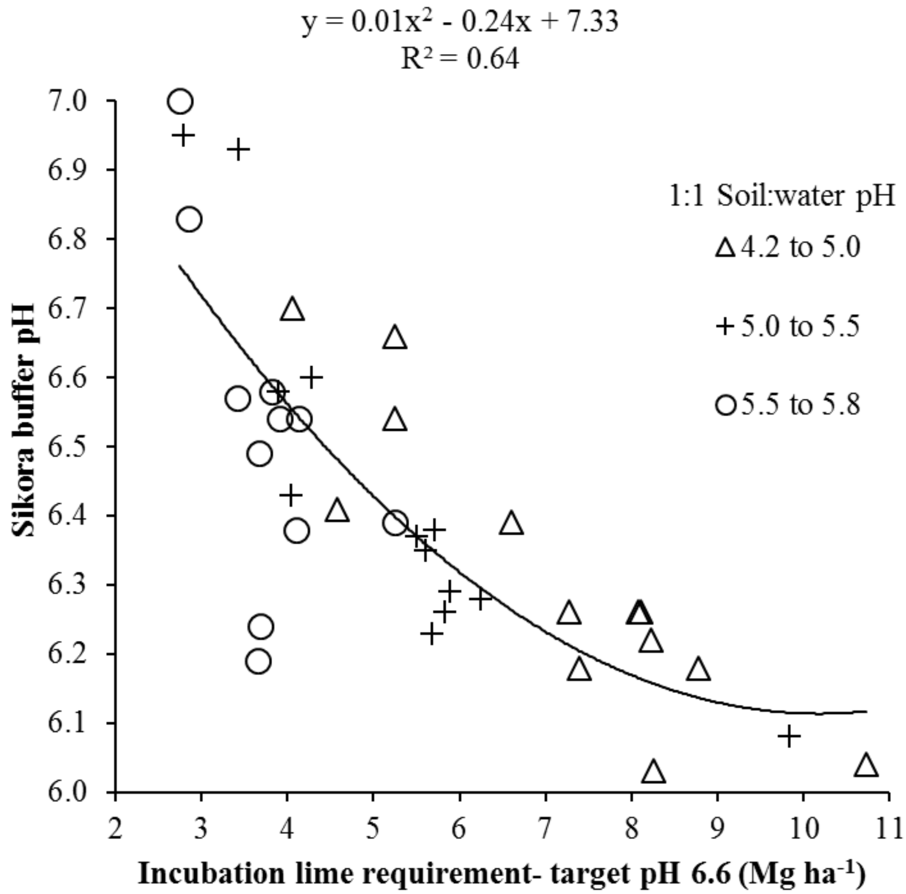

Figure 3-8. Regression of Sikora buffer pH values to incubated lime requirements to pH 6.6. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

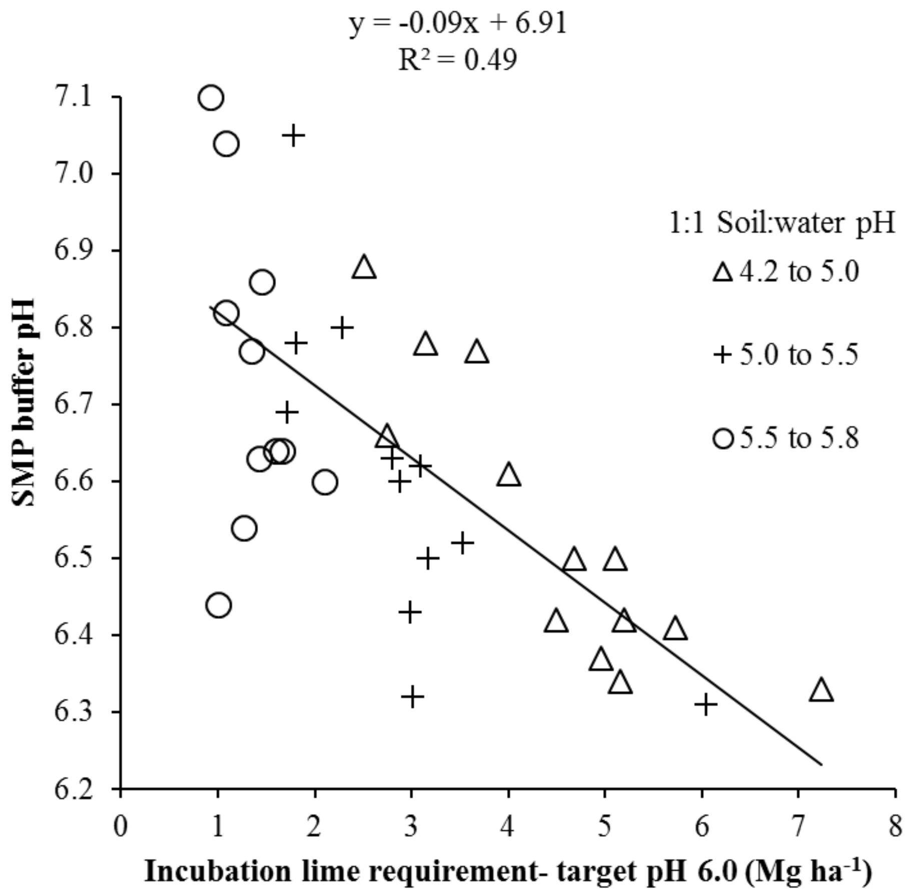

Figure 3-9. Regression of SMP buffer pH values to incubated lime requirements to pH 6.0. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

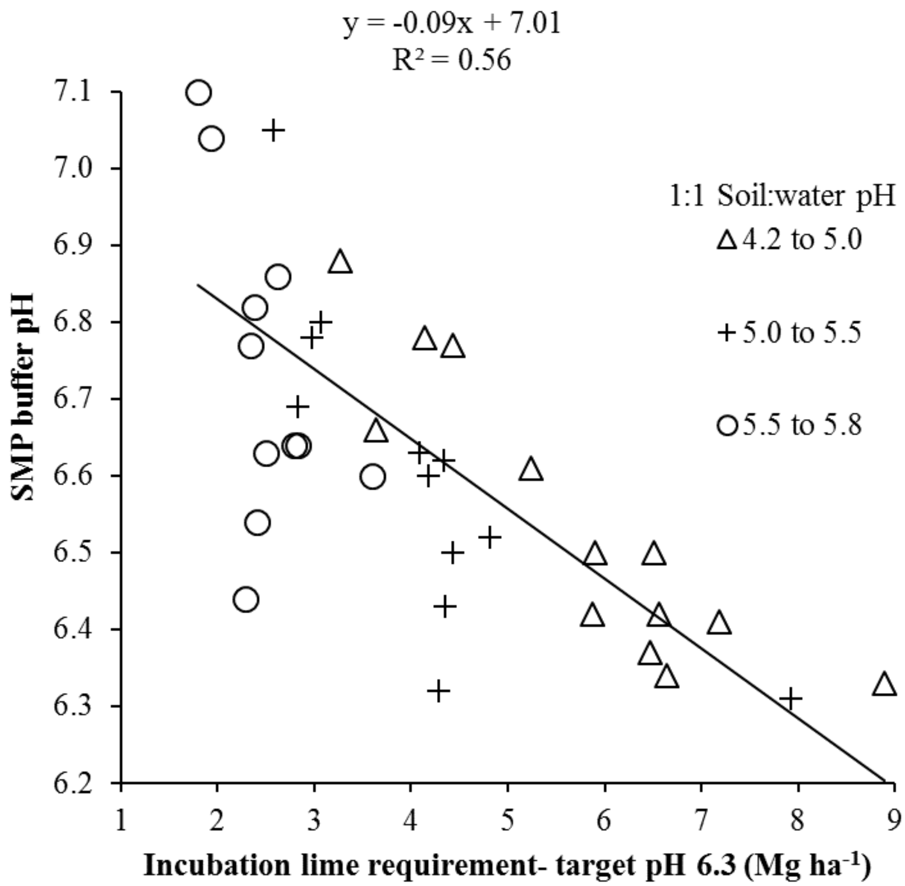

Figure 3-10. Regression of SMP buffer pH values to incubated lime requirements to pH 6.3. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

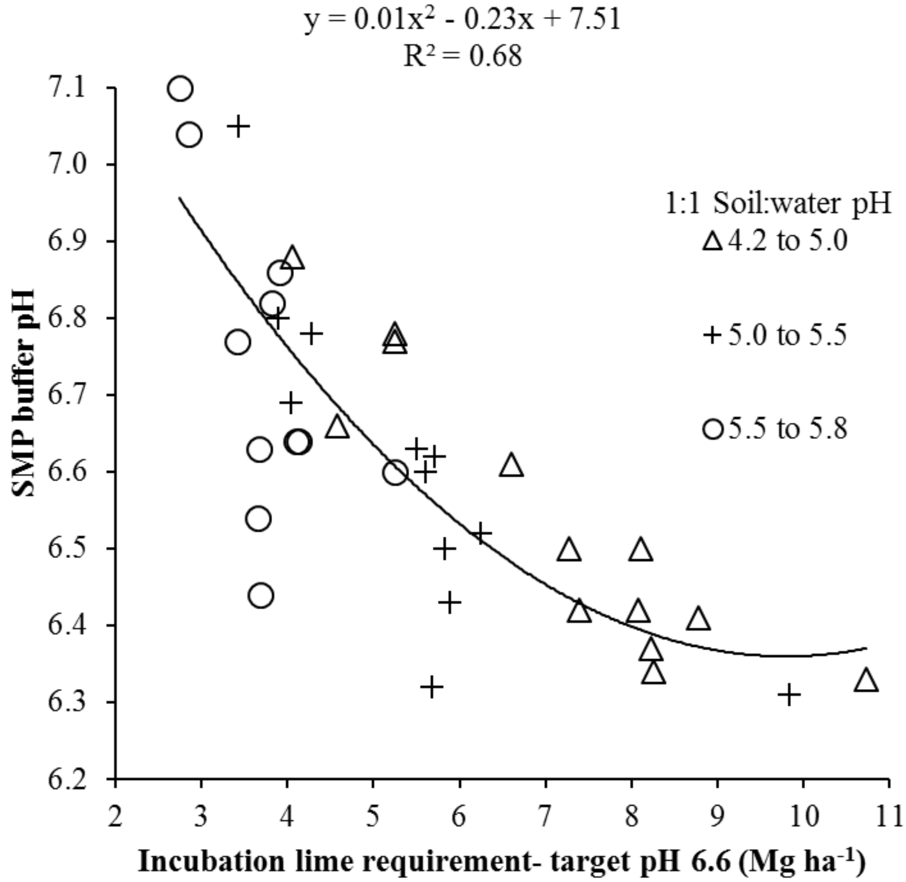

Figure 3-11. Regression of SMP buffer pH values to incubated lime requirements to pHs 6.6. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

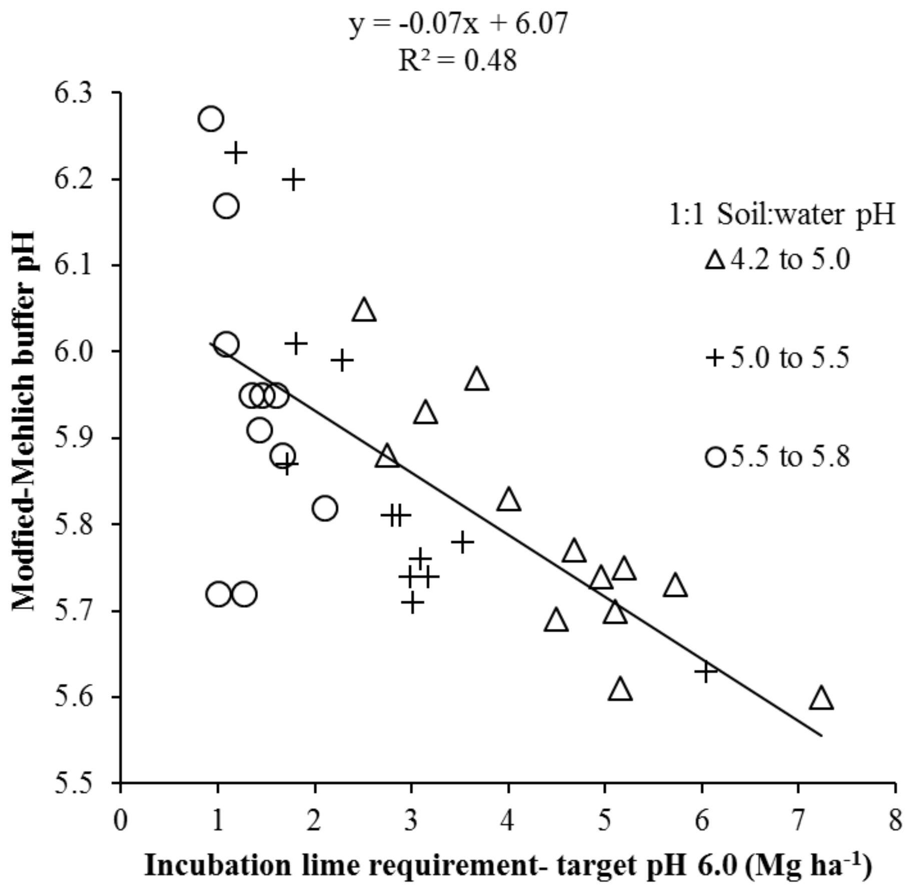

Figure 3-12. Regression of modified-Mehlich buffer pH values to incubated lime requirements to pH 6.0. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

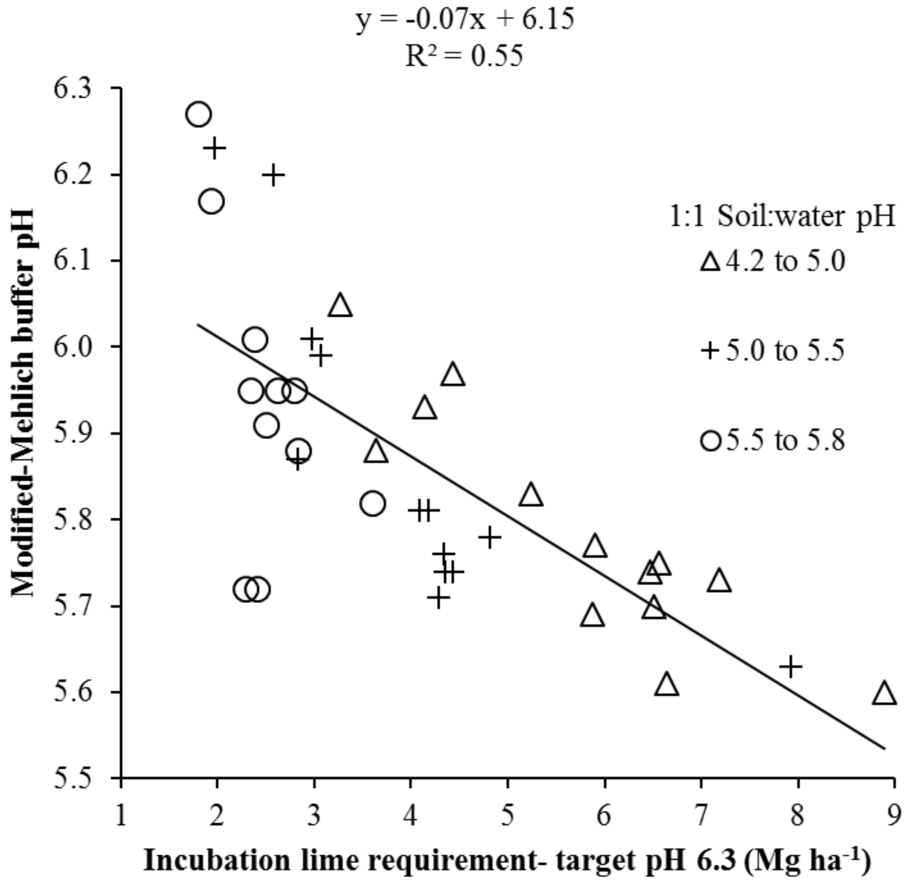

Figure 3-13. Regression of modified-Mehlich buffer pH values to incubated lime requirements to pH 6.3. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

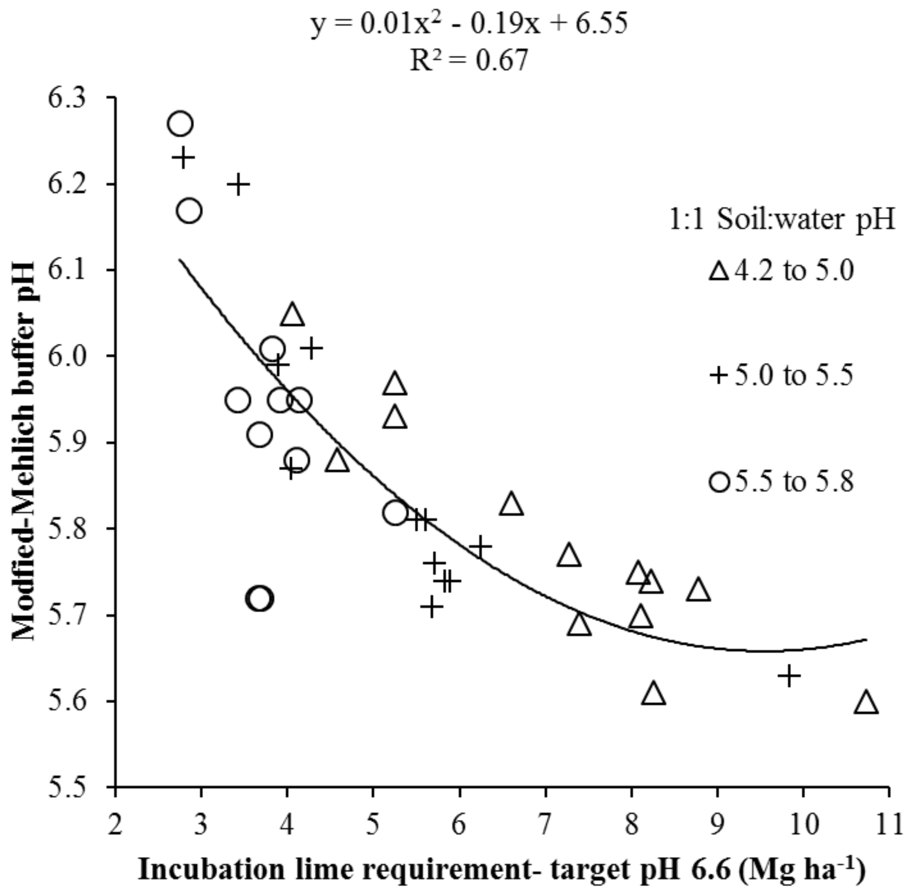

Figure 3-14. Regression of modified-Mehlich buffer pH values to incubated lime requirements to pH 6.6. Soils are broken into groups of 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5, and 5.5 to 5.8.

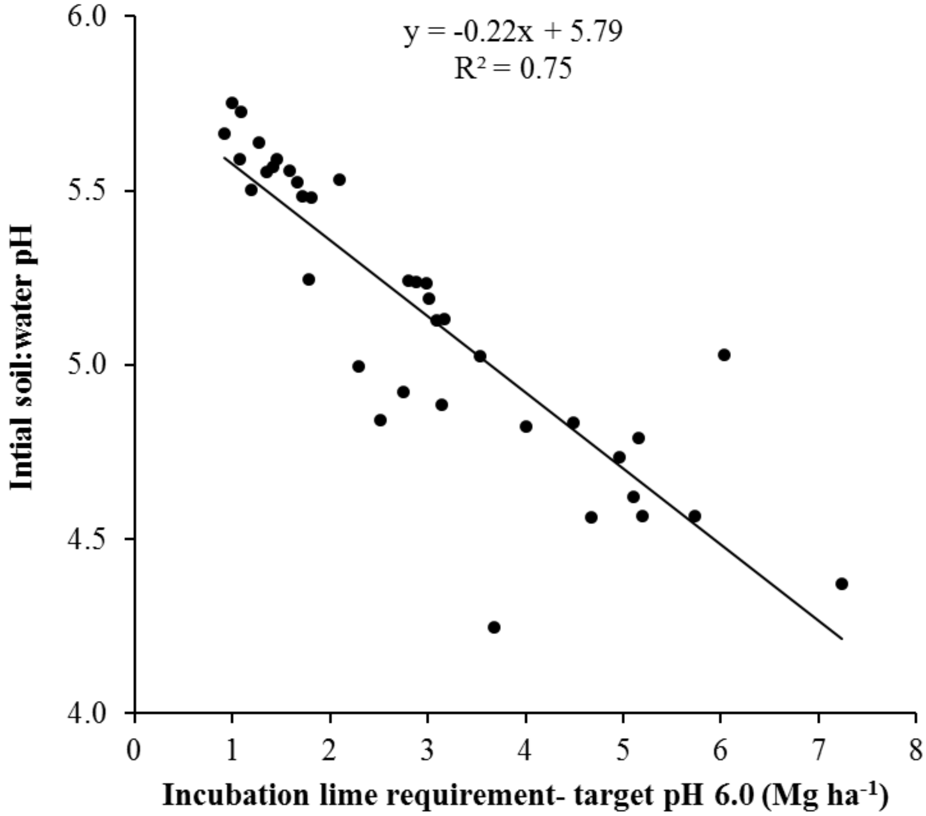

Figure 3-15. Regression of initial 1:1 soil:water pH to observed incubated lime requirements to target pH 6.0.

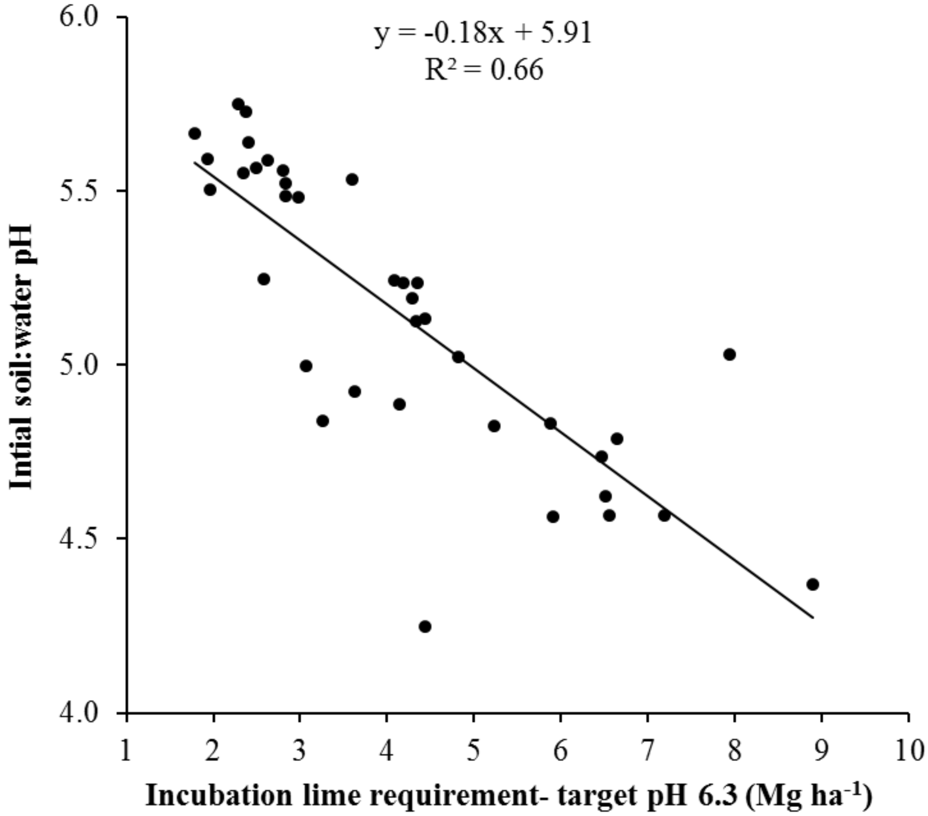

Figure 3-16. Regression of initial 1:1 soil:water pH to observed incubated lime requirements to target pH 6.3.

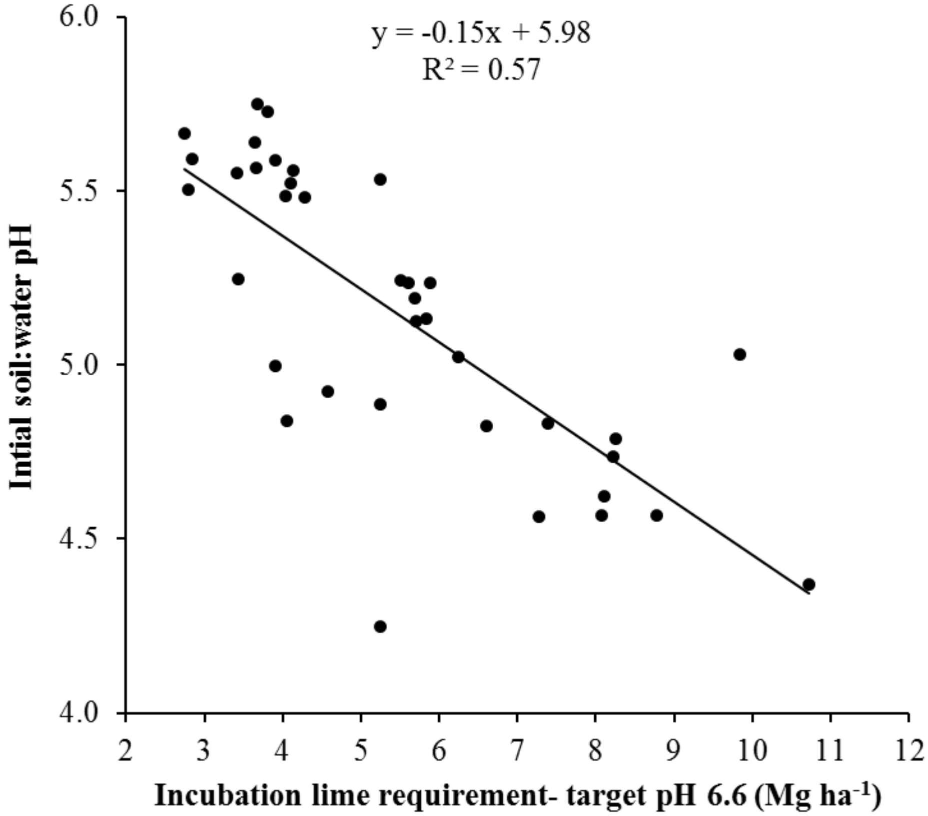

Figure 3-17. Regression of initial 1:1 soil:water pH to observed incubated lime requirements to target pH 6.6.

Table A-1. Regression equations for a soil's modified-Mehlich buffer pH value to lime requirements 6.0, 6.3, and 6.6 For soils with an initial 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5 and 5.5 to 5.8.

	Target pH 6.0						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	6.20	-0.09	0.00			0.75	0.07
5.0 to 5.5	6.55	-0.36	0.02	0.04	0.05	0.71	0.09
5.5 to 5.8	6.21	-0.20	0.21			0.17	0.16

	Target pH 6.3						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	6.23	-0.08	0.00			0.80	0.06
5.0 to 5.5	6.84	-0.36	0.00	0.03	0.02	0.80	0.08
5.5 to 5.8	6.43	-0.20	0.07			0.32	0.15

	Target pH 6.6						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	6.24	-0.07	0.00			0.61	0.10
5.0 to 5.5	7.04	-0.33	0.00	0.02	0.01	0.85	0.07
5.5 to 5.8	6.52	-0.15	0.04			0.38	0.14

Table A-2. Regression equations for a soil's SMP buffer pH value to lime requirements 6.0, 6.3, and 6.6 For soils with an initial 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5 and 5.5 to 5.8.

	Target pH 6.0						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	7.09	-0.12	0.00			0.75	0.10
5.0 to 5.5	6.97	-0.13	0.01			0.52	0.15
5.5 to 5.8	7.07	-0.25	0.20			0.17	0.07

	Target pH 6.3						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	7.14	-0.10	0.00			0.80	0.09
5.0 to 5.5	7.83	-0.44	0.02	0.03	0.05	0.74	0.12
5.5 to 5.8	7.33	-0.24	0.07			0.32	0.18

	Target pH 6.6						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	7.17	-0.09	0.00			0.84	0.08
5.0 to 5.5	8.08	-0.40	0.01	0.02	0.03	0.79	0.11
5.5 to 5.8	7.44	-0.19	0.04			0.38	0.17

Table A-3. Regression equations for a soil's Sikora buffer pH value to lime requirements 6.0, 6.3, and 6.6 For soils with an initial 1:1 soil:water pH of 4.2 to 5.0, 5.0 to 5.5 and 5.5 to 5.8.

	Target pH 6.0						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	6.93	-0.14	0.00			0.70	0.12
5.0 to 5.5	6.79	-0.14	0.01			0.55	0.16
5.5 to 5.8	6.89	-0.27	0.23			0.16	0.23

	Target pH 6.3						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	6.99	-0.12	0.00			0.76	0.11
5.0 to 5.5	7.73	-0.47	0.01	0.03	0.03	0.78	0.12
5.5 to 5.8	7.19	-0.27	0.08			0.30	0.21

	Target pH 6.6						
Initial pH	Intercept	x	P-value	x^2	P-value	R^2	RMSE
4.2 to 5.0	7.03	-0.10	0.00			0.79	0.10
5.0 to 5.5	8.02	-0.44	0.00	0.03	0.01	0.84	0.10
5.5 to 5.8	10.06	-1.65	0.03	0.18	0.05	0.61	0.16

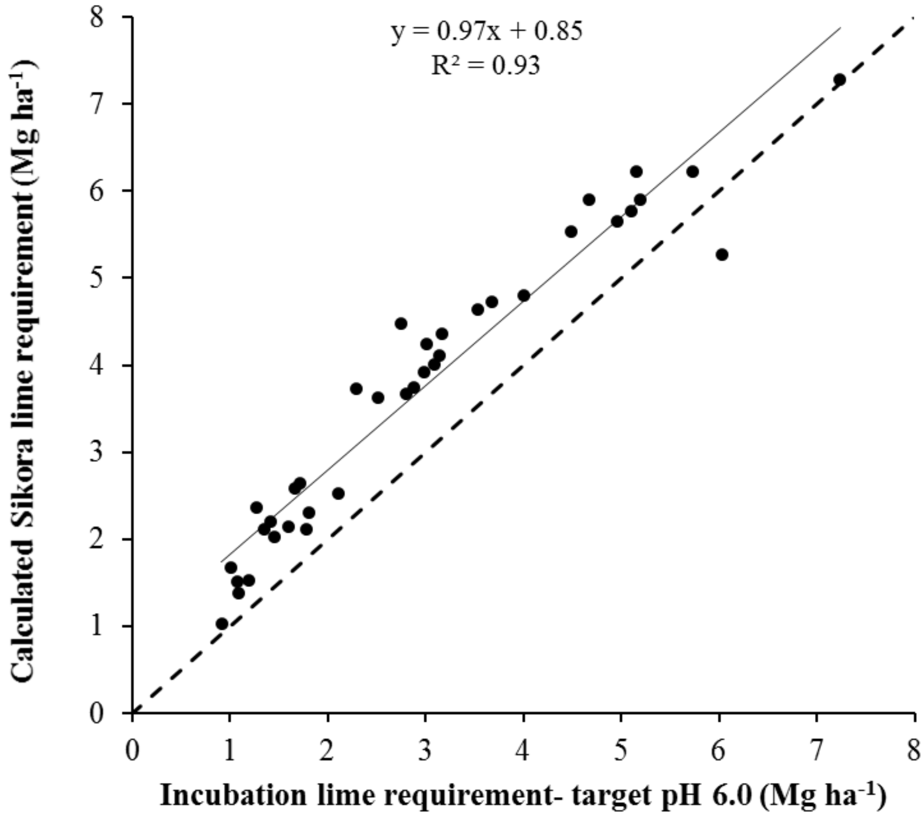

Figure 3-18. Regression of calculated Sikora lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.0.

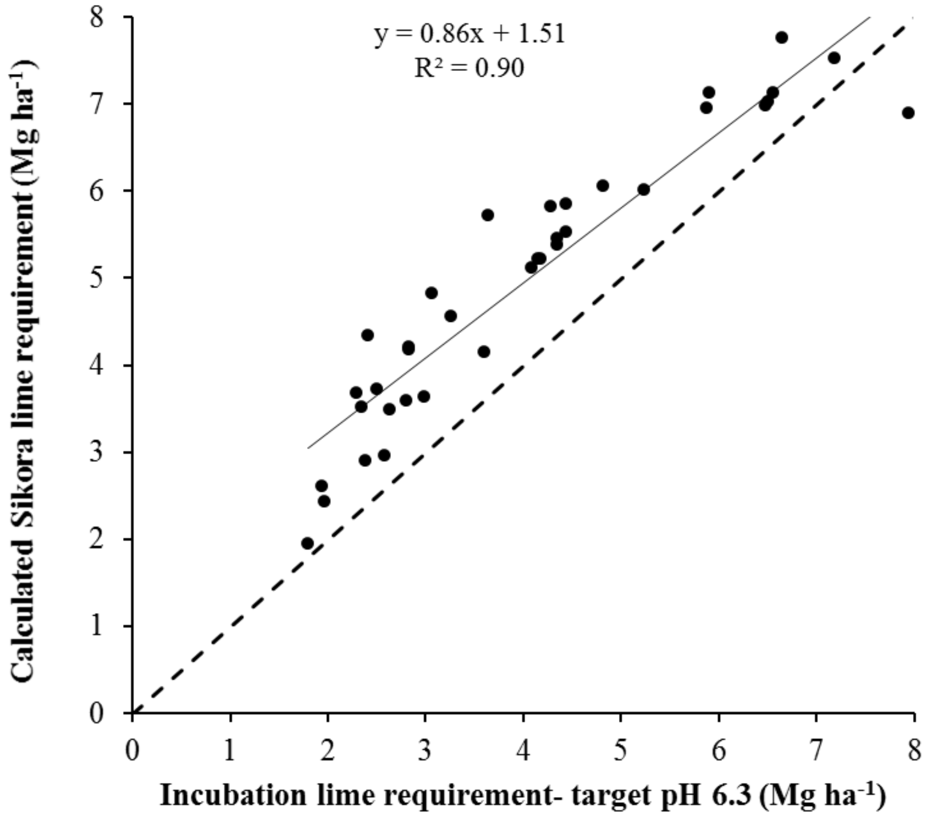

Figure 3-19. Regression of calculated Sikora lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.3.

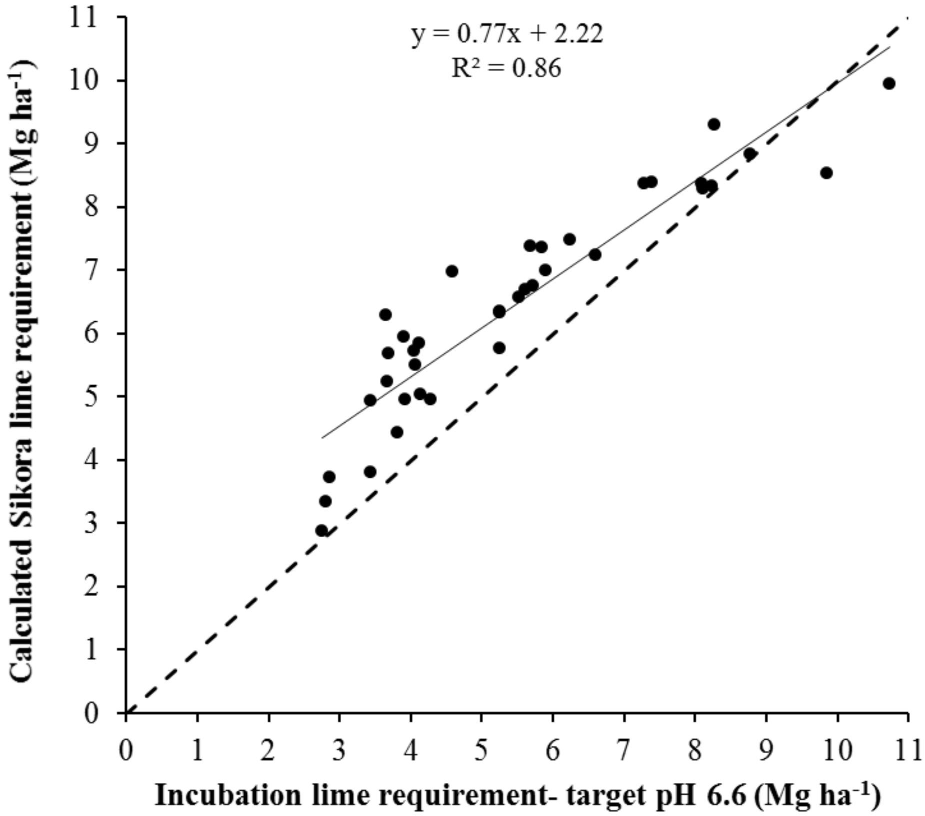

Figure 3-20. Regression of calculated Sikora lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.6.

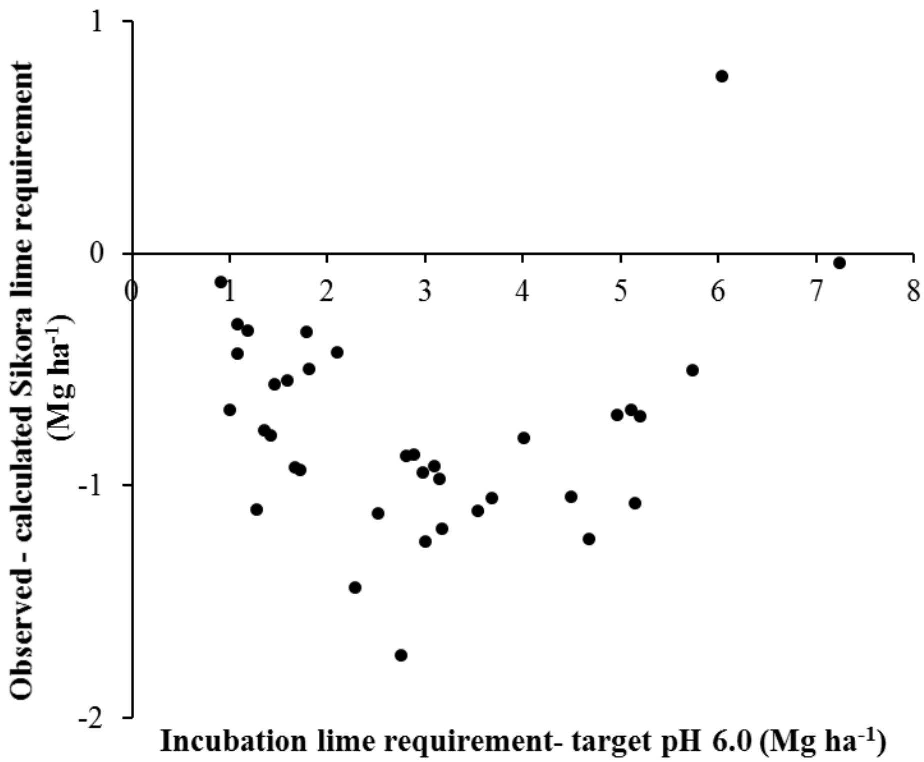

Figure 3-21. Observed incubated lime requirement minus lime requirement calculated using Sikora's buffer and Mehlich's equation for pH target 6.0.

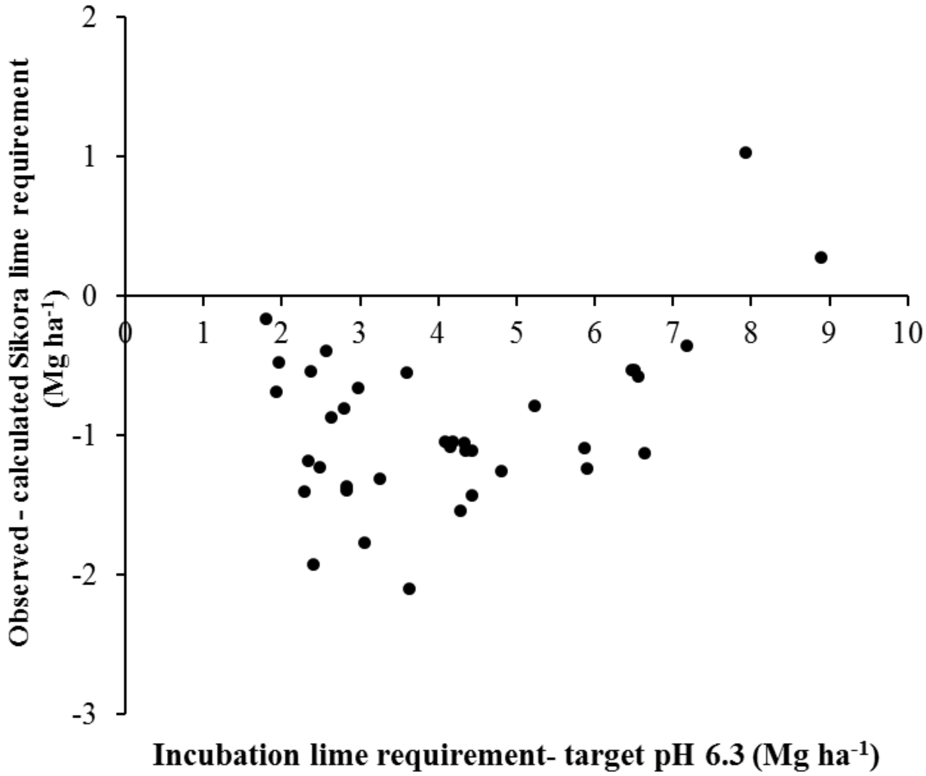

Figure 3-22. Observed incubated lime requirement minus lime requirement calculated using Sikora's buffer and Mehlich's equation for pH target 6.3.

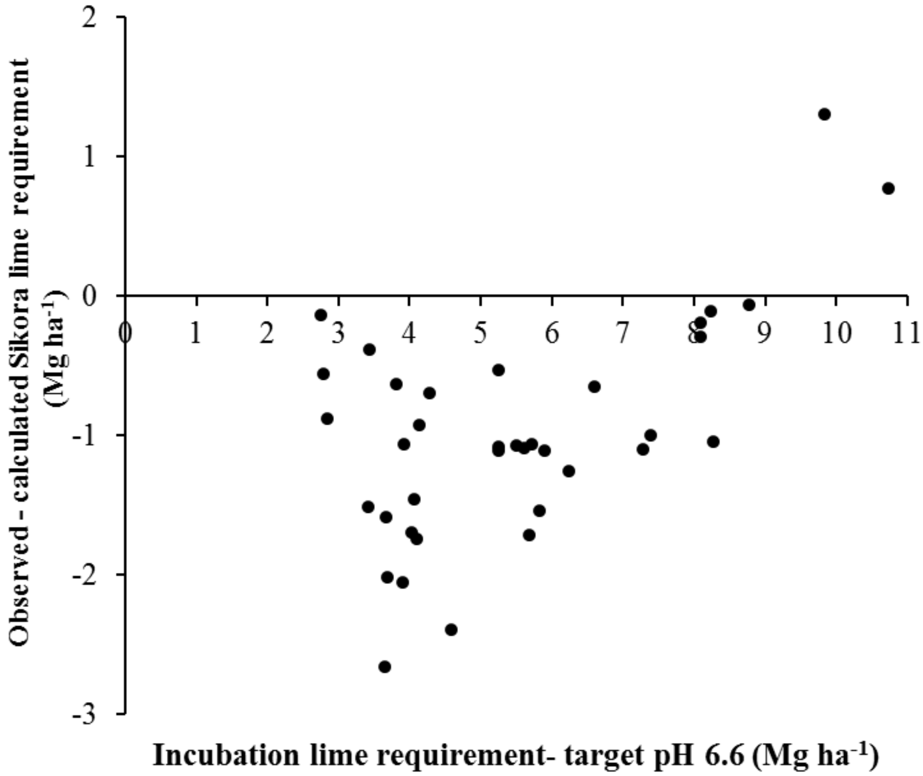

Figure 3-23. Observed incubated lime requirement minus lime requirement calculated using Sikora's buffer and Mehlich's equation for pH target 6.6.

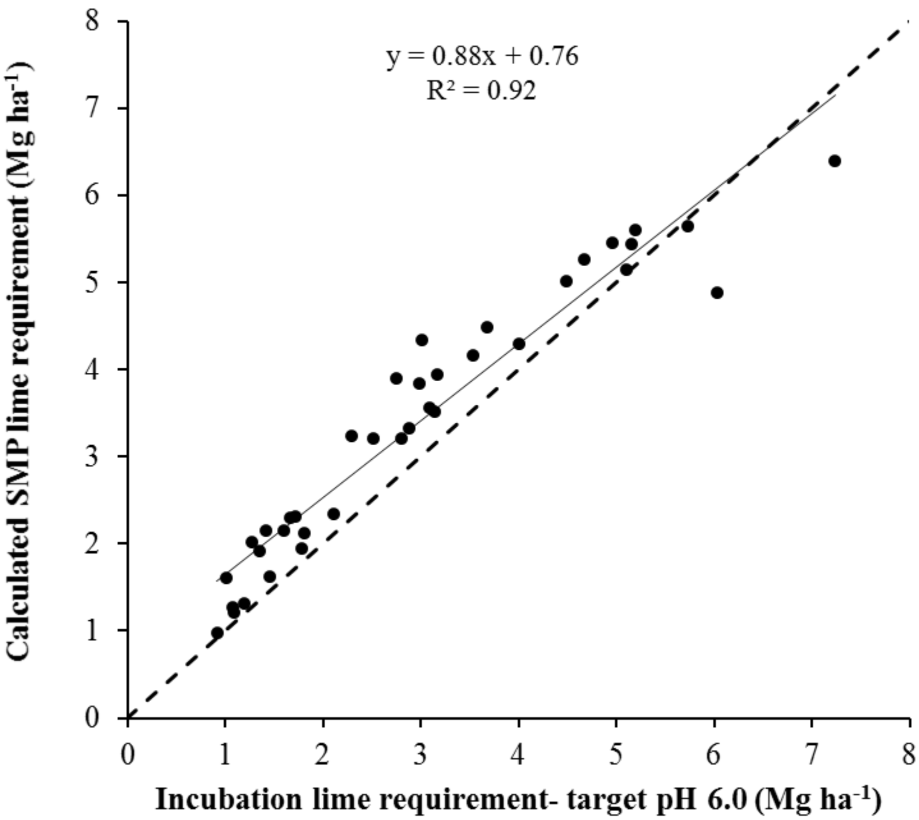

Figure 3-24. Regression of calculated SMP lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.0.

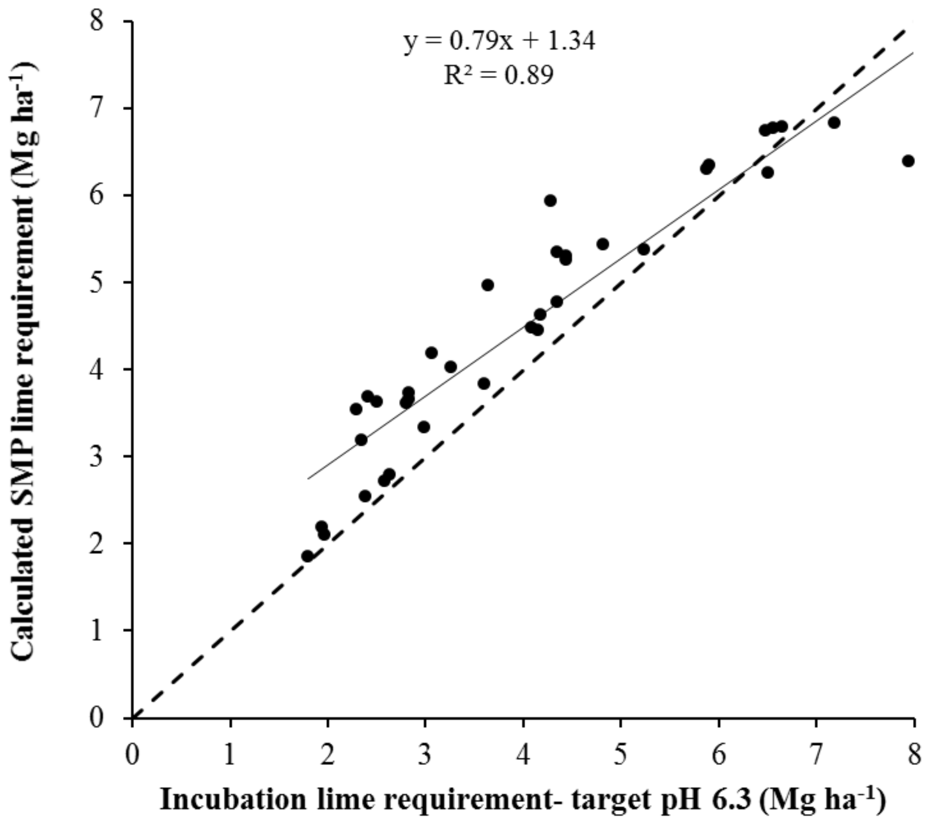

Figure 3-25. Regression of calculated SMP lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.3.

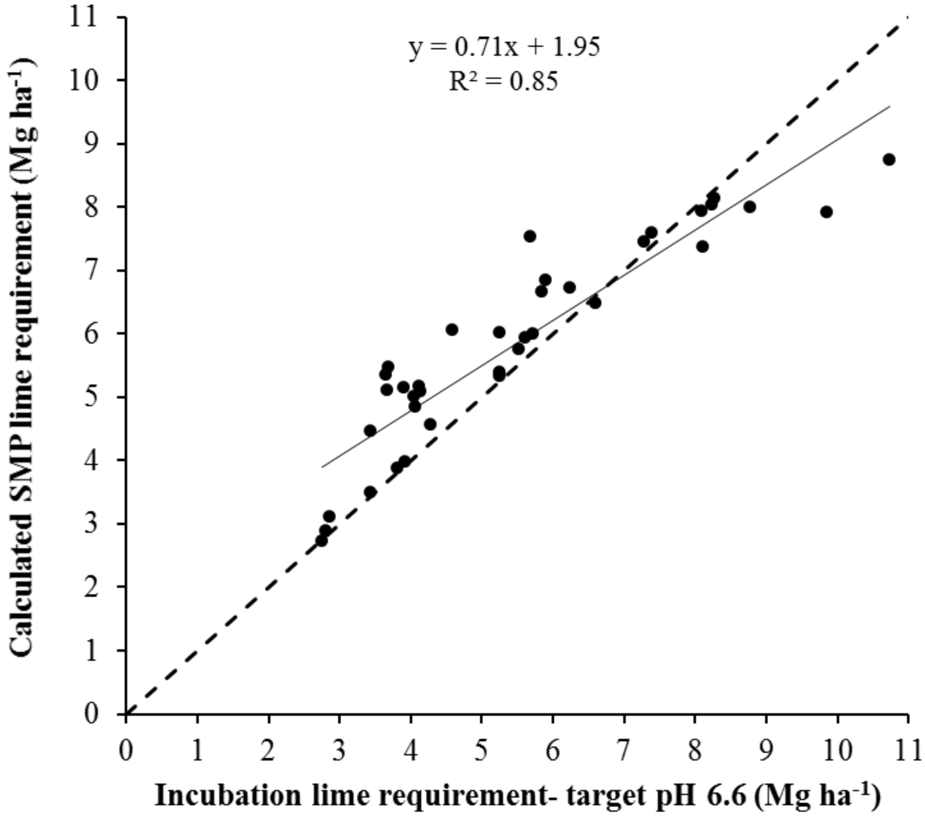

Figure 3-26. Regression of calculated SMP lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.6.

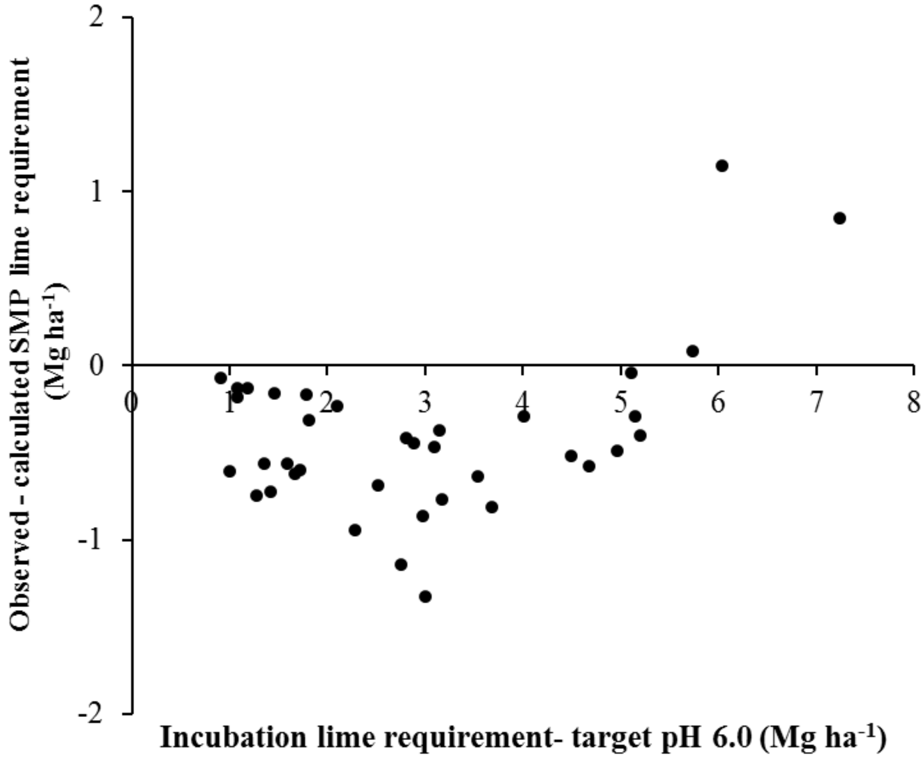

Figure 3-27. Observed incubated lime requirement minus lime requirement calculated using SMP buffer and Mehlich's equation for pH target 6.0.

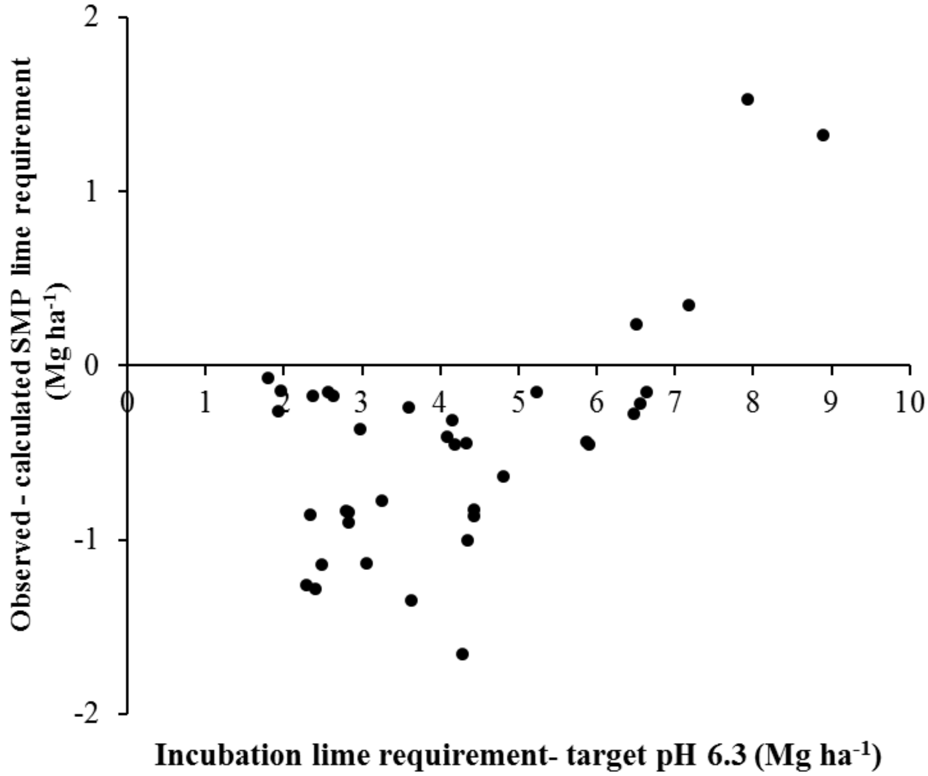

Figure 3-28. Observed incubated lime requirement minus lime requirement calculated using SMP buffer and Mehlich's equation for pH target 6.3.

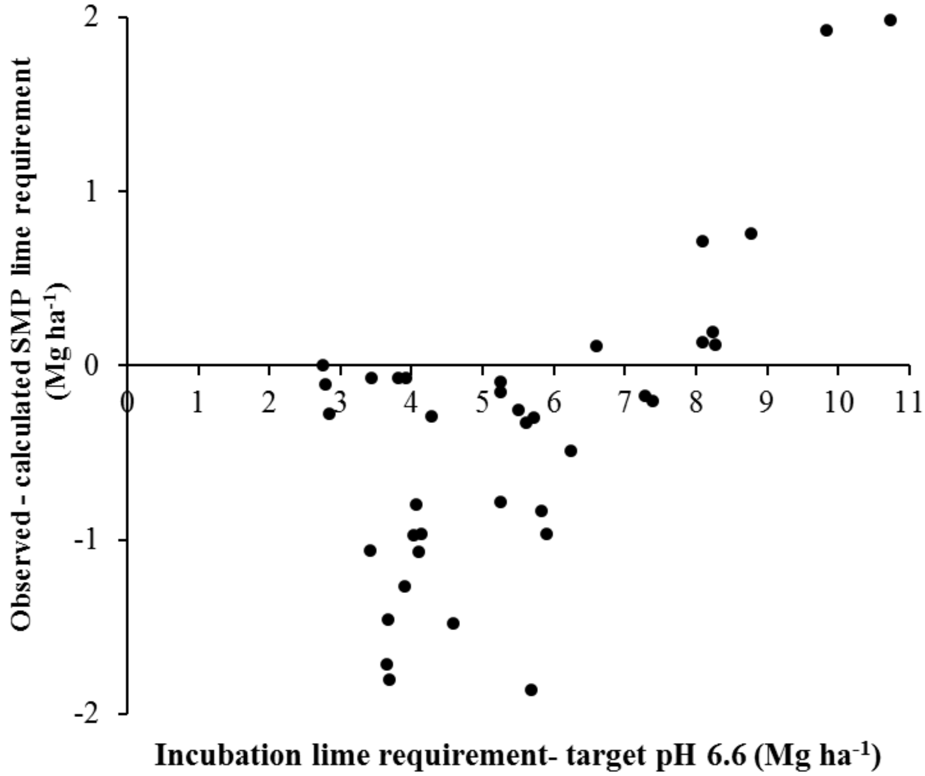

Figure 3-29. Observed incubated lime requirement minus lime requirement calculated using SMP buffer and Mehlich's equation for pH target 6.6.

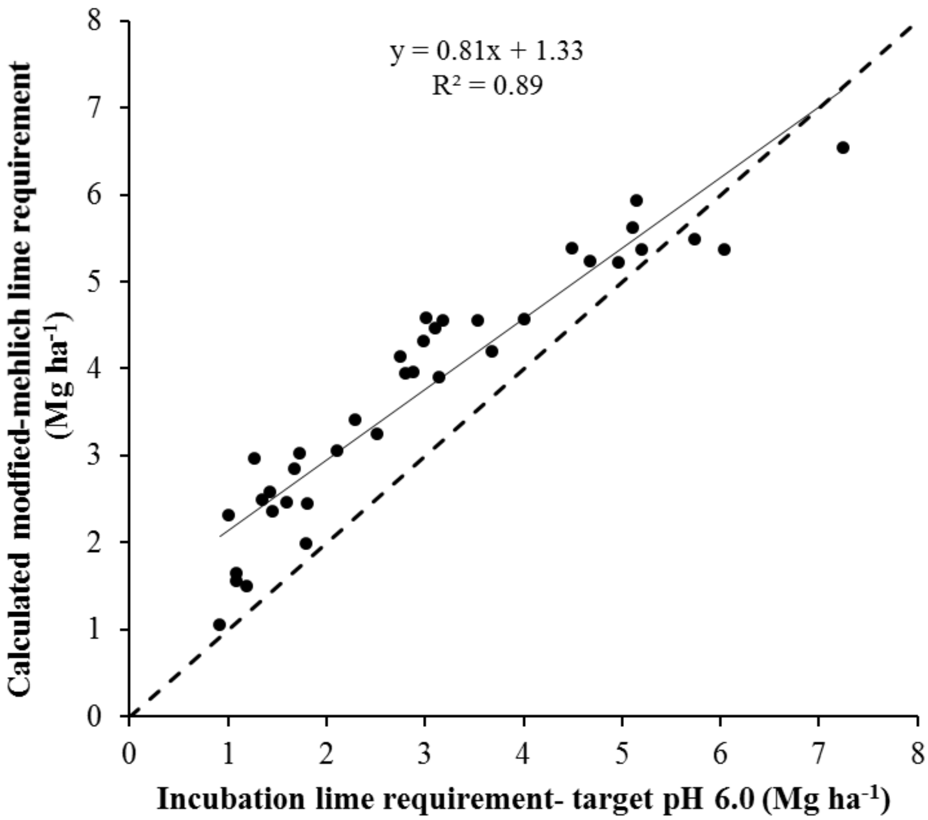

Figure 3-30. Regression of calculated modified-Mehlich lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.0.

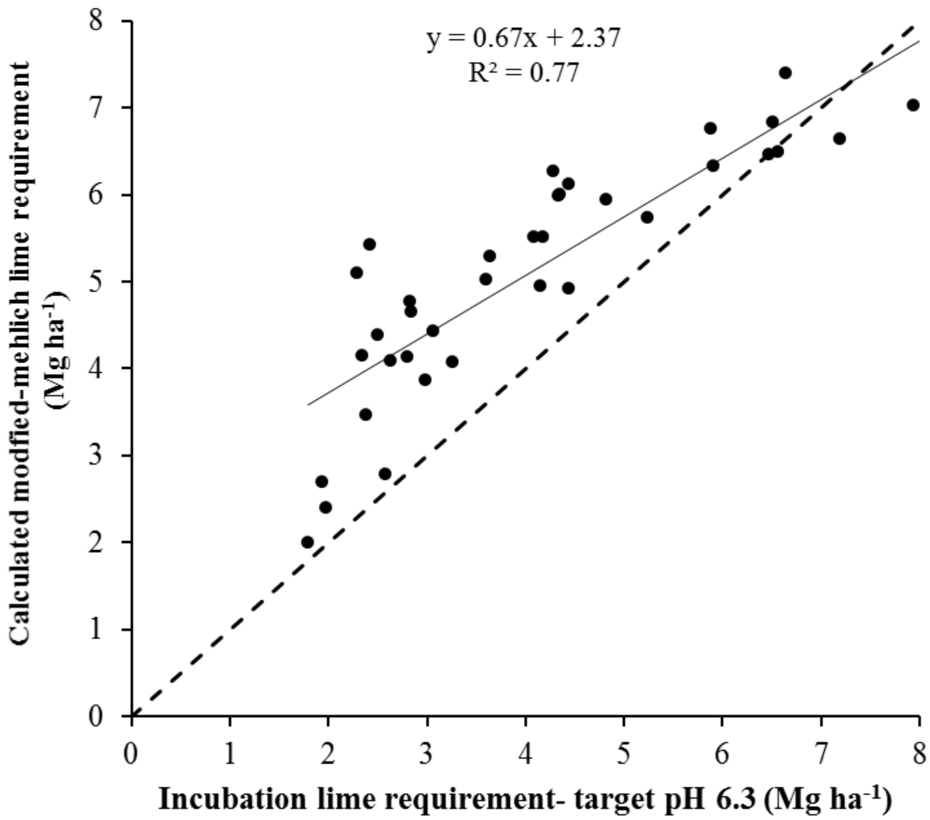

Figure 3-31. Regression of calculated modified-Mehlich lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.3.

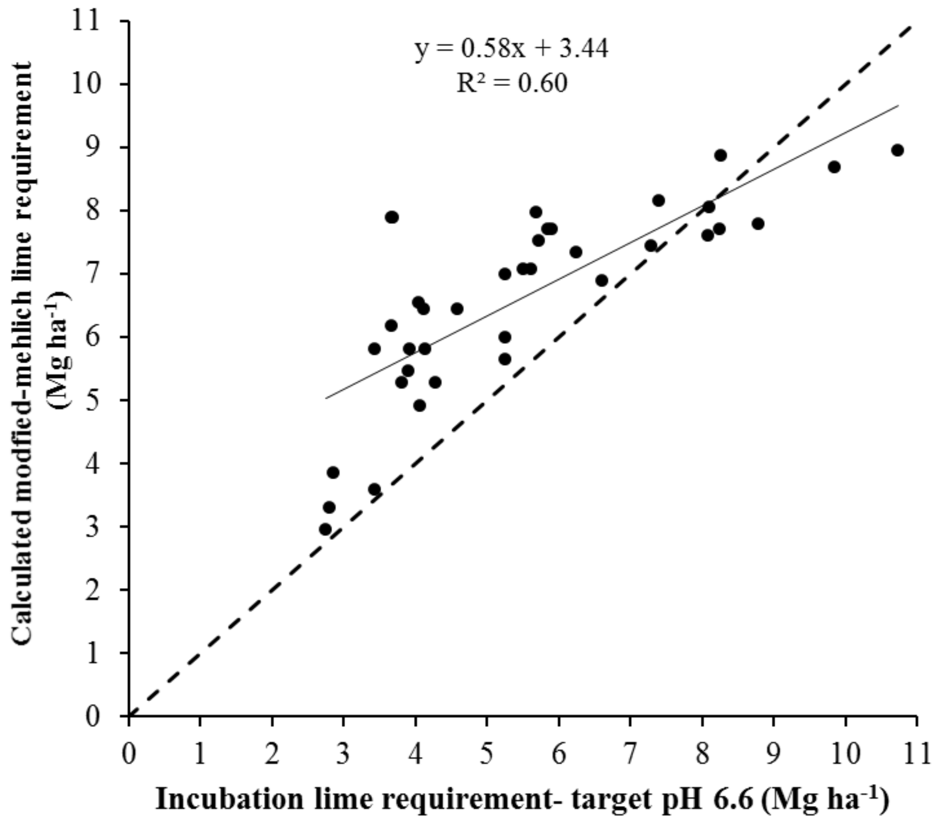

Figure 3-32. Regression of calculated modified-Mehlich lime requirement using Mehlich's equation to observed incubated lime requirement to target pH 6.6.

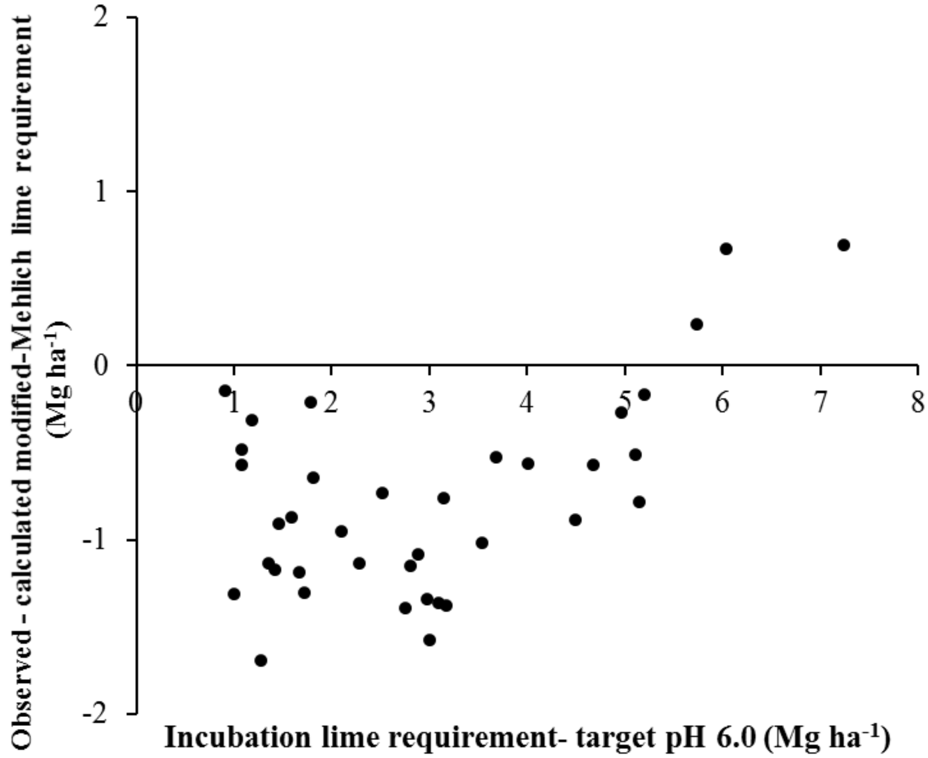

Figure 3-33. Observed incubated lime requirement minus lime requirement calculated using modified-Mehlich buffer and Mehlich's equation for pH targets 6.0.

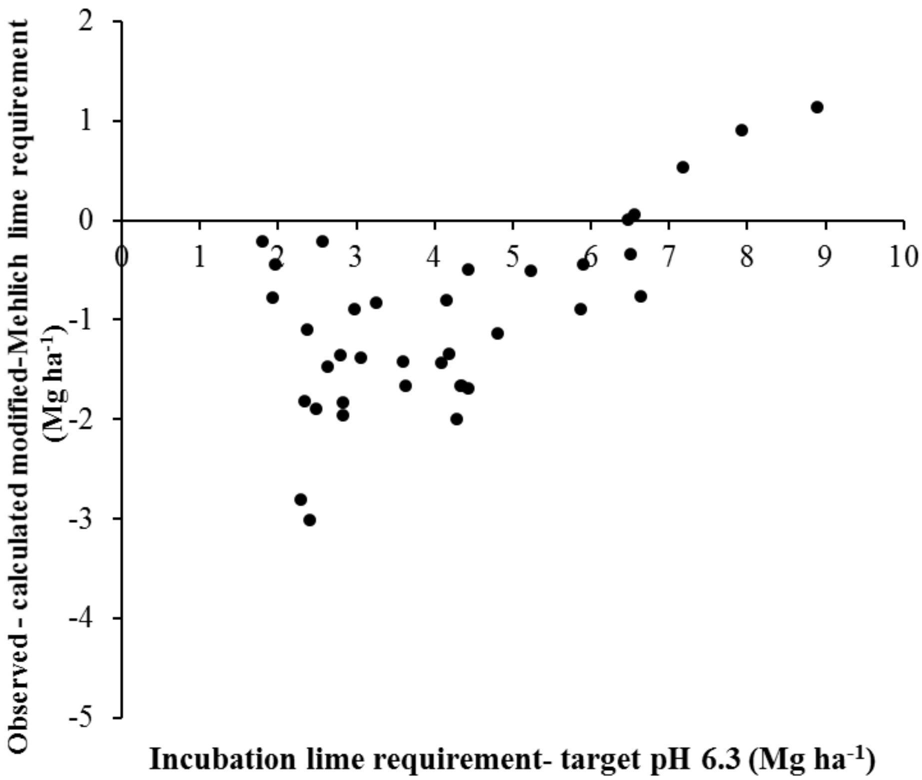

Figure 3-34. Observed incubated lime requirement minus lime requirement calculated using modified-Mehlich buffer and Mehlich's equation for pH targets 6.3.

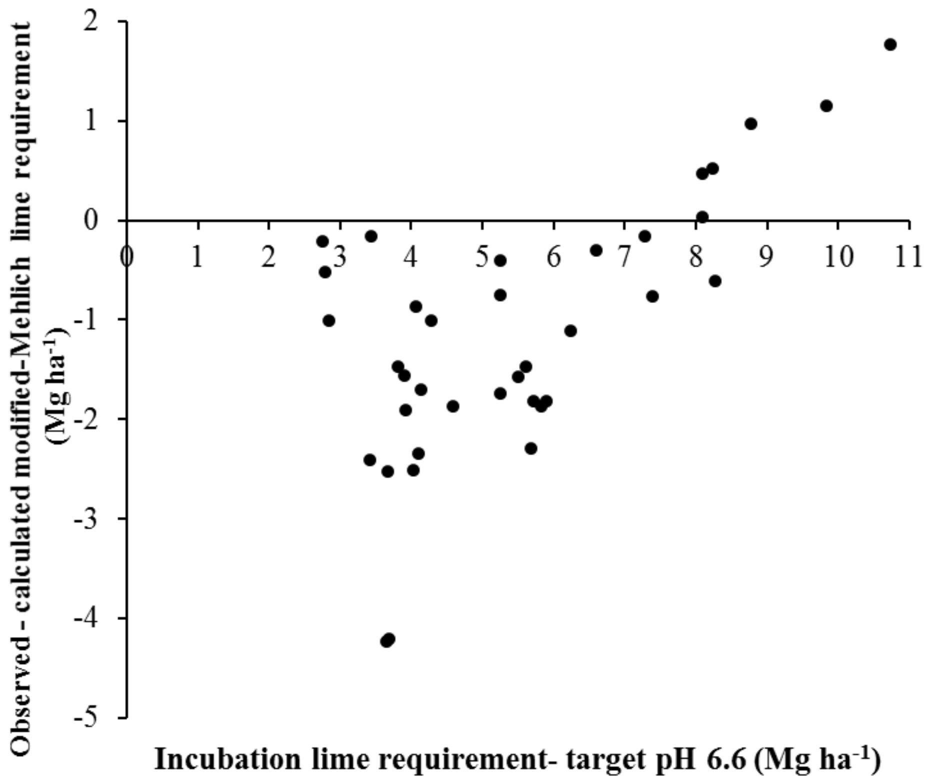

Figure 3-35. Observed incubated lime requirement minus lime requirement calculated using modified-Mehlich buffer and Mehlich's equation for pH targets 6.6.

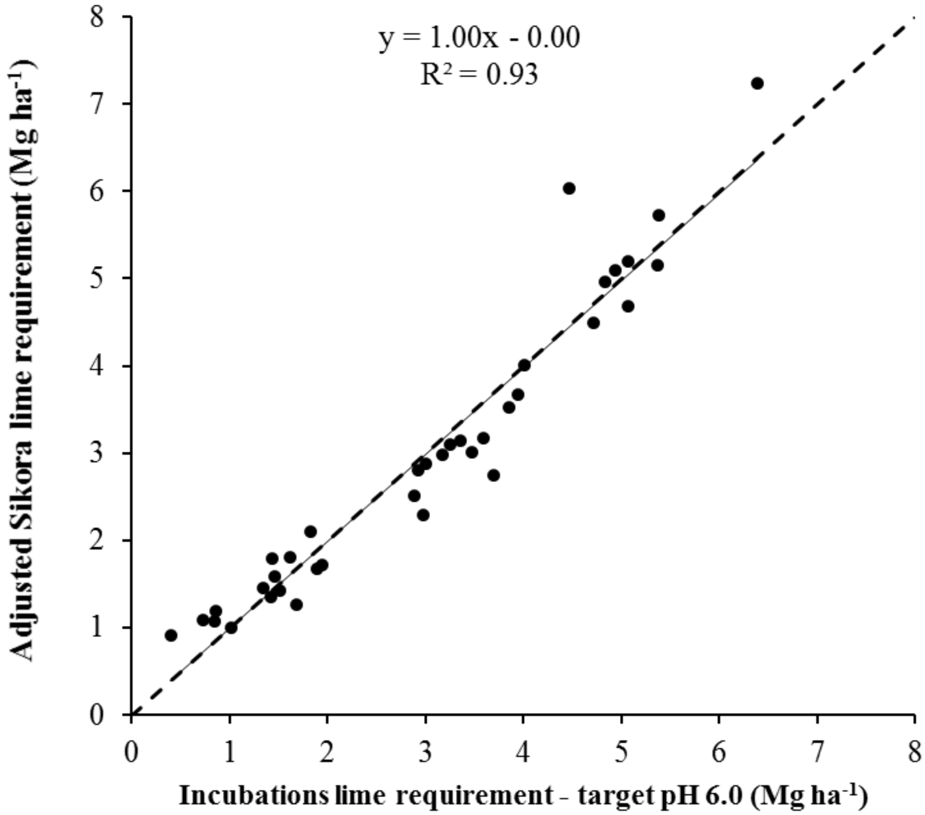

Figure 3-36. Regression of modified-Mehlich lime requirements adjusted using linear regression between calculated and observed modified-Mehlich lime requirement to target pH 6.0.

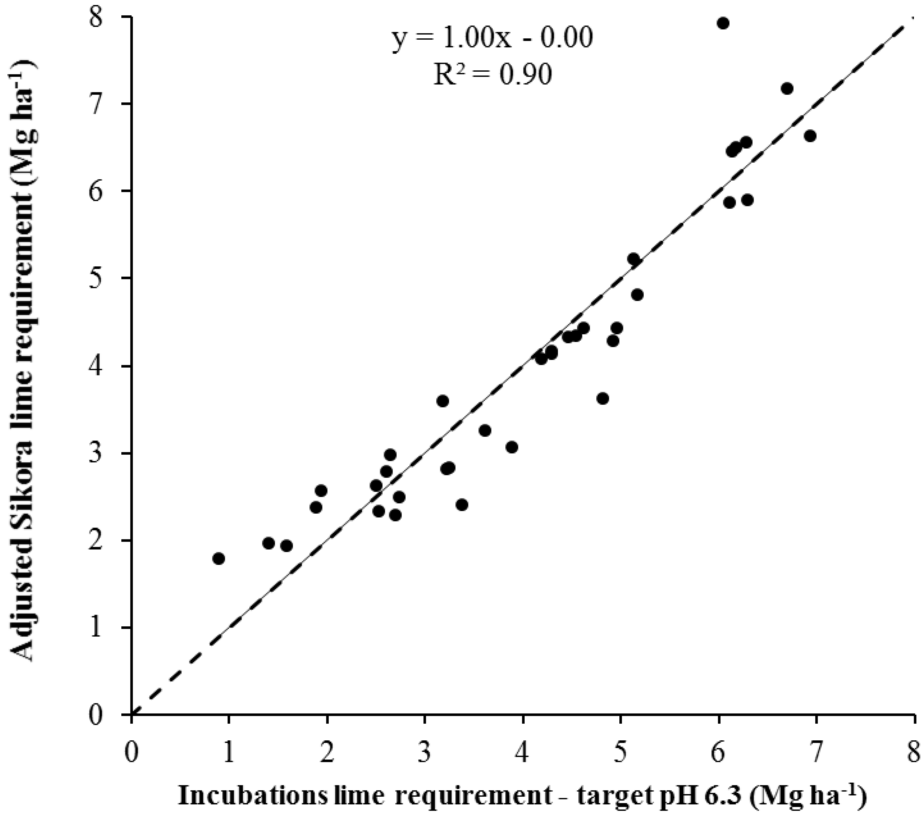

Figure 3-37. Regression of modified-Mehlich lime requirements adjusted using linear regression between calculated and observed modified-Mehlich lime requirement to target pH 6.3.

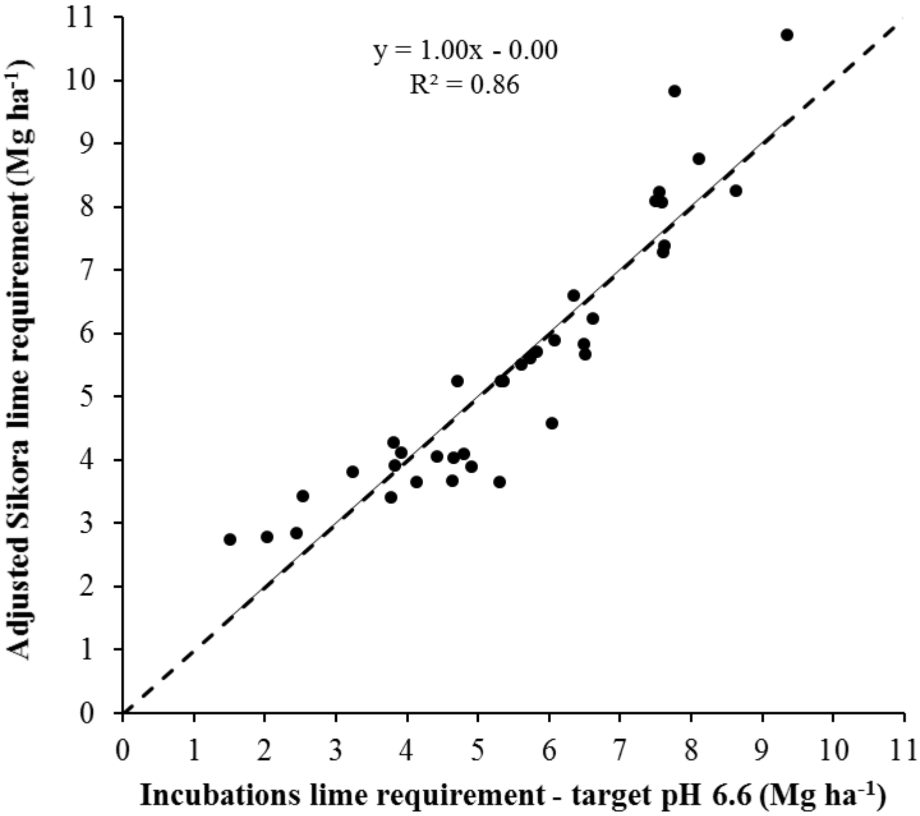

Figure 3-38. Regression of modified-Mehlich lime requirements adjusted using linear regression between calculated and observed modified-Mehlich lime requirement to target pH 6.6.

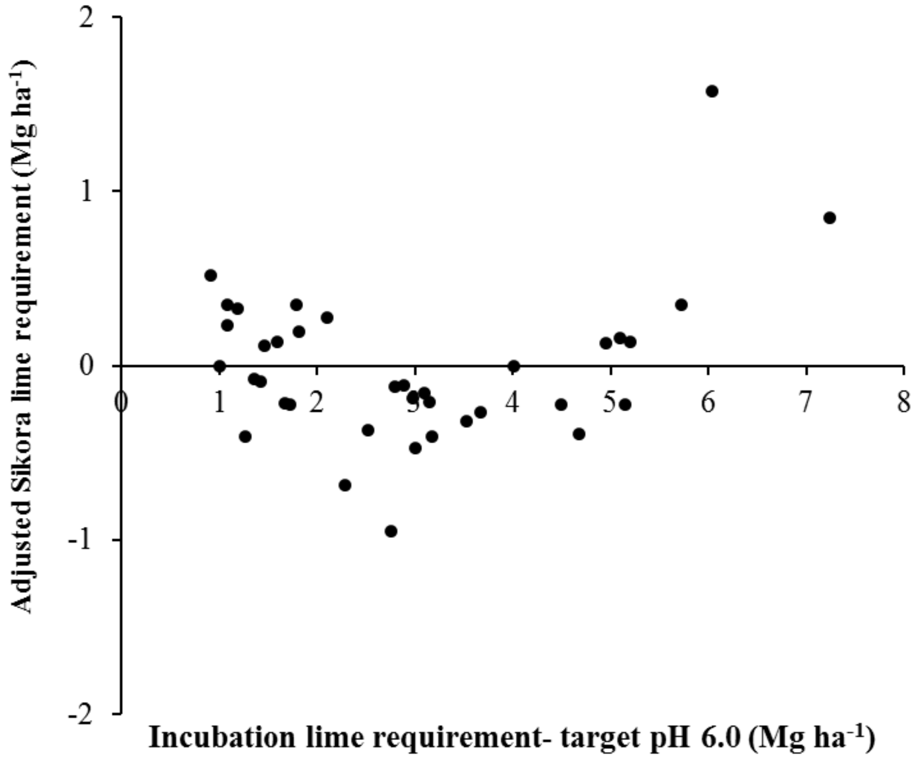

Figure 3-39. Observed incubated lime requirement minus adjusted modified-Mehlich lime requirement calculated for pH target 6.0.

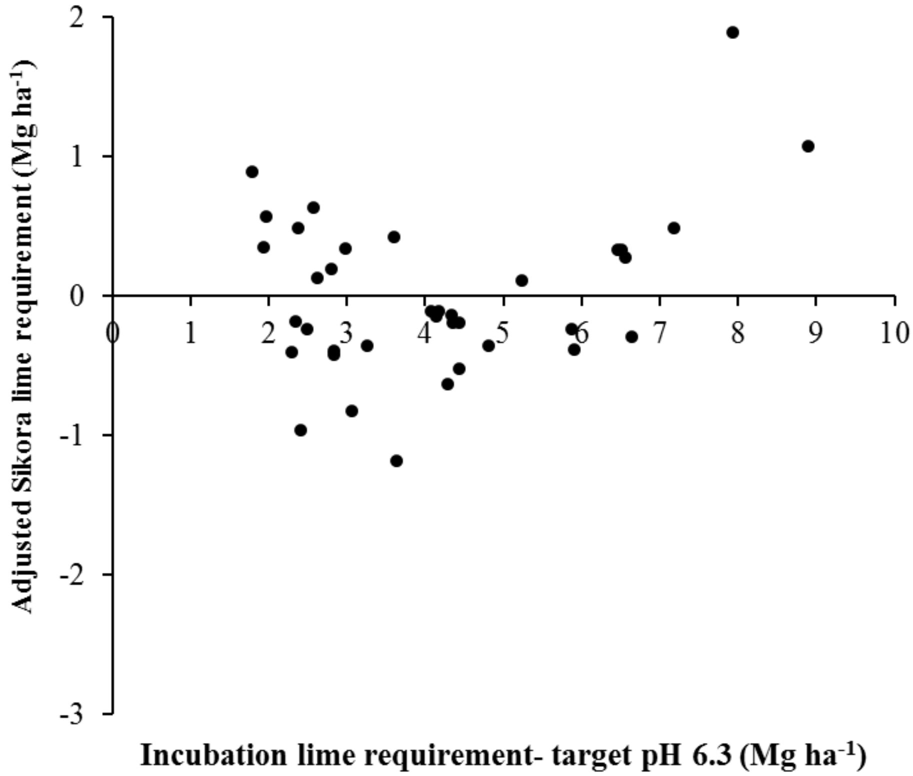

Figure 3-40. Observed incubated lime requirement minus adjusted modified-Mehlich lime requirement calculated for pH target 6.3.

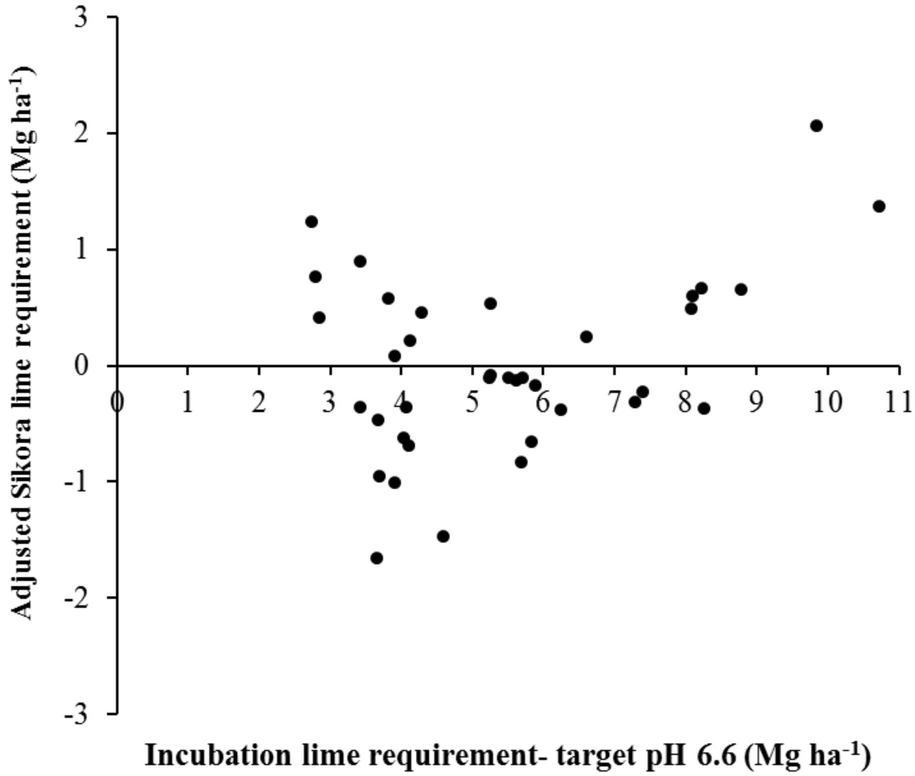

Figure 3-41. Observed incubated lime requirement minus adjusted modified-Mehlich lime requirement calculated for pH target 6.6.

Conclusions

Conclusion may be drawn about incubation length, moisture effect on final pH, and using buffers for lime recommendations. If one uses reagent grade lime and keeps samples moist, even as low as 10 percent moisture, 28 days is sufficient to measure a pH change due to added lime. One should not saturate samples in a lime incubation study as the final pH measured may be artificially inflated due to reducing conditions created. Using buffer pH value alone to estimate a soil's requirement is not always appropriate. Initial soil pH can also have an effect on lime required. Use of an equation including soil and buffer pH, such as Mehlich's equation, improves lime requirement estimations. When using Mehlich's equation, SMP provided the closest calculation to actual lime required. Modified-Mehlich performed well to pH target 6.0, but poorly to 6.3 and 6.6. Even though SMP better predicted lime requirements, Sikora would be the buffer suggest for commercial laboratories to use as it performed reasonable well to all pH targets, without hazardous materials. Adjustments for Sikora's overestimation of lime needs could be adjusted for using it regression to observed lime needs. This adjustment also improves its accuracy in estimating lime requirements.

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Chapter 4 - Phosphorus fertilizer correlation and calibration on soybeans, evaluation of banding P on yield response, and soybean P removal rate

Abstract

Total planted area to soybeans has almost double since 1982 in Kansas. Phosphorus (P) fertilizer recommendations are currently made using a general Mehlich-3 STP critical value of 20 mg kg^{-1}.for all crops. Banding fertilizer has been observed to enhance yield and nutrient uptake as compared to broadcasting fertilizer, at low soil test levels for corn and wheat. At low soil test levels using optimum fertilizer rates, a combination of broadcast and banding produces optimum yields. Maintenance P fertilizer rates for soybean, designed to replace the soil P removed in harvested grain and maintain a ST level above the critical value, are based off assumed removal of 6.6 mg P kg^{-1} dry soybean. Objectives of this study were to 1) perform a P correlation, to determine the soybean critical STP value using the Mehlich-3 extract, and determine sufficiency fertilizer application using a calibration study 2) determine if soybeans respond to starter fertilizer at low soil tests as we currently recommend and 3) to determine how much P soybeans remove when harvested, to allow calculation of replacement P fertilizer rates.

Historical P fertilization to soybean data from 1966 to 1988 was collected from Kansas State University Fertilizer Research Reports to provide a preliminary assessment of the appropriateness of the current estimates of STP critical value and P fertilizer recommendations. Starting in 2011, 23 P response experiments were conducted across Eastern Kansas, the area where soybeans are most commonly grown. In 2011 two experiments were conducted. At these sites P was broadcasted at 0, 10, 20, and 39 kg P ha^{-1}. In 2012, 2013, and 2014, with seven sites each, P was applied at rates of 0, 10, 20, 39, and 49 kg P ha^{-1} either as all broadcasted or split with 10 kg P ha^{-1} banded and remaining P broadcasted. All sites utilized a randomized complete block design with four replications, with individual plot 4.6 m x 12.2 m minimum size. Colorimetric Mehlich-3 soil P was measured in the top 15 cm by block in 2011 and 2012 and by individual plot in 2013 and 2014. The middle two rows of each plot were harvested for grain

yield, and adjusted for moisture to 13 percent. Soybean P content was also measured from 2012 to 2014.

Historical data showed a Cate-Nelson critical value of 15 mg kg^{-1}. Current data shows a Cate-Nelson and linear-plateau critical values between 10 and 15 and 11.6 mg kg^{-1}, respectively. Current data also showed a significant linear yield response to P fertilizer on soils with a STP level between 3 and 8 mg kg^{-1}. Banding P increased yield significantly, but only minimally, at one site, when compared to not banding. Grain removal was, on average, 5.0 mg P per kg of soybeans, less than the assumed 6.6 mg P kg^{-1} soybean currently recommended by Kansas State University (Liekam et al, 2003a) and International Plant Nutrition Institute (IPNI, 2005). Soybean P removal was also observed to increase with P fertilizer at one site in the drought year of 2012, six sites in 2013, and four in 2014.

Introduction

Increasing amounts of Kansas hectares are being planted to soybeans. National Agricultural Statistic Service has recorded that soybean hectares planted in Kansas has grown from 684,835 ha in 1982 to 1,616,000 ha in 2014 (NASS, 2015). With main crops in Kansas historically being wheat, grain sorghum, and corn; soybeans did not receive much research attention. Currently the soil test phosphorus (STP) critical value for soybean in Kansas is assumed to be equal to the historic crops at 20 mg P kg^{-1} using Bray-Kurtz P-1. The lack of previous P fertilizer research on soybeans and the increasing hectares planted to soybeans creates a need to examine what the soybean STP critical level is and the appropriate fertilizer recommendation to make on soils at various P levels.

Soil test critical values are determined by a correlation study. A correlation study defines the soil test level below which a response to added nutrient would be expected. Correlation studies are performed by comparing yields of fertilized and unfertilized areas, across a range of soil test values, years, and relevant locations. Fertilizer recommendations for optimum yield are made when a soil test extract value falls below an established critical soil test level.

The critical value may be determined by multiple methods such as Cate-Nelson visual approach or with a linear or quadratic-plateau, or other agronomically appropriate mathematical models. Cate-Nelson involves drawing a vertical and horizontal line on a correlation graph and maximizing the number of points in the lower left and upper right quadrants. A plateau model defines a mathematical and statistically significant point at which a crop's response switches from a linear or non-linear response to increasing soil test level, to a stable, plateau yield when describing the correlation between soil test value and relative yield. The Cate-Nelson method has been observed to give lower Bray-Kurtz P-1 P critical values for corn and soybeans in Iowa (Mallarino and Blackmer, 1992). Cate-Nelson has also been observed to provide economically superior profits, on an annual basis, when compared to a linear plateau model, quadratic, and exponential models at various sufficiency levels (Mallarino and Blackmer, 1992). Mallarino and Blackmer explain that the Cate-Nelson may have provided better economic returns than the linear plateau model because they set the constraint assuming that relative yield increases linearly to a certain STP level. Mallarino and Blackmer explain that the quadratic model performed worse than the Cate-Nelson because there were no data points showing a decreasing trend at high STP values.

While correlation studies determine if fertilizer is needed, it does not tell one how much fertilizer must be applied to optimize yield at low soil test levels. The amount of fertilizer to apply is determined by a calibration study. Calibration studies are normally conducted in conjunction with a correlation study. A rate response to fertilizer using relatively small increments of increasing nutrient is conducted over a broad range of soil test levels. Barber (1967) suggested to start the initial interpretation of the obtained data by grouping the experiments into three soil test groups (responsive, moderately responsive, and low response) and subdivide the responsive soil test groups more as additional data allows. The premise upon which this concept is based is that as soil test level for the nutrient increases, the response to applied fertilizer will decrease.

Determining an exact rate of P fertilizer to apply at a given ST level has been deemed weak by Fixen and Grove (1990) because of confounding factors. They summarize literature arguing that tillage (Fixen et al., 1987), mineralization of P (Vivekanandan and Fixen, 1988), and moisture availability (Randall et al., 1986) will all affect results of a calibration study, making interpretations difficult.

Yields from correlation and calibration studies are often transformed into relative yield (Equation 4.1) to allow for comparisons across moisture regimes, soils, and managements.

Relative yield and yield have been observed to give a similar relationship and P critical value for soybeans (Evans, 1987). Relative yield is also shown to be consistent when yields are improved due to a more favorable moisture regime in alfalfa (Stanberry et al., 1955).

Equation 4-1. Relative yield

Relative yield = (yield of observed plot / yield of plot with no limiting nutrients) x 100.

Relative yields from correlation and calibration studies are compared to soil test value from P extracts. Multiple soil P extracts have been designed, and the critical value may vary between these different tests. Thus separate correlation studies must be conducted for each different soil test extract being used. Due to the cost of conducting the required correlation and calibration work to adopt a new soil test procedure, development of new and improved extracts has declined in recent years. Soil P on north central US soils was commonly extracted with Bray-Kurtz P-1 on acid soils. Bray-Kurtz P-1 does not correlate well to yield on soils with free carbonates. Because of this, Olsen et al. (1954) developed an extract to remove P on alkaline soils. Currently, many commercial labs use Mehlich-3 as it works well on both acid and alkaline soils and correlates well to both extracts. Unpublished data from Kansas State University Soil Testing Laboratory suggest a 1:1 and 1:1.6 relationships between Bray-Kurtz P-1 on acid soils and Olsen-bicarbonate, on alkaline soils, to Mehlich-3, respectively.

Fertilizer recommendations derived from a calibration study may be further adjusted by application methods. Banding fertilizer has been observed to be more efficient than broadcast on corn and wheat, especially at low soil test levels. Chapiro et al. (2008) recommend using half P rate application to corn when banding fertilizer as opposed to broadcast. Peterson et al. (1984) observed that banding efficiency increased over broadcast as Bray-Kurtz P-1 P decreased for winter wheat. Soybeans have not been observed to show a different yield response to banded or broadcast P (Borges and Mallarino, 2000).

In some situations fertilizer recommendations may be to just maintain soil test levels at or slightly above the soil test critical level by replacing the nutrients removed at harvest. These recommendations are also called “maintenance rates”. This is intended to prevent soil test levels from dropping to deficient levels, below the critical level, over time. Many universities use 5.8 kg P Mg^{-1} as a removal or replacement fertilizer rate for soybeans. Mallarino et al. (2003) found average soybean P removal rates across eleven site years, to be 5.7 kg P Mg^{-1} for soybeans. More notable than the average soybean P removal rate was the variation with 3.0 to 7.6 kg P Mg^{-1}. This variation could affect soil test values over time if removal rates differ from those assumed.

Objectives of this study were to 1) perform a P correlation calibration study with soybeans to determine the soybean P critical value using the Mehlich-3 P test 2) determine if soybeans respond to starter fertilizer at low soil tests as Liekam et al. (2003a) currently recommends and 3) to determine how much P soybeans remove when harvested, to allow calculation of replacement P fertilizer rates.

Method and Materials

A preliminary correlation and calibration was performed from a review of 23 soybean P fertilizer experiments published in the Kansas State University Fertilizer Research Reports from 1966 to 1988. Beginning in 2011, a total of 23 field trials were conducted on cooperating farmer's production fields and university experiment stations. In 2011 and 2012, 0-15 cm soil samples for P were taken by block to determine initial colorimetric Mehlich-3 P levels. Soil P was determined by scooping 1.70 cm^3 of soil into a 50 mL plastic Erlenmeyer flask, adding 20 mL of Mehlich-3 (0.2 N CH_3 COOH, 0.25 N NH_4NO_3, 0.015 N NH_4F, 0.013 N HNO_3, and 0.001 M EDTA), swirling for 5 minutes on an oscillating shaker, filtering, and measuring extract with a LACHAT QuikChem 8000 (Frank et al., 1997). In 2013 and 2014, soil sampling was intensified to each individual plot, due to the intense short-range variability in soil test P observed at many research sites.

A randomized complete block design with four replications was used at all locations. Individual plots were 4.6 m x 12.2 m minimum size.

Table A-1. Site locations, planting date, variety, seeding rate, row spacing and notes to differentiate sites on same farm for 2011 to 2014.

County	planting date	variety	seeding rate	row spacing	notes
			2011		
Cherokee	24-Apr	Asgrow 5405	130,000	76	
Woodson	24-Apr	Pioneer 94Y70	105,000	76	
2012					
Saline	24-Apr	Pioneer 93Y70	144,000	76	Flood irrigated
Saline	24-Apr	Pioneer 93Y70	139,000	76	
Woodson	17-May	Pioneer 94Y70	110,000	76	meadow
Woodson	17-May	Pioneer 94Y70	110,000	76	lynx
Nemaha	10-May	Midland 4339LL	177,000	76	
Riley	16-May	3406	120,000	76	
Riley	18-May	Pioneer 9370		76	
			2013		
Atchison	17-May			76	
Douglas	15-Jun			76	
Riley	18-May			76	
Riley	24-May			76	
Lyon	21-May			76	
Woodson	8-Jun			76	upland
Woodson	8-Jun			76	lowland
			2014		
County	planting date	variety	seeding rate	row spacing	notes
Woodson	15-May	P39T67R	135,000	76	meadow
Woodson	15-May	P39T67R	135,000	76	pasture
Lyon	20-May	Midland 450R52	161,000	19	
Riley	20-May			76	
Jackson	15-May			38	
Osage	30-May	AG4531	130,000	76	
Clay	20-May			76	

In 2011, P was broadcast at rates of 0, 10, 20, 29 and 39 kg P ha^{-1}. In 2012, 2013, and 2014, P was applied at rates of 0, 10, 20, 29, 39, and 49 kg P ha^{-1} either as all broadcasted or split with 10 kg ha^{-1} banded and the remainder broadcast. Broadcast P was applied as monoammonium phosphate (MAP, 11 N -25 P- 0 K) and banded P as liquid ammonium poly phosphate (APP, 10 N -15 P -0 K). Split applications were not made in Lyon or Jackson Counties in 2014, due to wet field conditions. In 2014, N contributed to split plots from APP was matched on broadcast plots with urea-ammonium nitrate (28 N- 0 P - 0 K), totaling 15 kg N ha^{-1}. All P fertilizer applications were made immediately after the field was planted by cooperating farmer, or research staff.

Yield was determined by combine harvesting two middle rows of each plot, at maturity. Moisture was measured using a Dickey John GAK 1000 moisture meter, and yield normalized to 13 percent grain moisture. Grain P was measured in all years, except 2011, by the KSU Soil Testing Lab. Palnt tissue was digested using a sulfuric acid-hydrogen peroxide digestion as described by Thomas et al., (1967). Digests were analyze for P using an Inductively Coupled Plasma (ICP) Spectrometer (Varian Austrailia Pty Ltd, Mulgrave, Vic Australia)

Control plot relative yield was determined as percentage of highest yielding plot in it respective block. Critical values were determined by both a visual Cate-Nelson (Cate and Nelson, 1971) and non-linear plateau method, using PROC NLIN (SAS 9.3; Cary, NC), for both historical data and current data excluding 2012 (drought), Lyon County in 2013 (flooded) and 2014 (late planting). Treatment differences for each site were determined with Proc Mixed (SAS 9.2; Cary, NC) with blocks as random effects. Broadcast P Economics were analyzed assuming soybeans price at $440 USD Mg^{-1} and MAP fertilizer at $2906 USD Mg^{-1} P.

Results and Discussion

Yield responses

Yield difference by treatment at each historical site analysis on the historical data could not be performed, as only treatment averages were reported, but trends are present. Table 4-2 lists the experimental sites by their STP value, along with yield at various P application rates. One could argue that 4 of the 25 sites showed a response to P fertilizer. These sites are Parsons in 1966 and 1978, Powhattan in 1967, and Ottawa in 1967. All of these sites had a STP of 12 mg kg^{-1} or less. One would probably not conclude that P application improved yield on the eight sites < 12 mg kg^{-1}, supporting previous research that soybeans do not consistently respond to P fertilizer. The lack of yields trending up with P application once STP levels are above 12 mg kg^{-1} would suggest that this is the critical level, and that no P fertilizer should be recommended at higher STP levels.

Table A-1. Summary of soybean P fertilizer experiments from Kansas State University's Fertilizer Research Reports.

			P applied (kg P ha^{-1})						
Site	**Year**	**Soil P**	**0**	**7**	**15 to 20**	**20 to 30**	**30 to 40**	**40 to 50**	**> 50**
		Mg kg^{-1}	**Average soybean yield (Mg ha^{-1})**						
Parsons	1978	6	1.46			1.64		1.75	1.81
Powhattan	1966	7	2.77	2.57					2.64
Powhattan	1967	8	2.58	2.63	2.63		2.73		2.63
Columbus	1969	8		1.74	1.76		1.71		1.93
Powhattan	1969	8	2.49	2.35	2.45		2.35		2.43
Parsons	1966	9	1.66	1.73	1.93		1.74		1.83
Parsons	1981	9	2.67		2.68		2.72		
Newton	1966	10	1.30	1.25	1.16		1.10		1.12
Ottawa	1966	12	3.31	3.36	3.28		3.50		3.21
Ottawa	1967	12	1.57	1.71	1.77		1.77		1.71
Ottawa	1969	12		2.28	2.27		2.35		2.15
Cherokee	1970	12	1.86			1.95			
Columbus	1964	13	1.16		1.23		1.16		
Pawnee	1974	13	1.95		2.12		2.12		2.10
Cherokee	1978	13	1.28		1.25	1.29		1.33	
Cherokee	1988	13	1.59		1.59		1.59		
Cherokee	1980	14	0.73		0.76		0.79		
Columbus	1978	17	1.99		1.90	2.03		2.04	
Unknown	1970	19	2.02			2.05	2.10		
McPherson	1970	19	2.25		2.18		2.22		
Cherokee	1988	20	2.50		2.56		2.53		
Gardner	1970	23	1.21		1.19				
St John	1969	35	3.23			2.89	2.96		
Desoto	1971	37	2.10		2.25				
St John	1970	41	3.70			3.49	3.39		

Of the 23 sites used from 2011 to 2014, only three responded to P fertilizer. These sites were Woodson County in 2011, Atchison County in 2013, and Riley County in 2014. In 2011, only two sites were observed (Table 4-4). The results from this were promising from a correlation stand point but inconclusive for calibration. The Woodson County site showed a yield response to 10 kg P ha^{-1} with 5 mg kg^{-1}, and the Cherokee County sites did not response to any fertilizer at 16 mg kg^{-1}. The lack of response at 16 mg kg^{-1} started to build evidence against using STP level of 20 mg kg^{-1} as a soybean critical value. No difference between the fertilizer treatments themselves at Woodson County, was foretelling of future calibration data. One could conclude that fertilizer was needed at 5 mg kg^{-1}, and either only 10 mg kg^{-1} was needed for optimal yield or soybean response to increasing amounts of fertilizer is inconsistent.

No yield response was observed in 2012 (Table 4-5). Soil P may not have been the yield limiting factor this year as it was a hot and dry year. Sites in Riley and Woodson County went through July with less than 2.2 cm of rain, while Saline and Nemaha Counties went through May with less than 1.02 and 1.78 cm of rain, respectively (Kansas State University weather data library). Even with Woodson County only receiving 23 cm of rain from May to August, Woodson County – Lynx showed a field yield average almost triple the Woodson County average in 2012 at 1.02 Mg ha^{-1} (NASS, 2013). With this high of a yield on such low STP, one might have expected a response to P fertilizer but none was seen (P-value 0.47). When comparing this with 2011 results one may conclude that the crucial level might be lower than 16 mg kg^{-1}.

Favorable weather in 2013, lead five of the seven sites to have yields consistently above the state average of 2.41 Mg ha^{-1} (NASS, 2015) (Table 4-6). Through May to August all counties with a site received at least 35 cm of rain (Kansas State University weather data library). Even with good weather and three sites having STP values $\leq$ 11 mg kg^{-1} only one site, Atchison County at 11 mg kg^{-1}, responded to P fertilizer. Lyon County had a STP test of 8 mg kg^{-1} but yield was limited because of flooding. Douglas County had a soil test P value of 11 mg kg^{-1} and did not respond to P applications. No response was observed at four sites with STP values > 16 mg kg^{-1}.

Comparable weather to 2013 returned in 2014 (data not yet posted), and similar results to 2013 were observed (Table 4-7). Two sites had a STP of 11 mg kg^{-1} and one response to P while another did not. Three sites had a STP $\geq$ 15 mg kg^{-1} and did not respond to P applications. Lyon County had a STP of 9 mg kg^{-1} plants did not grow above 45 cm tall, limiting yields. Woodson County pasture had a STP of 7 mg kg^{-1} but did not response to P applications.

The lack of a response at or above STP 16 mg kg^{-1} further supports not using 20 mg kg^{-1} as the STP critical value for soybeans. An inconsistence in yield response observed at a STP of 11 mg kg^{-1} and no response at one site at 7 mg kg^{-1} may be due to factors pointed out by Fixen and Grove (1990). They mention that past literature has shown how tillage (Fixen et al., 1987), mineralization of P (Vivekanandan and Fixen, 1988), moisture availability (Randall et al., 1986) may affect P fertilizer trail results. If more P is mineralized at one site then another then the critical level at that site would be lower. Climate can affect the P critical level as more rainfall will increase the amount of soil water solution, leading to greater diffusion of P to the plant. The more soil P that can diffuse to the plant the lower the STP value will be at which a response to fertilizer is seen.

Another variable which Fixen and Grove (1990) do not bring up is soil P variability. Table 4-3 shows that the STP standard deviation for the 2013 and 2014 sites ranged from 1.2 to 6.9 and 2.6 to 13.0, respectively. This could be major factor in why two sites at 11 mg kg^{-1} responded significantly to P, while two did not. In site variability could have played a role in the yield response. If a plot receiving 50 kg P ha^{-1}, had a lower STP than a plot receiving no P but had a higher STP then the results could be skewed.

Table A-2. Mehlich-3 STP Average and standard deviation for each site in 2013 and 2014.

	Mehlich-3 P	
County	**Average**	**Standard deviation**
	mg kg^{-1}	
	2013	
Lyon	8	1.2
Douglas	11	2.1
Atchison	11	2.1
Woodson - upland	16	4.3
Riley - Randolph	23	5.8
Riley - Manhattan	21	6.7
Woodson- lowland	16	6.9
	2014	
Woodson - pasture	7	2.6
Lyon	9	2.9
Riley- Randolph	11	3.1
Woodson - meadow	11	3.9
Osage	15	6.6
Jackson	34	13.0
Clay	22	13.0

Our results are similar to past studies. Borges and Mallarino (2000) found no yield response to soybeans on soils higher testing higher than 9 mg kg^{-1} in top 15 cm, using Bray-Kurtz P-1. Dodd and Mallarino (2005) rarely saw a soybean yield response to P fertilizer when 0 to 15 cm soil test P was above 16 mg kg^{-1} Bray-Kurtz P-1.

Table A-3. Soybean yield response to MAP fertilizer broadcasted at 0, 10, 20, 29, and 39 kg P ha^{-1}, at two sites in 2011.

Location Site	Soil P mg kg^{-1}	Broadcast MAP (kg P ha^{-1}) 0	10	20	29	39	Pr > F
		------------------ Yield Mg ha^{-1} at 13 percent moisture				------------------	
Woodson	5	2.15 B†	2.55 A	2.49 A	2.49 A	2.49 A	0.07
Cherokee	16	1.88	1.75	1.88	1.95	1.95	0.66

†Letters signify differences at α=0.10, across rows, using Proc Mixed in SAS 9.2 with blocks as the random effect.

Table A-4. Soybean yield response to MAP fertilizer broadcasted at 0, 10, 20, 29, 39, and 49 kg P ha^{-1}, at six sites in 2012.

County	Soil P mg kg^{-1}	Broadcast MAP (kg P ha^{-1}) 0	10	20	29	39	49	Pr > F
		------------------ Yield Mg ha^{-1} at 13 percent moisture†					------------------	
Nemaha	3	1.48	1.28	1.28	1.14	1.34	1.34	0.25
Woodson – Lynx	7	3.16	3.29	3.36	3.43	3.29	3.23	0.47
Woodson– Meadow	15	1.81	2.15	1.61	1.95	2.08	2.22	0.14
Riley - Leonardville	18	1.28	1.41	1.14	1.34	1.41	1.34	0.89
Saline – Dryland	43	1.01	1.14	0.87	0.81	0.94	0.81	0.43
Saline – Flood irrigated	56	2.35	2.28	2.35	2.49	2.28	2.49	0.98

† Letters signify differences at α=0.10, across rows, using Proc Mixed in SAS 9.2 with blocks as the random effect.

Table A-5. Soybean yield response to MAP fertilizer broadcasted at 0, 10, 20, 29, 39, and 49 kg P ha^{-1}, at seven sites in 2013.

		Broadcast MAP (kg P ha^{-1})												
	Soil P	**0.0**		**9.8**		**19.6**		**29.3**		**39.1**		**48.9**		
County	**mg kg^{-1}**	**------------------- Yield Mg ha^{-1} at 13 percent moisture ------------------**												**Pr > F**
Lyon	8	1.14		1.14		1.21		1.14		1.28		1.21		0.57
Douglas	11	2.89		2.89		2.76		2.89		3.09		3.02		0.90
Atchison	11	3.23	B†	2.76	C	3.36	B	3.23	B‡	3.56	AB	3.90	A	0.00
Woodson-Upland	16	2.15		2.42		2.49		2.28		2.22		2.28		0.42
Woodson-Lowland	16	4.03		4.10		4.10		4.10		4.03		4.10		0.76
Riley - Manhattan	21	3.56		3.43		3.63		3.56		3.43		3.76		0.65
Riley - Randolph	23	3.76		3.96		3.83		3.96		3.90		4.17		0.32

† Letters signify differences at α=0.10, across rows, using Proc Mixed in SAS 9.2 with blocks as the random effect.

Table A-6. Soybean yield response to MAP fertilizer broadcasted at 0, 10, 20, 29, 39, and 49 kg P ha^{-1}, at seven sites in 2014.

		Broadcast MAP (kg P ha^{-1})												
Location	**Soil P**	**0**		**10**		**20**		**29**		**39**		**49**		
Site	**mg kg^{-1}**	**------------------- Yield Mg ha^{-1} at 13 percent moisture ------------------**												**Pr > F**
Woodson - pasture	7	1.98		1.89		2.12		2.02		2.18		2.02		0.87
Lyon	9	0.70		0.71		0.91		0.78		0.79		0.82		0.24
Woodson - meadow	11	2.12		1.95		2.32		2.12		1.98		1.86		0.35
Riley	11	1.76	C†	2.04	B	1.96	B	2.11	AB	2.07	B	2.24	A	0.00
Osage	15	3.07		3.06		3.08		3.11		3.21		3.28		0.79
Clay	22	2.51		2.40		2.57		2.59		2.41		2.65		0.94
Jackson	34	4.58		4.78		4.16		4.63		4.53		4.48		0.41

† Letters signify differences at α=0.10, across rows, using Proc Mixed in SAS 9.2 with blocks as the random effect.

Correlation

Compiled historical Kansas data shows a P critical value of 15 mg kg^{-1} when determined by the visual Cate-Nelson method (Figure 4-1). No significant (P-value = 0.26) linear-plateau model could be constructed (Figure 4-2). This may be due to the lack of data collected on soils testing higher than 15 mg P kg^{-1}. This shows an advantage that the visual Cate-Nelson approach has to linear-plateau models. However it also can be potentially miss-used to imply significance when the trends may be due to random error.

Data collected from 2011, 2013, and 2014 show Cate-Nelson (Figure 4-3) and linear–plateau (Figure 4-4) derived critical P values around 10 to 15, and 11.6 mg kg^{-1}, respectively. The critical value observed from the historic data and current data suggest that Kansas State University's current general critical level of 20 mg kg^{-1} for soybeans is too high. The current correlation data agreeing with the historical lack of response above 11 mg kg^{-1} lends additional support to the conclusion that soybeans are relatively non-responding to P, unlike wheat and corn, two other important crops in Kansas. The linear-plateau critical value 95 percent confidence level is from 6.8 to 16.3 mg kg^{-1}. This wide range may be attributed to the soil P variability observed from the sites. This confidence interval also stresses that the critical value is not an exact number and may change depending on factors describe by Fixen and Grove (1990) of P mineralization, and rainfall.

The historical critical value observed agrees with other north central universities recommendations. North and South Dakota State, and Michigan State Universities have STP critical values of 15 mg kg^{-1}, and Iowa State University has a STP critical value of 16 mg kg^{-1}.

The current data suggests the STP critical value may be lower than many currently considered university critical levels. The current critical level observed does agree with suggestions by Kaiser and Lamb (2012) in a University of Minnesota extension publication, which does not recommend applying P fertilizer above 11 mg kg^{-1} by Bray-Kurtz P-1. It also is similar to the linear-plateau critical level found for 0-15 cm Bray-Kurtz P-1 on soybeans in Iowa of 12.4 mg kg^{-1} by Dodd and Mallarino (2005).

It is important to note that any appropriate mathematical model may be used to estimate the critical value. Dodd and Mallarino (2005) examined Cate-Nelson, linear-plateau, quadratic, and exponential models, each with different results. The Cate-Nelson and linear plateau models were used in this study because Dodd and Mallarino (2005) found the Cate-Nelson to be most economical and the linear plateau to give the lowest critical value of the other mathematical models. The use of a mathematical method takes out user bias as compared to the Cate-Nelson, and also prevents critical levels being established that may be due to random error. Quadratic and exponential models giving higher STP critical value estimations not preferred from an economical and environmental perspective. To be profitable one wants to apply the least amount of fertilizer needed to obtain an economically optimum yield. Applications of P when they are not needed may increase P runoff from fields which can increase algae bloom occurrences in lakes.

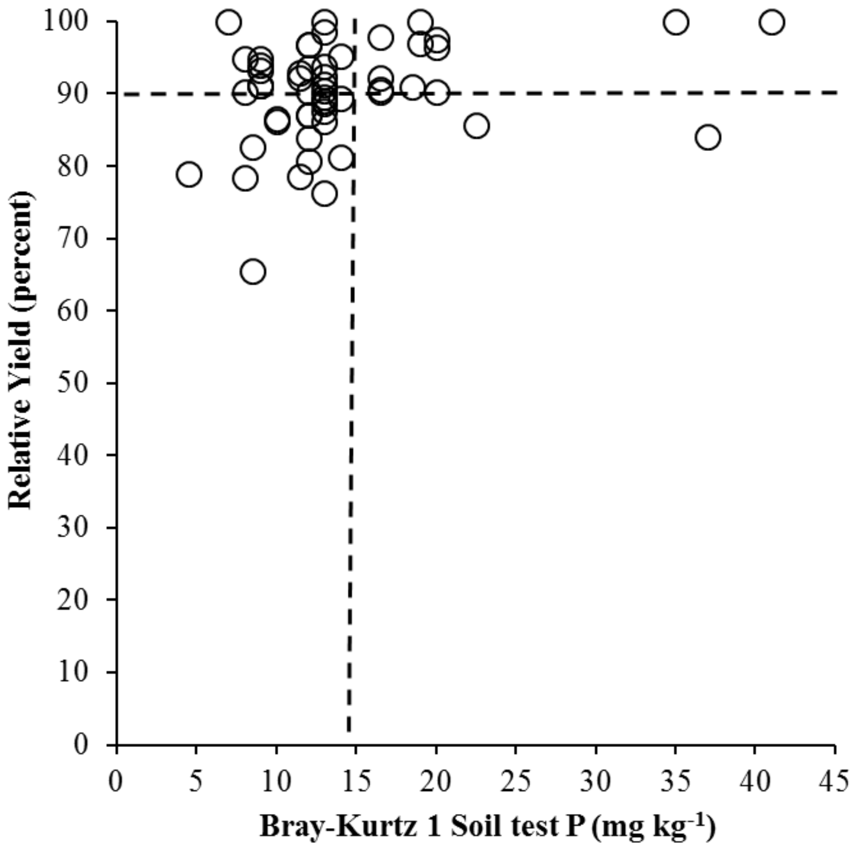

Figure 4-1 . Cate-Nelson critical value for soybean P correlation data to 0-15 cm Mehlich-3 STP values from results published in Kansas State University Fertilizer Research Reports from 1966 to 1980.

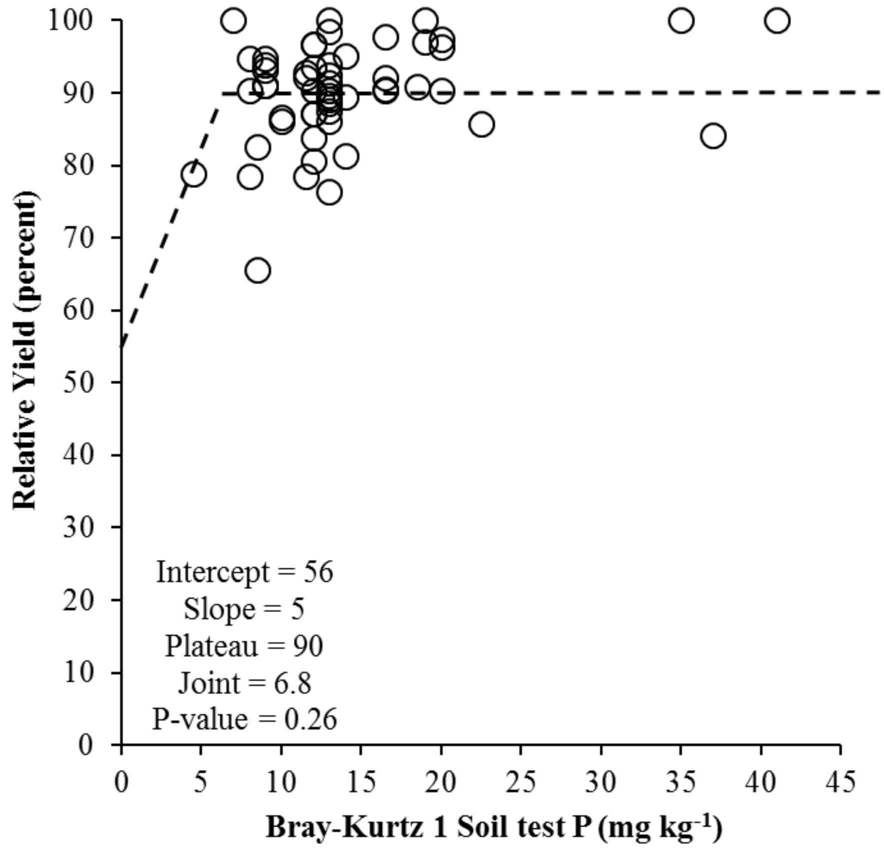

Figure 4-2. Linear-plateau critical value model to Soybean P correlation data to 0-15 cm Mehlich-3 STP values from results published in Kansas State University Fertilizer Research Reports from 1966 to 1980.

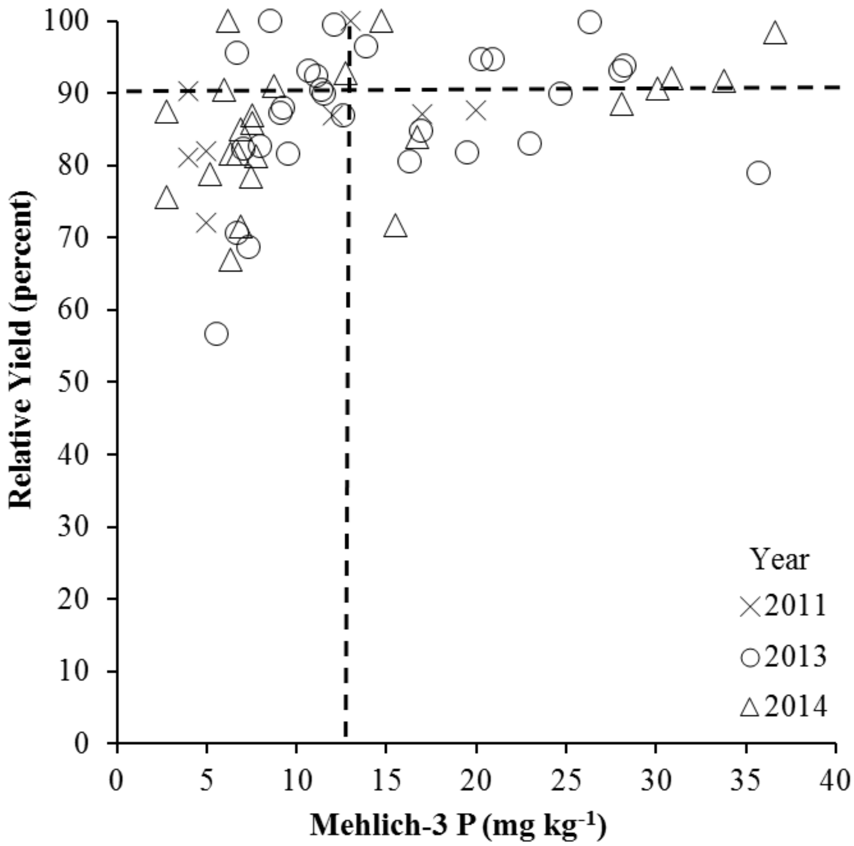

Figure 4-3. Cate-Nelson critical value to Soybean P fertilizer correlation to 0-15 cm Mehlich-3 STP values in 2011, 2013, and 2014.

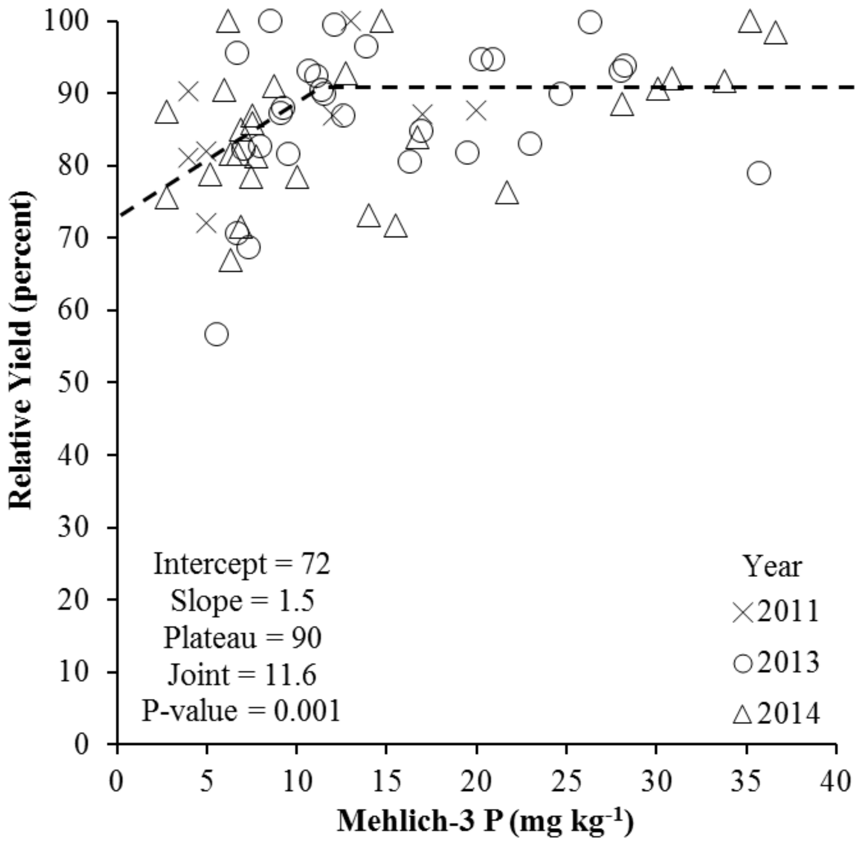

Figure 4-4 . Linear-plateau critical value model to Soybean P fertilizer correlation to 0-15 cm Mehlich-3 STP values in 2011, 2013, and 2014.

Calibration

No significant linear relationship between relative yield and P fertilizer applied was found using the historical response data broken into soil test groups 4.5 to 8 (Figure 4-5), 8 to 12 (Figure 4-6), 12 to 16.5 (Figure 4-7), and 18.5 to 41 mg kg^{-1} (Figure 4-8). A significant linear relationship between yield and P applied was found on the current data when soil test values were between 3 and 8 mg kg^{-1}, but not on higher P soils (Figures 4-9 to 4-13). One might have expected a significant calibration for soils between 8 to 12 mg kg^{-1} as that is also below the Cate-Nelson and linear-plateau critical values. Likely the response to P fertilizer is too small to statistically detect, or soil P variability is affecting the yield results.

Reasons for why a statistical significant calibration was found for the current data and not the historical data may be found in the number of sites studied and the way relative yield was calculated. The historical data was from only two sites one in Labette County in 1978 and one in Brown County in 1966. Relative yields of the treatments were averaged across the replicated blocks, creating one data point per treatment per site. The current data is comprised of seven sites over three years, and the relative yields were calculated by replicated block, which may have helped tease out environmental differences in blocks such as moisture availability. Blocks were placed in their appropriately delineated soil test category as opposed to the whole site fitting in one category. This may have helped account for soil P variability within sites.

While the response on soils between 3 and 8 mg kg^{-1} may be statistically significant it may not be profitable at all times. From the regression one can calculate that applying 49 kg P ha^{-1} only raises relative yield eleven percent. If one assumes a high market price for soybeans of \$440 USD Mg^{-1} and P fertilizer at \$2906 USD Mg^{-1} P, the eleven percent increase in yield would only be profitable when a field's average yield is more than 2.90 Mg ha^{-1}. To put this in perspective the average soybean yield in Kansas for 2013 was 2.95 Mg ha^{-1} (NASS, 2014). If the soybean price fell to a low market price of \$256 USD Mg^{-1} the field's average would have to be 5.04 Mg ha^{-1}. The implications of this force those making recommendations to farmers to not only consider if a response to fertilizer is likely but will the response be profitable. When recommendations are made it is important to disclose this information putting more power in the hands of the farmer to make their own educated decisions.

The scarcity of published calibration data, in peer reviewed papers, research reports or extension bulletins, makes comparison of these results to other studies difficult. The absence of such studies is probably due to lack of funding for work of this nature and the variable results they produce.

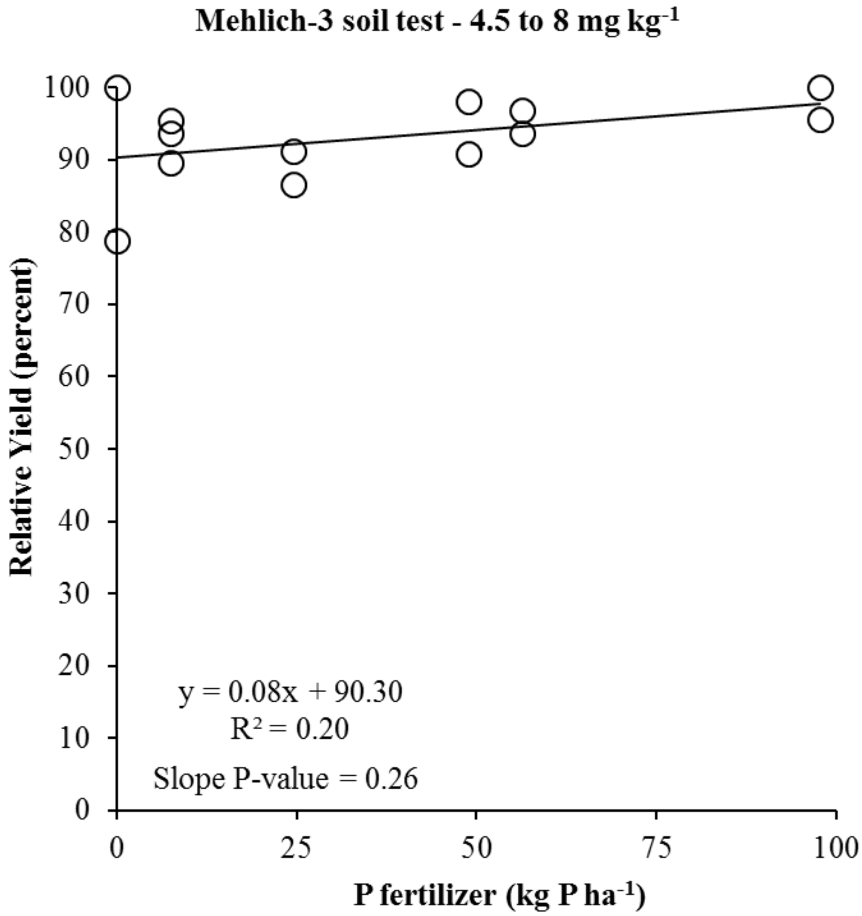

Figure 4-5 . Soybean yield calibrations to P fertilizer for Mehlich-3 between 4.5 to 8 mg P kg^{-1}. Linear regressions and slope P-values were calculated in using Proc REG in SAS 9.2. Data collected from Kansas State University Fertilizer Research Reports from 1966 to 1980.

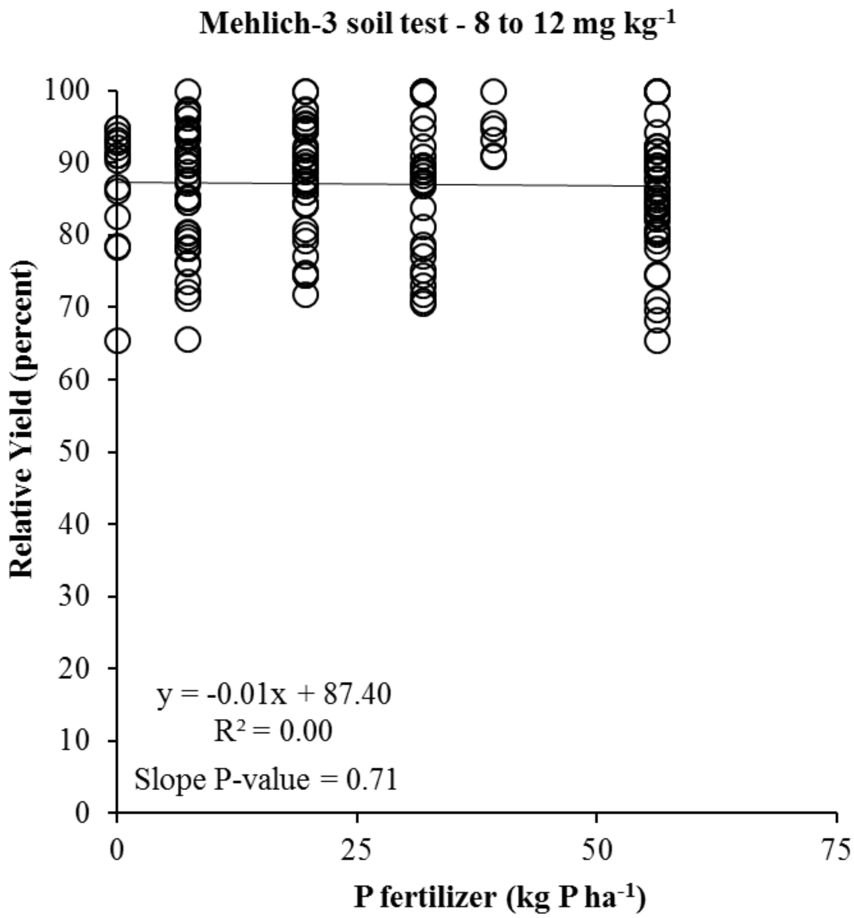

Figure 4-6 . Soybean yield calibrations to P fertilizer for Mehlich-3 between 8 to 12 mg P kg^{-1}. Linear regressions and slope P-values were calculated in using Proc REG in SAS 9.2. Data collected from Kansas State University Fertilizer Research Reports from 1966 to 1980.

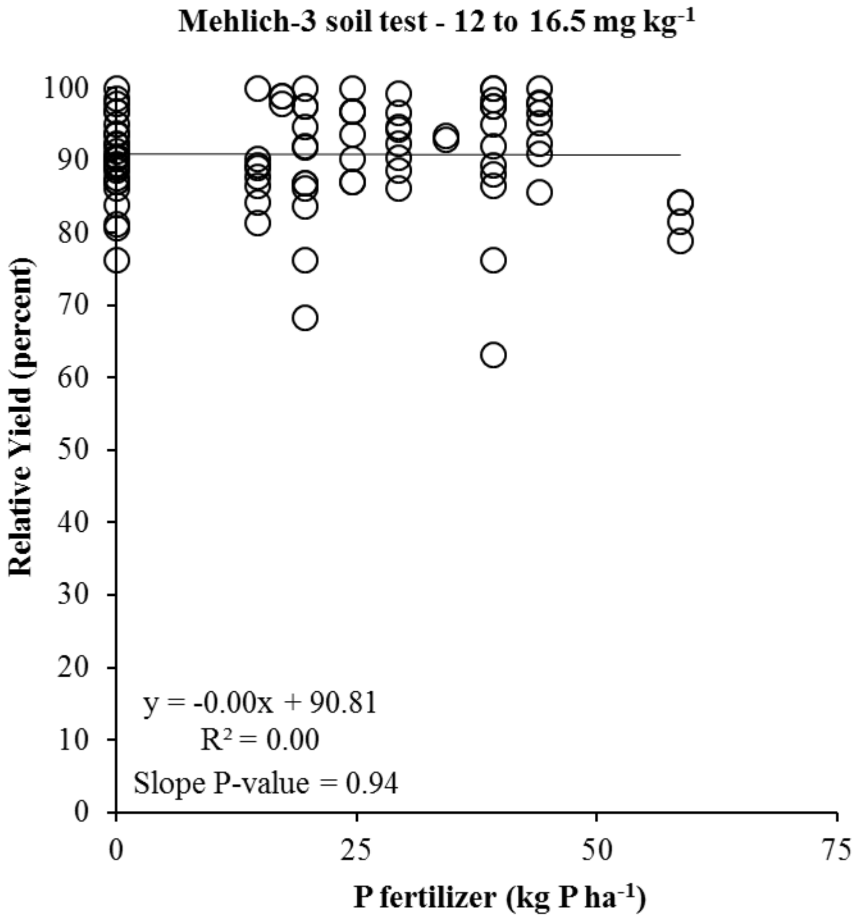

Figure 4-7 . Soybean yield calibrations to P fertilizer for Mehlich-3 between 12 to 16.5 mg P kg^{-1}. Linear regressions and slope P-values were calculated in using Proc REG in SAS 9.2. Data collected from Kansas State University Fertilizer Research Reports from 1966 to 1980.

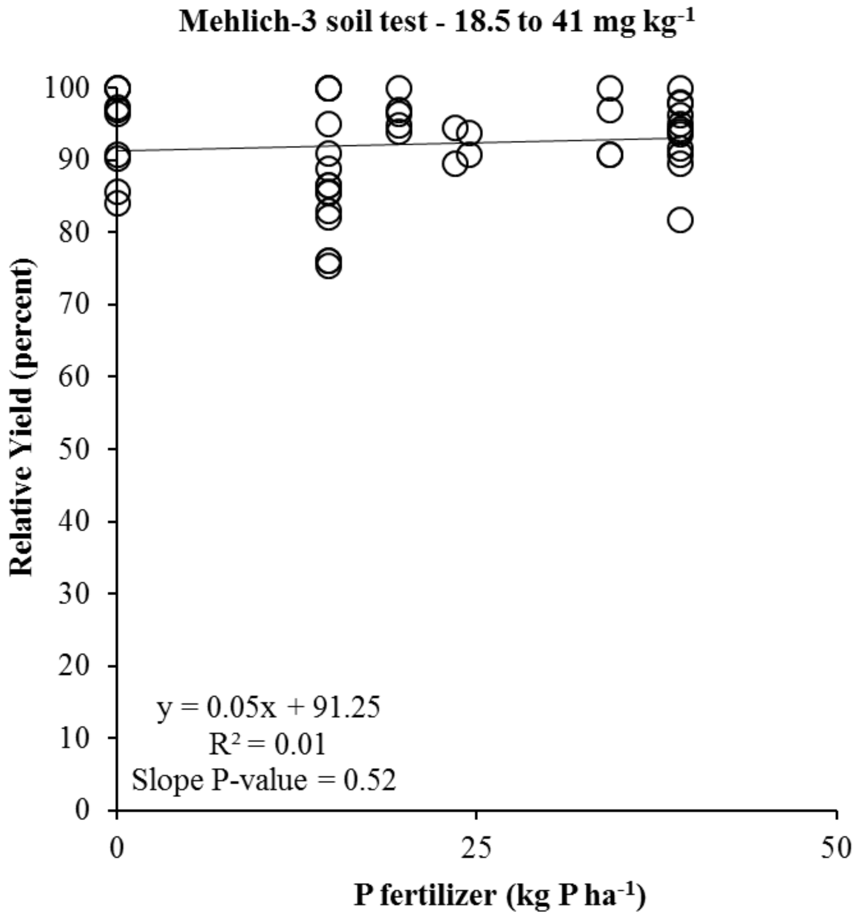

Figure 4-8 . Soybean yield calibrations to P fertilizer for Mehlich-3 between 18.5 to 41 mg P kg^{-1}. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2. Data collected from Kansas State University Fertilizer Research Reports from 1966 to 1980.

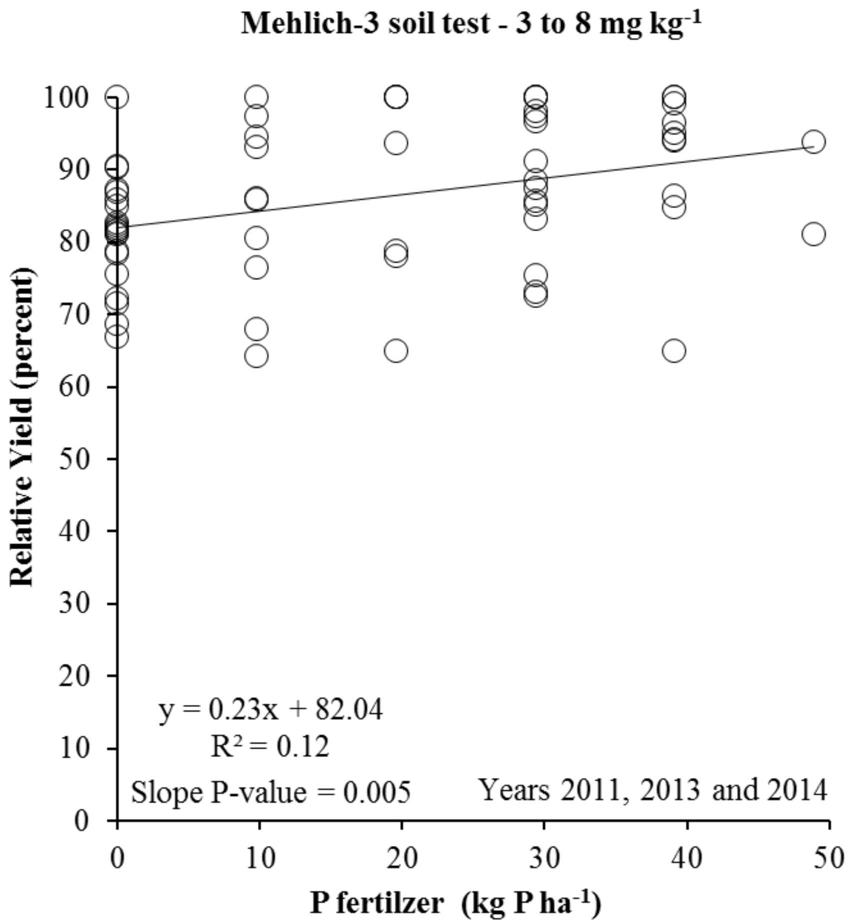

Figure 4-9 . Soybean yield calibrations to P fertilizer by Mehlich-3 between 3 to 8 mg P kg^{-1} for 2011, 2013, and 2014. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2.

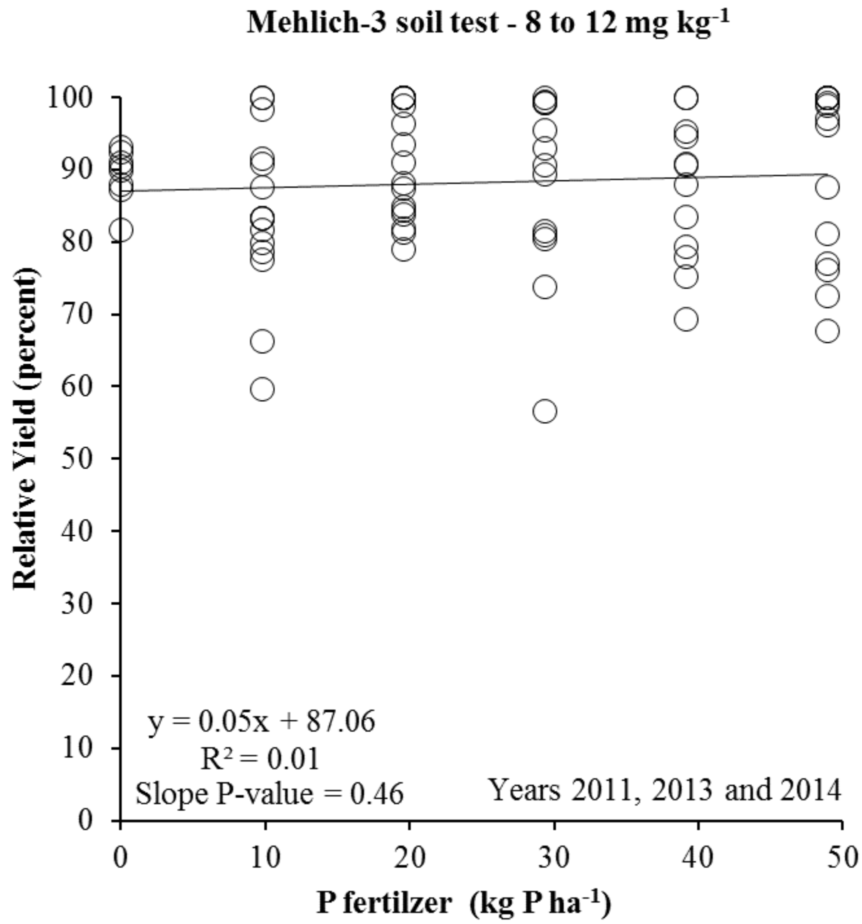

Figure 4-10. Soybean yield calibrations to P fertilizer by Mehlich-3 between 8 to 12 mg P kg^{-1} for 2011, 2013, and 2014. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2.

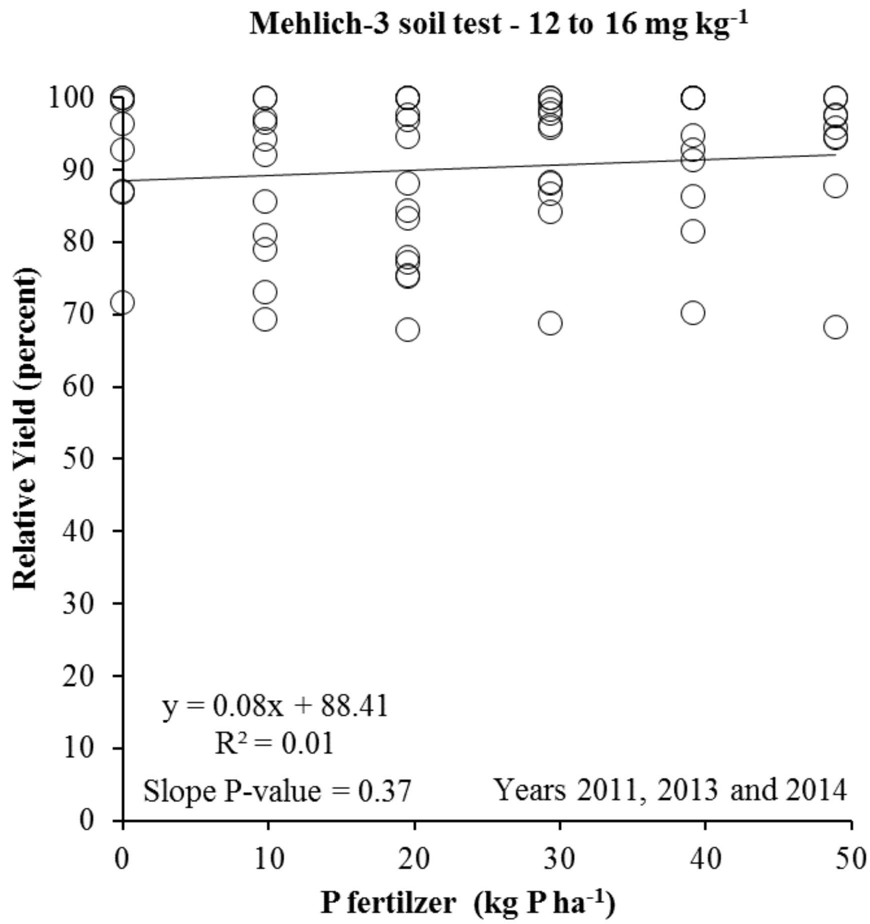

Figure 4-11. Soybean yield calibrations to P fertilizer by Mehlich-3 between 12 to 16 mg P kg^{-1} for 2011, 2013, and 2014. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2.

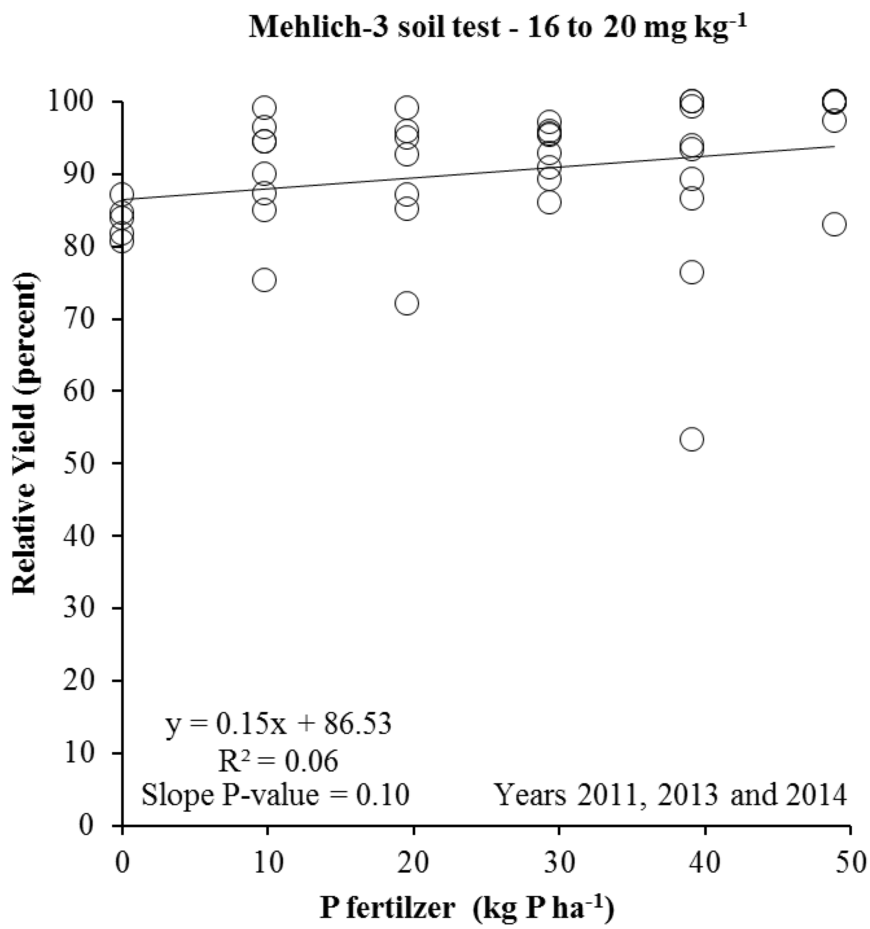

Figure 4-12 . Soybean yield calibrations to P fertilizer by Mehlich-3 between 16 to 20 mg P kg^{-1} for 2011, 2013, and 2014. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2.

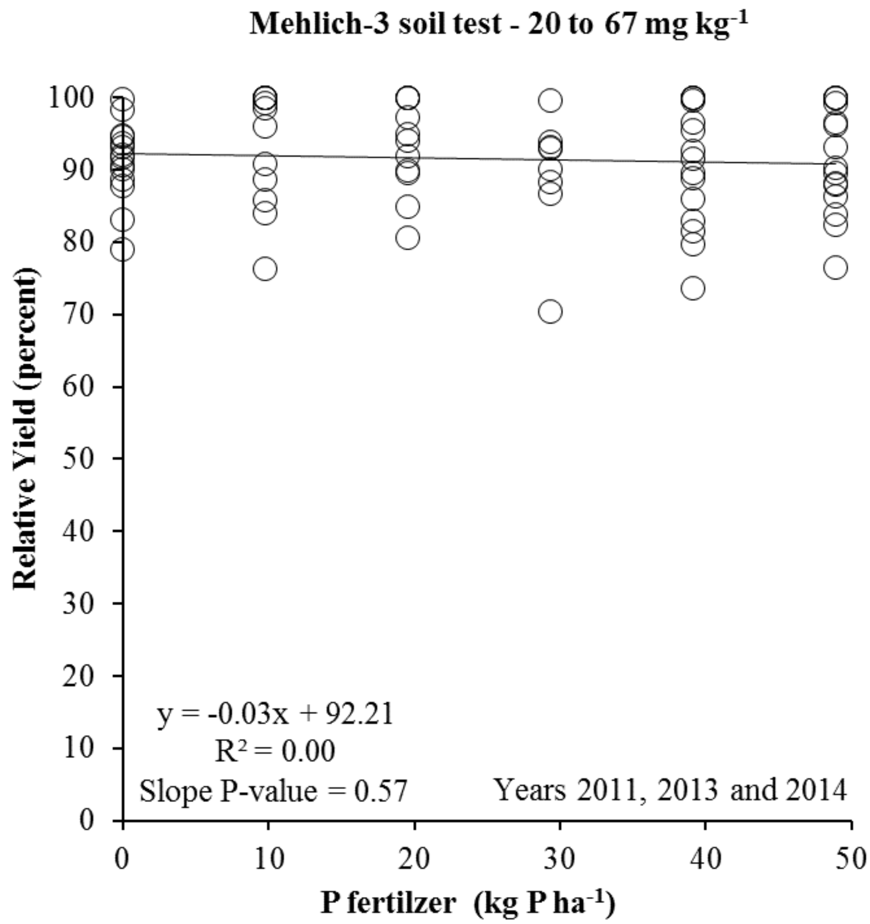

Figure 4-13. Soybean yield calibrations to P fertilizer by Mehlich-3 between 20 to 67 mg P kg^{-1} for 2011, 2013, and 2014. Linear regressions and slope P-values were calculated using Proc REG in SAS 9.2.

Efficiency

Banding, or the application of starter fertilizer, did not improve yield above not banding at all sites in 2012 (Table 4-8), all but one site in 2013 (Table 4-9), and all sites in 2014 (Table 4-10). There was no interaction between banding P and broadcast P at any sites. Of the two responsive sites to P fertilizer, Riley in 2014 and Atchison in 2013, only Atchison showed a statistically significantly yield increase with 9.8 kg P ha^{-1} banded. The mean difference between banding P and not banding P, at Atchison, was 0.07 Mg ha^{-1}, and while it may be statistically significant, it is minimally significant to a farmer. A significant effect of banding or an interaction between broadcasting and banding was not seen at Woodson – pasture with a STP of 7 mg kg^{-1}. One might have expected banding to improve yield at this site, as banding on low STP sites has been observed to do on corn (Chapiro et al. 2008) and wheat (Peterson et al. 1984). Other low STP sites may not have responded to banding or banding and broadcast interactions because of environmental factors.

This study's results are similar to what Borges and Mallarino (2000) observed, where only two out of twenty sites showed a statically significant difference between broadcast and banding. This study further support evidence that soybean yield does not respond differently between broadcast and banded P fertilizer. One possible difference between corn or wheat and soybeans which could explain this lack of starter fertilizer response is the higher P content in soybean seed as compared to grass crops. An additional potential explanation is the difference in early season growth conditions. Corn is generally planted very early in the spring, when soil temperatures are low. Soybeans are normally planted 2-3 weeks, or more, later under warmer conditions more conducive to seedling growth.

It is also important to point out that an additional 6.5 kg ha^{-1} of nitrogen (N) applied from banded APP in 2012, and 2013 was not matched on the broadcast only plots. In 2014, a total of 16.8 kg N ha^{-1} was applied to both split and broadcast alone plots. Not matching N in years 2012 and 2013 was justified because a farmer would apply the two products separate and not account for disproportionate amounts of applied N. The justification in 2014 for matching N rates was to ensure that any response observed was due to banded P and not N. This lack of a treatment difference in 2013 may allow one to also draw evidence that an additional 6.5 kg N ha^{-1} does not improve soybean yield. The lack of a treatment difference in 2014 may assure one that banded P, alone, does not improve soybean yield above broadcast only. If we observed a treatment difference in 2014 and did not apply even amounts of N, we could not have concluded decisively if it was a response to P, N, or a combination of the two.

Table A-1. ANOVA significance of broadcast P, banded P, and their interaction on soybean yield at seven sites in 2012.

	P application method		
County	**Broadcast**	**Banded**	**Interaction**
	ANOVA significance		
Nemaha	ns†	ns	ns
Woodson - lynx	ns	ns	ns
Woodson - meadow	ns	ns	ns
Riley	ns	ns	ns
Saline - Flood irrigated	ns	ns	ns
Saline - dry land	ns	ns	ns

†ns means no significance at α = 0.10

Table A-2. ANOVA significance of broadcast P, banded P, and their interaction on soybean yield at seven sites in 2013.

	P application method		
County	**Broadcast**	**Banded**	**Interaction**
	ANOVA significance		
Riley - Manhattan	ns†	ns	ns
Riley - Randolph	ns	ns	ns
Woodson - lowland	ns	ns	ns
Woodson - upland	ns	ns	ns
Atchison	**	*	ns
Douglas	ns	ns	ns
Lyon	ns	ns	ns

†** and * signify ANOVA P-values <0.05 and <0.10, respectively. ns means no significance at α = 0.10

Table A-3. ANOVA significance of broadcast P, banded P, and their interaction on soybean yield at five sites in 2014.

	P application method		
County	**Broadcast**	**Banded**	**Interaction**
	ANOVA Significance		
Clay	ns†	ns	ns
Riley	**	ns	ns
Osage	ns	ns	ns
Woodson - meadow	ns	ns	ns
Woodson - pasture	ns	ns	ns

†** signifies ANOVA P-value <0.05. ns means no significance at α = 0.10

Grain removal

Average P removal in the harvested soybean seed from all sites and treatments was 5.0 mg P kg^{-1} dry soybean. This average is less than the removal rate suggested by many university's and that found by Mallarino et al. (2003) of 6.7 and 6.6 mg P kg^{-1}, respectively. A possible explanation for this studies average being less than Mallarino et al.'s (2003) average may be attributed to the sites targeted. In this study low P soil sites were targeted, Mallarino et al. (2003) covered hundreds of sites across Iowa. No soil P data is given in Mallarino's work but it would not be unreasonable to assume that some sites were quite high in soil P. It may be possible that soybeans undergo luxury uptake on higher P soils, causing higher P soybean content.

This explanation of luxury uptake is supported by the evidence that many of this studies sites did not show a yield response to P fertilizer, but grain P did increase with P fertilizer at many sites. In 2012, P fertilizer increased grain P at Woodson County – lynx (Table 4-11). In 2013, six of the seven sites showed a significant increase in grain P with P fertilizer (Table 4-12). In 2014, four of the seven sites showed an increase in grain P with P fertilizer (Table 4-13)

A trend was also observed as increasing STP increased grain P on control plots. In 2012, Nemaha County had a STP of 3 mg kg^{-1} and grain P content of 4.3 mg kg^{-1}, while dryland and flood irrigated sites in Saline County had STP of 43 and 56 mg kg^{-1}, respectively, and Grain P contents of 5.6 and 5.4 mg kg^{-1}, respectively. In 2013, the three highest STP sites, Woodson-lowland, Riley- Manhattan and Randolph, also had the highest Grain P contents. In 2014, Woodson- meadow and pasture had the lowest grain P contents of 4.6 mg kg^{-1} at STP levels of 7 and 11 mg kg^{-1}, respectively. The highest grain P content was observed at Jackson County with a STP of 34 mg kg^{-1} and grain P content of 6 mg kg^{-1}.

It would be suggested that Kansas State University lowers the assumed soybean P removal rate from 6.7 to the observed average removal of 5 mg kg^{-1} or a level equal to that found in the fertilized plots and the higher ST control plots of approximately 5.5 mg P kg^{-1} This recommendation would be appropriate with the knowledge that soybeans grown in low STP fields would probably have fertilizer applied to them, increasing grain P, while those in high ST P fields would have removal rates > 5 mg P kg^{-1} but they would not receive replacement or maintain recommendations for P, as over P application can cause environmental damage.

The range of soybean P contents ranged for all sites and treatments from 3.67 to 6.2 mg P kg^{-1} dry soybean. Mallarino et al. (2003) observed a wider range in soybean P contents with 3.4 to 8.7 kg P Mg^{-1} dry soybean. These observations of soybean P varying considerable from the average could affect soil test levels over time. If one is using a build and maintain system or a sufficiency system based of fractions of grain removal, and only uses average soybean P content, they may be under or over applying P fertilizer.

There are two ways a farmer may adjust for varying P removal rates. They may either take grain samples and have them analyzed for P and adjust fertilizer rates accordingly or they may take routine soil samples on a regular basis and monitor the trend in ST levels. Sampling grain for P content would be an added step in the harvest process, and may be more trouble than it is worth. The samples would have to be saved, labeled with a GPS location, and sent into a lab for analysis adding costs. Soil sampling on a regular basis is something that a farmer should be doing normally, so it would not be an added task or cost. If they keep track of soil P levels over time and location the samples are from, they may see areas in which soil P values are rising or dropping. This rise or drop would be associated with either applying more or less than crop removal rates. Farmers could then adjust fertilizer rates accordingly.

Table A-1. Soybean P removal during 2012 at seven sites across P fertilizer applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1}.

		Broadcast MAP fertilizer (kg P ha^{-1})											
	Soil P	0		10		20		29		39		49	
County	mg kg^{-1}	Soybean P removal (mg P kg^{-1} dry grain)											
Nemaha	3	4.3		4.0		4.1		4.1		4.2		4.4	
Woodson– lynx	7	4.7	D†	4.8	CD	5.0	BC	5.2	AB	5.2	AB	5.3	A
Woodson – meadow	15	5.2		6.1		5.5		5.6		5.6		5.7	
Riley	18	5.2		4.9		4.9		5.2		4.9		4.9	
Saline - dry land	43	5.6		5.8		5.9		5.8		5.7		5.7	
Saline- flood irrigated	56	5.4		5.2		5.3		5.3		5.2		5.6	

† Letters signify significant difference α=0.10, across rows, using Proc Mixed with blocks as the random effect (SAS 9.2 Cary, NC)

Table A-2. Soybean P removal during 2013 at seven sites across P fertilizer applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1}.

		Broadcast MAP fertilizer (kg P ha^{-1})											
	Soil P	0		10		20		29		39		49	
County	mg kg^{-1}	Soybean P removal (mg P kg^{-1} dry grain)											
Lyon	8	4.4	C†	4.7	B	5.1	A	5.0	A	5.1	A	5.2	A
Douglas	11	4.4	C	4.8	AB	4.6	BC	4.7	AB	4.9	AB	5.0	A
Atchison	11	3.7	C	4.0	B	4.2	B	4.4	A	4.4	A	4.6	A
Woodson - upland	16	4.2	C	4.5	B	4.6	B	4.9	A	4.9	A	5.0	A
Woodson - lowland	16	5.1		4.8		5.2		5.1		5.1		5.4	
Riley - Manhattan	21	4.9	C	5.0	BC	5.2	B	5.2	B	5.6	A	5.7	A
Riley - Randolph	23	4.7	CD	4.6	D	4.8	C	5.2	B	5.1	AB	5.2	A

† Letters signify significant difference α=0.10, across P fertilizer rates, using Proc Mixed with blocks as the random effect (SAS 9.2 Cary, NC)

Table A-3. Soybean P removal during 2014 at seven sites across P fertilizer applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1}.

County	Soil P mg kg^{-1}	Broadcast MAP fertilizer (kg P ha^{-1}) 0		10		20		29		39		49	
		Soybean P removal (mg P kg^{-1} dry grain)											
Woodson - pasture	7	4.6		4.9		4.8		5.0		5.0		5.2	
Lyon	9	5.0	C†	5.1	C	5.4	B	5.3	B	5.4	AB	5.6	A
Woodson - meadow	11	4.6	D	4.9	C	5.1	BC	5.0	BC	5.2	AB	5.3	A
Riley	11	4.8	C	4.9	BC	4.9	B	4.9	B	5.1	A	5.0	AB
Osage	15	4.8	B	4.8	B	5.1	AB	5.0	AB	5.3	A	5.3	A
Clay	22	4.8		4.7		4.5		4.8		4.6		4.8	
Jackson	34	6.0		5.9		6.2		6.0		6.1		6.1	

† Letters signify significant difference α=0.10, across P fertilizer rates, using Proc Mixed with blocks as the random effect (SAS 9.2 Cary, NC)

Economics

Assuming MAP costs \$2906 USD P Mg^{-1}, and soybeans are \$440 USD Mg^{-1}, it was only profitable in the short-term to add P fertilizer to three of the 23 sites. In 2011, at Woodson County all P fertilizer rates were profitable (Figure 4-14). In 2012, application of P lowered profit per hectare at all sites (Figure 4-15), even at the relatively high yielding Woodson Lynx site. In 2013, at Atchison County applications of 20, 39, and 49 kg P ha^{-1} were profitable (Table 4-16). In 2014, at Riley County only 10 kg P ha^{-1} was profitable (Figure 4-17). So few sites responding economically to P fertilizer is due to the lack of a yield response at most sites. The only sites to show an economic response were ones that also show a yield response to P applications. Maximum return was observed with the lowest P application rates at Riley in 2013 and Woodson in 2011. Only at Atchison County was the maximum P rate applied also the maximum economic return.

Even as P applications are not always being profitable to soybeans, one needs to consider the longer-term impact of P being removed at harvest. If P removal is not replaced, STP values could go down negatively affecting other crops in the rotation that do show a response to P such as corn and wheat. Because other crops in the rotation may be more responsive to P, one strategy would be to apply the normal fertilizer recommendation on the responsive crop plus P to replace P removed by the soybeans. This could reduce or prevent a decline in STP level.

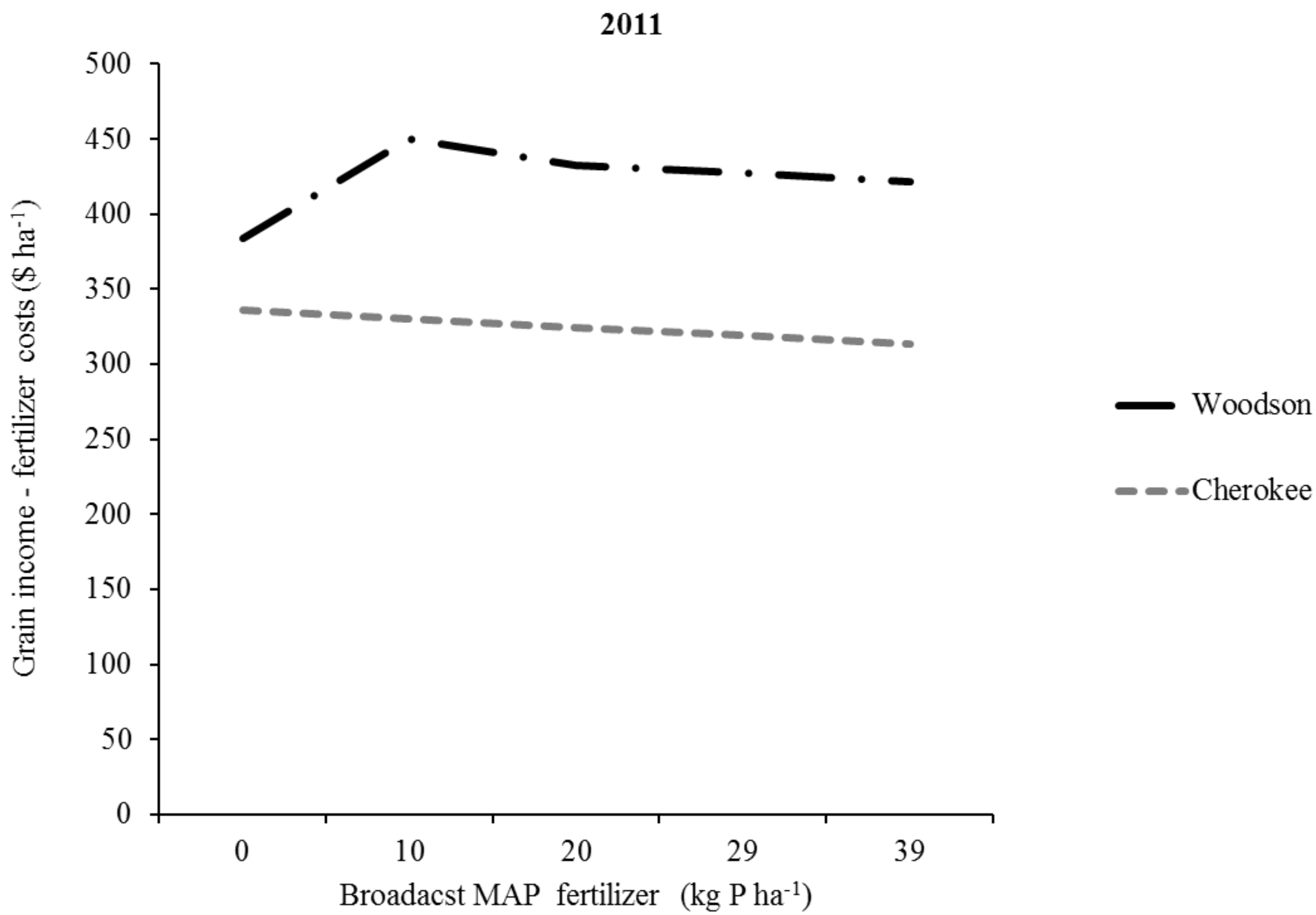

Figure 4-14. 2011 results for grain income minus fertilizer costs on a USD ha^{-1} basis with MAP applications of 0, 10, 20, 29, and 39 kg P ha^{-1} with P costs at $2906 USD Mg^{-1} P and a soybean price of $440 USD Mg^{-1}.

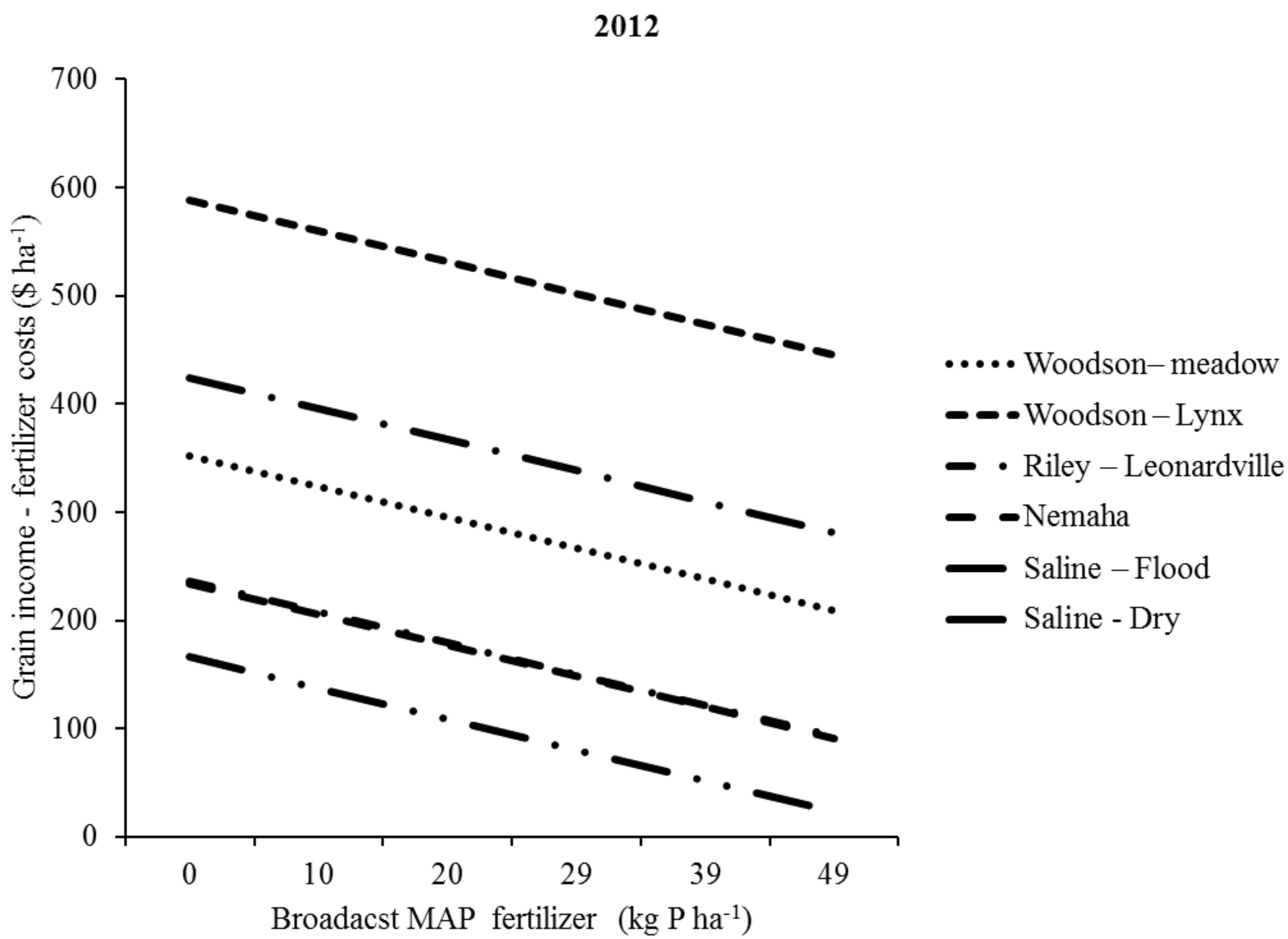

Figure 4-15. 2012 results for grain income minus fertilizer costs on a USD ha^{-1} basis with MAP applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1} with P costs at $2906 USD Mg^{-1} P and a soybean price of $440 USD Mg^{-1}.

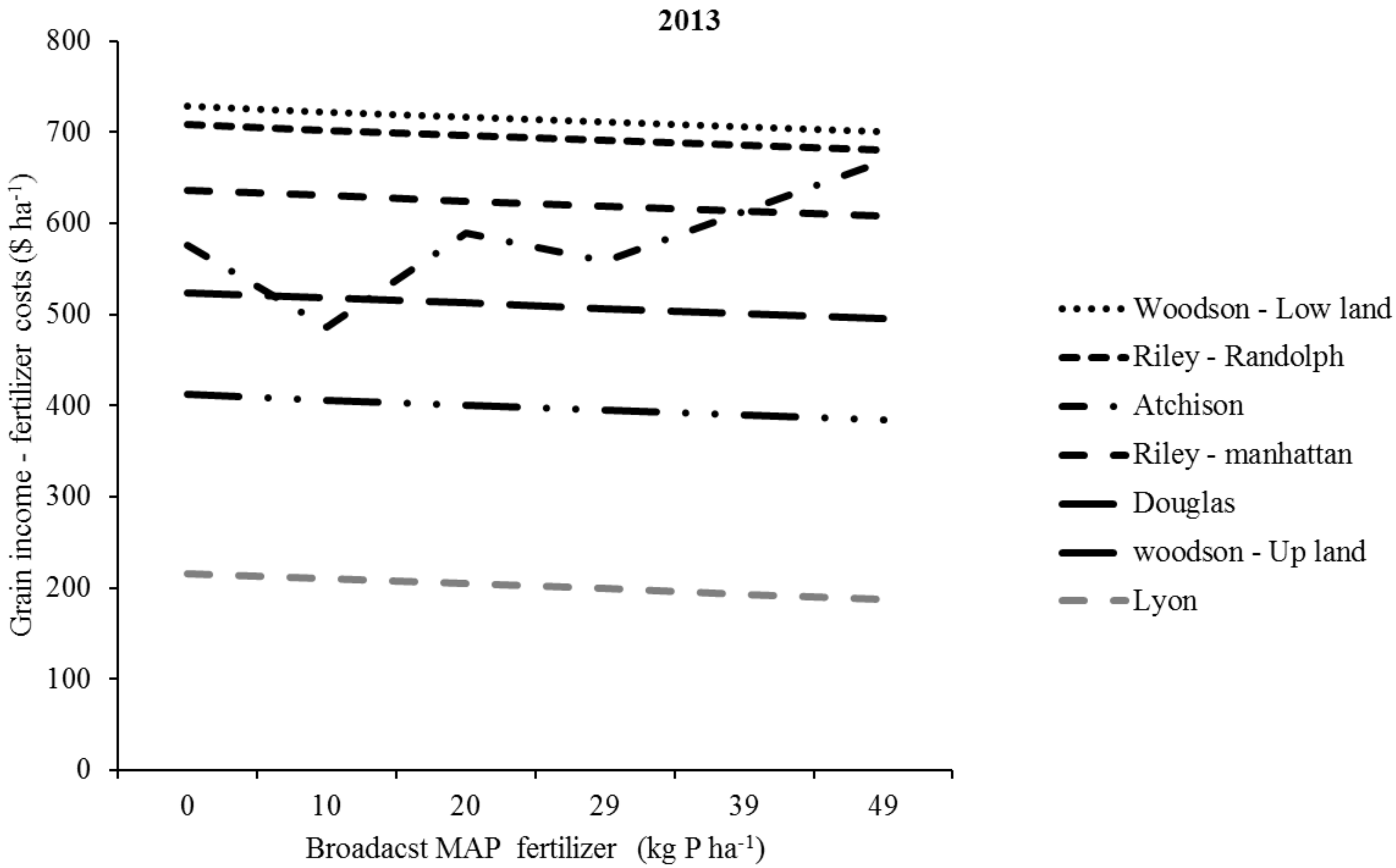

Figure 4-16. 2013 results for grain income minus fertilizer costs on a USD ha^{-1} basis with MAP applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1} with P costs at \$2906 USD Mg^{-1} P and a soybean price of \$440 USD Mg^{-1}.

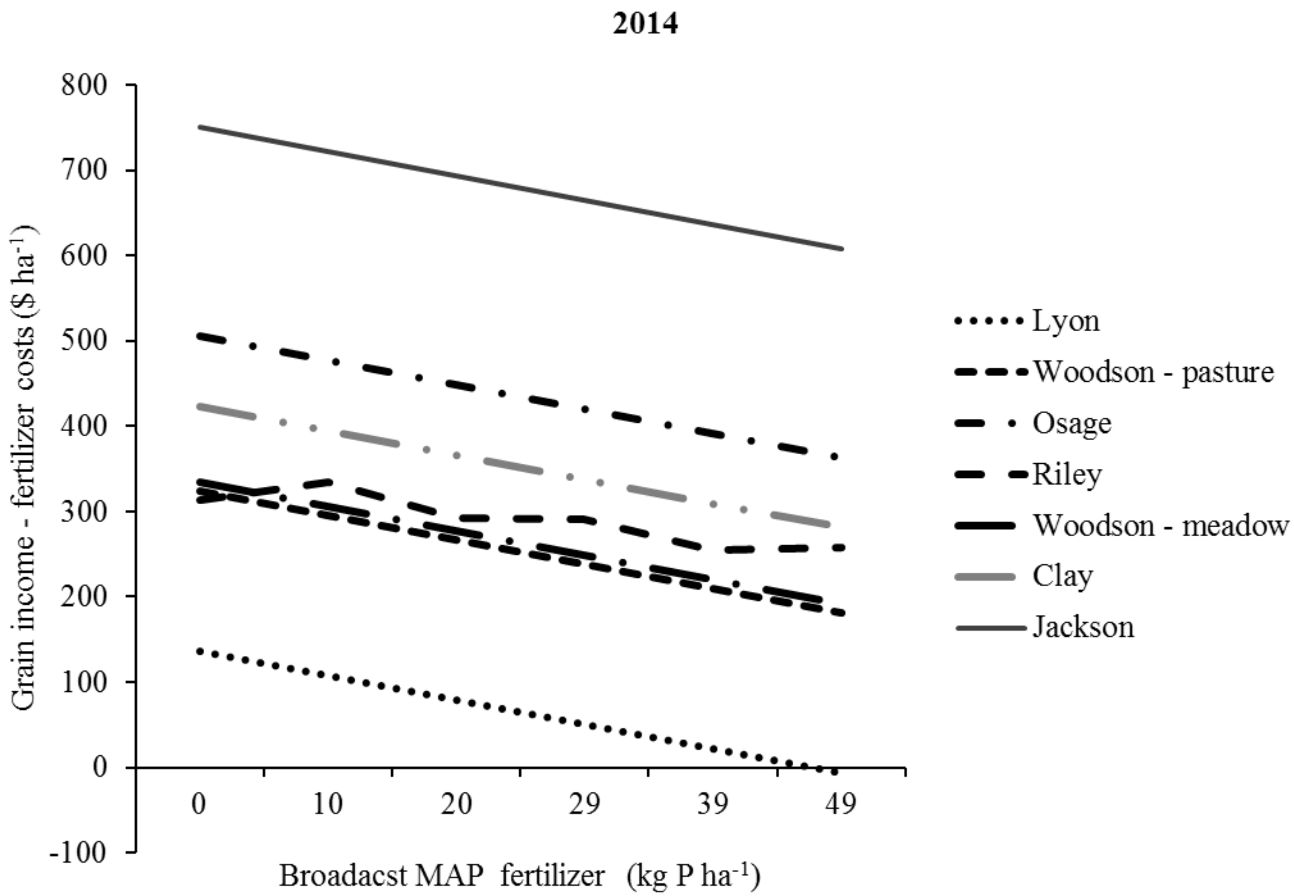

Figure 4-17. 2014 results for grain income minus fertilizer costs on a USD ha^{-1} basis with MAP applications of 0, 10, 20, 29, 39, and 49 kg P ha^{-1} with P costs at $2906 USD Mg^{-1} P and a soybean price of $440 USD Mg^{-1}.

Conclusions

Current correlation data suggests that the soybean P critical level in Kansas should be 12 mg kg^{-1}. Current calibration data showed a significant linear response of relative yield to P fertilizer on soil test levels 4.5 to 8.0 but not above 8.0 mg kg^{-1}. The lack of a response on soils 8 up to 12 mg kg^{-1} may be due to soil P variability. Inconsistent yield responses to P applications have also been previously reported in Iowa by Dodd and Mallarino (2005) and Borges and Mallarino (2000).

Banding fertilizer showed no significant yield increase over not banding in this study. This would suggest that the KSU standard recommendation to apply 25% of all recommended P as a starter fertilizer band at low STP levels may not be appropriate for soybeans. Starter P has was also not observed to consistently improve soybean yield above broadcasting in Iowa (Borges and Mallarino, 2000).

Grain removal was observed to be, on average, lower than currently assumed by many university laboratories at 5.0 compared to 6.6 mg P kg^{-1} soybean. This study suggests that a removal value of 5.0 to 5.6 mg P kg^{-1} soybean would be more appropriate when making replacement applications.

Fertilizer applications to soybeans were rarely observed to be profitable in this study. It is important to understand that while it may not be profitable to apply fertilizer to soybeans, they do remove P at harvest, which if not replaced will lower a soil's P content. Thus this presents opportunities to focus P fertilizer applications to more responsive crops in the rotation, and to make multi-year applications to these responsive crops, contrary to current recommendations and dogma. If the STP is above 12 mg kg^{-1}, the results of this study would suggest no yield penalty from not applying P directly to the soybean crop, but rather focusing on wheat or corn, crops known to be much more responsive. This would save significant time in the stressful planting season, and reduce application costs. However ignoring the P removing effect of producing soybeans would result in declines in STP levels over time, eventually dropping STP below 12 mg kg^{-1} and triggering a response to direct fertilization of soybeans.

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Chapter 5 - Interprative chapter

There are many key points that a person running a laboratory should take away from these studies when communicating with farmer and researcher clients. When looking at soil organic matter (SOM) measurements it is important for one to find the right balance between method cost, turn a round time and accuracy when recommednating tests. When reporting values it is suggested that the reported values are not based on calculated assumptions. The results from the lime recommendation chapter show the importance for evaluation of soil test methods and recommednations for soils to a particular region. The soybean P correlation and calibration study helps reiterate that fertilizer recommendations are not exact. It reinforces the concept of regular soil sampling and data organization.

Organic matter

The results from the SOM chapter show that a laboratory agronomist must match a soil test method to their clients' wants and needs. Balancing how much one will pay for a sample, speed of turnaround time and how accurate one wants their results is important. This balancing is seen when recommending a SOM test to clients. The most accurate and precise method is dry combustion (DC), but it cost the most and has the longest turnaround time compared to Walkley-Black (WB) and loss on ignitigion (LOI). Because of these factors DC would normaly only be recommended to researchers seeking accurate and precise results. While LOI is not as accurate or precise as DC it is still a good choice for farmers becsaue of low costs and quick turnaround time. Even though one loses accuracy and prescion with LOI compared to DC, the level of accuracy obtained is well within the soil sampling and N fertilizer application errors. This makes it a suitable test for farmers.

Another key point brought out by this research is reporting units fully, and without modifications. Laboratories report SOM as a percent but commonly leave out on which basis the percent was made. The differences found between percent by scooped and weighed samples was quite noticable. If a farmer sent a sample to a laboratory that reported SOM on a volume/weight and later sent a sample, from the same field, to a laboratory that reported on be weight/weight, they may incorrectly assume that their SOM increased dramatically.

Because SOM is estimated by different methods which do not directly measure SOM, assumptions are made to estimate SOM. It is important that clients receiving these values, know which assumptions the laboratory makes in their calclulation. It would be prefered that a laboratory report only the value of what exactly was measured, and leave it up to the client to make further assumptions. Using this format WB would be reported as percent easily oxidizable carbon (C). Reuslt from DC would be reported as percent total C wt/wt, or as total organic C if acid treated or no carbonates present. Results for LOI would reported as percent weight loss. This could prevent researchers from falsely assuming inoformation about the data. This would also allow those who use SOM as a varible in fertilizer or herbicide calculations to be able to adjust rates based on how the SOM N credits or effects on herbicied rate were originally estimated.

Liming

Results from the lime recommendation chapter show just how few soils that have been used to create buffer lime equations. It also shows that laboratories need to constanntly check their recommendations and continually build the data set used in equations. Lime recommendations being built onn so few soils in a regions, brings to light the imporatance of record keeping by farmers. The assumption that buffer pHs values were linearly related to all pH targets on all soils is drawn into question with this dissertations results. This shows that laboratories need to validate their recommendations. The fact that only one publication used more than 22 soils to build their their lime recommednation equation stresses how valable it is for laboraties to continually build a data set. Continually checking and susequent building of a data set would allow a lab to make lime recommendations for specific soils or circumstances.

The chance athat a farmer's soil may not behave like those in ann incubation study stresseses the idea of good book keeping. If a farmer knows the previous pH, amount of lime applied, and suequent change in pH they may get an idea of how their soils react to lime. Over time farmers could get a strong feeling of how the different soils under their care react to lime and make adjustments.

Soybean P fertilizer correlation and calibration

Results from the soybean P correlation and calibration show that a laboratory agronomist and farmer must understand that fertilizer recommendations are not prescriptions. That is to say those fertilizer recommendations are hopefully research based, but are not always exact, or give similar results every time they are used. One cannot expect to apply 29 kg P ha^{-1} to 11 mg kg^{-1} STP soil and expect to see a yield increase every time. One cannot also expect maintenance fertilizer rates to replace the exact amount of P removed in grain.

One way to account for recommendations not being 100 percent accurate all the time, is for a farmer to regularly soil sample and keep track of ST trends. A laboratory agronomist may assist the farmer by providing soil results in a manner that make data origination easier. It has been recommended to the author that soil testing laboratories could offer “added value” in their results if they not only reported soil test values but could also link previous results from a particular field for a farmer. This would allow a farmer to observe trends as well as have their current results. The implementation of this could be tricky as a farmer would have to decide what to call a particular field, management zone, grid point, or grid and use the same name every time a sample from that area was submitted.

Appendix

Appendix A - Organic matter measurement raw data

Table A-1. Raw data for Walkley-Black, Loss on ignition, and dry combustion studies.

Walkley-Black - weighed 1 g							
Using NAPT soil as standard curve							
If OM was above 4.0, then a weighed 0.5 g sample was used							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Calculated C recovery percent**
8034	1	1.87	1.95	1.77	1.86	0.09	63.11
8037	2	0.93	0.98	1.03	0.98	0.05	75.08
8321	3	1.45	1.45	1.40	1.44	0.03	71.92
8325	4	1.41	1.43	1.34	1.39	0.05	69.76
8329	5	1.69	1.68	1.54	1.63	0.09	73.05
8546	7	2.57	2.43	2.49	2.50	0.07	69.12
8565	9	3.45	3.35	3.39	3.40	0.05	69.15
8571	10	2.59	2.55	2.54	2.56	0.02	65.17
8598	11	2.40	2.11	2.09	2.20	0.17	68.93
8602	12	2.88	2.78	2.66	2.77	0.11	72.27
8604	13	2.65	2.86	2.66	2.73	0.12	59.59
8620	14	3.59	3.29	3.19	3.36	0.21	70.06
8621	15	3.47	3.37	3.39	3.41	0.05	70.20
8705	16	2.42	2.24	2.38	2.34	0.09	70.51
8728	17	4.85	4.82	5.25	4.97	0.24	72.40
8735	18	1.20	1.11	1.16	1.16	0.05	71.42
8785	19	2.82	2.79	2.93	2.85	0.07	70.57
8836	20	4.24	4.28	4.32	4.28	0.04	67.32
8907	21	4.03	4.24	4.08	4.12	0.11	66.97
8910	22	4.16	4.42	3.94	4.17	0.24	73.65
8911	23	5.89	6.27	5.82	6.00	0.24	66.88
8946	24	2.75	2.99	2.62	2.79	0.19	58.97
8948	25	4.52	4.77	4.92	4.74	0.20	65.09
8951	26	5.78	5.14	5.56	5.49	0.33	71.23
8953	27	5.89	6.15	5.59	5.88	0.28	71.74

Walkley-Black - weighed 1 g							
Using NAPT soil as standard curve							
If OM was above 4.0, then a weighed 0.5 g sample was used							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Calculated C recovery percent**
8954	28	3.53	3.39	3.48	3.47	0.07	68.13
8957	29	1.56	1.37	1.25	1.39	0.16	70.59
8961	30	1.04	1.16	0.95	1.05	0.11	65.26
9032	31	3.30	3.55	3.21	3.35	0.18	67.91
9130	32	2.49	2.80	2.69	2.66	0.16	69.29
9142	33	4.68	5.23	4.78	4.90	0.29	75.28
9181	34	6.60	7.06	6.41	6.69	0.34	55.95
9189	35	4.52	5.11	4.44	4.69	0.37	60.32
9264	36	4.68	5.07	4.73	4.83	0.21	57.01
9265	37	5.31	5.52	4.76	5.20	0.40	56.15
9269	38	1.93	2.37	2.10	2.13	0.22	67.85
8037	40	0.85	1.10	0.85	0.93	0.14	71.93
8095	41	1.63	1.87	1.85	1.78	0.13	74.89
8096	42	1.55	1.80	1.64	1.66	0.13	74.48
8098	43	1.87	2.03	1.83	1.91	0.11	72.69
8099	44	1.61	1.99	1.73	1.78	0.20	79.95
8268	45	5.14	5.57	5.05	5.25	0.28	71.10
8270	46	5.31	5.94	5.20	5.48	0.40	75.76
8271	47	5.27	5.69	5.18	5.38	0.27	70.74
8276	48	2.59	2.64	2.60	2.61	0.02	70.22
8280	49	2.06	2.28	2.07	2.14	0.13	73.47
8364	50	2.51	2.62	2.52	2.55	0.06	72.60
8476	51	2.61	2.64	2.63	2.62	0.01	73.23
8545	52	1.98	2.03	2.00	2.00	0.03	72.58
8554	53	1.32	1.37	1.40	1.37	0.04	71.90

Walkley-Black - weighed 1 g							
Using NAPT soil as standard curve							
If OM was above 4.0, then a weighed 0.5 g sample was used							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Calculated C recovery percent**
8557	54	3.91	3.84	3.96	3.90	0.06	74.01
8560	55	5.77	5.63	5.67	5.69	0.07	62.62
8608	56	4.73	4.80	5.03	4.85	0.16	78.37
8610	57	2.04	2.02	2.20	2.08	0.10	69.75
8619	58	2.40	2.43	2.43	2.42	0.02	66.04
8688	59	3.73	3.38	3.66	3.59	0.19	69.69
8713	60	2.51	2.16	2.30	2.32	0.17	68.08
8732	61	6.64	6.28	6.31	6.41	0.20	62.82
8789	62	1.87	2.02	2.13	2.01	0.13	71.82
8795	63	1.96	1.95	1.96	1.96	0.00	68.93
8813	64	3.34	3.15	3.36	3.28	0.12	65.23
8814	65	2.63	2.64	2.67	2.65	0.02	68.60
8821	66	2.08	2.08	2.22	2.13	0.08	62.84
8826	67	4.89	4.65	4.94	4.83	0.16	59.67
8835	68	3.18	2.94	3.29	3.14	0.18	67.81
8950	69	3.99	3.98	4.15	4.04	0.09	68.92
9035	70	2.16	2.12	2.18	2.15	0.03	68.49
9136	71	1.85	1.70	1.73	1.76	0.08	67.40
9266	72	4.22	4.09	4.11	4.14	0.07	61.86
9271	73	2.12	1.95	2.11	2.06	0.09	69.94
9308	74	0.65	0.57	0.65	0.63	0.04	58.87
9309	75	0.90	0.89	0.93	0.91	0.02	55.14
9411	76	0.81	0.74	0.72	0.76	0.05	63.68
9413	77	0.57	0.51	0.50	0.53	0.04	58.27
9414	78	0.59	0.64	0.65	0.63	0.03	62.83

Walkley-Black - weighed 1 g							
Using NAPT soil as standard curve							
If OM was above 4.0, then a weighed 0.5 g sample was used							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Calculated C recovery percent**
10430	80	1.12	1.08	1.04	1.08	0.04	60.27
10442	81	2.79	2.73	2.75	2.76	0.03	67.74
10613	82	2.24	2.04	2.15	2.14	0.10	67.35
10615	83	1.96	1.77	1.74	1.82	0.12	64.22
10617	84	2.12	2.00	2.13	2.08	0.07	67.16
10631	85	4.05	4.13	3.88	4.02	0.13	65.49
10670	86	2.53	2.54	2.42	2.49	0.07	69.07
10717	87	2.10	2.16	2.13	2.13	0.03	70.25
10738	88	2.51	2.48	2.58	2.52	0.05	69.17
10744	89	2.28	2.23	2.15	2.22	0.07	72.01
10889	90	2.14	1.79	1.80	1.91	0.20	75.34
10892	91	2.84	2.18	2.27	2.43	0.36	73.56
10897	92	2.34	2.29	2.21	2.28	0.07	67.90
10901	93	2.53	2.35	2.23	2.37	0.15	68.07
10932	94	3.61	3.48	3.31	3.47	0.15	65.88
10937	95	2.97	3.10	3.01	3.03	0.07	64.07
10941	96	2.22	2.16	2.09	2.16	0.07	64.53
10961	97	3.49	3.48	3.31	3.43	0.10	68.05
10985	98	3.28	3.21	2.90	3.13	0.20	65.74
11044	99	0.70	0.66	0.56	0.64	0.07	72.92
11049	100	1.06	0.76	0.91	0.91	0.15	73.75
11050	101	0.97	0.83	0.99	0.93	0.09	75.77
11060	102	3.99	3.54	3.58	3.70	0.25	73.91

Walkley-Black - scooped 0.85 cc						
Using NAPT soil as standard curve						
If OM was above 4.0, then a 1:1 water dilution absorbance was measured						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8034	1	2.10	1.79	2.05	1.98	0.17
8037	2	1.10	1.25	1.10	1.15	0.09
8321	3	1.40	1.43	1.48	1.44	0.04
8325	4	1.60	1.43	1.69	1.57	0.13
8329	5	1.50	1.56	1.76	1.61	0.13
8546	7	2.20	2.08	2.33	2.20	0.13
8565	9	2.70	2.61	3.31	2.87	0.38
8571	10	1.90	2.23	2.42	2.18	0.26
8598	11	1.80	1.90	2.17	1.96	0.19
8602	12	2.40	2.14	2.37	2.31	0.14
8604	13	2.30	2.39	2.53	2.41	0.12
8620	14	2.60	2.81	2.83	2.75	0.13
8621	15	2.80	3.14	3.33	3.09	0.27
8705	16	2.50	2.05	2.28	2.28	0.22
8728	17	3.70	3.63	3.77	3.70	0.07
8735	18	1.20	1.34	1.39	1.31	0.10
8785	19	2.90	2.50	2.58	2.66	0.21
8836	20	3.40	3.72	3.61	3.58	0.16
8907	21	3.80	3.54	4.39	3.91	0.43
8910	22	3.20	3.63	3.88	3.57	0.35
8911	23	4.92	4.71	5.40	5.01	0.36
8946	24	3.10	2.70	2.88	2.89	0.20
8948	25	4.00	3.45	3.79	3.75	0.28
8951	26	3.92	4.54	4.35	4.27	0.32
8953	27	4.63	4.79	4.56	4.66	0.12

Walkley-Black - scooped 0.85 cc						
Using NAPT soil as standard curve						
If OM was above 4.0, then a 1:1 water dilution absorbance was measured						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8954	28	3.60	3.14	3.65	3.47	0.28
8957	29	1.00	1.28	1.44	1.24	0.22
8961	30	0.90	1.03	1.19	1.04	0.14
9032	31	2.00	2.63	2.95	2.53	0.48
9130	32	3.00	2.34	2.47	2.60	0.35
9142	33	3.97	3.83	3.68	3.83	0.14
9181	34	5.17	5.85	5.95	5.66	0.42
9189	35	4.59	4.87	4.69	4.72	0.14
9264	36	3.30	3.81	4.20	3.77	0.45
9265	37	4.42	4.75	3.85	4.34	0.45
9269	38	1.30	1.72	1.76	1.59	0.25
8037	40	1.10	1.18	1.25	1.18	0.08
8095	41	1.50	1.76	1.66	1.64	0.13
8096	42	1.30	1.55	1.58	1.48	0.15
8098	43	1.60	1.55	1.76	1.64	0.11
8099	44	1.40	1.57	1.38	1.45	0.11
8268	45	3.88	4.01	3.89	3.93	0.07
8270	46	3.60	4.02	4.46	4.03	0.43
8271	47	4.21	4.42	4.10	4.24	0.16
8276	48	2.90	3.23	2.78	2.97	0.23
8280	49	2.10	2.06	1.86	2.01	0.13
8364	50	2.30	2.54	2.50	2.45	0.13
8476	51	2.00	2.22	2.09	2.10	0.11
8545	52	1.70	2.33	1.94	1.99	0.32
8554	53	1.20	1.55	1.45	1.40	0.18

Walkley-Black - scooped 0.85 cc						
Using NAPT soil as standard curve						
If OM was above 4.0, then a 1:1 water dilution absorbance was measured						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8557	54	3.10	3.21	3.54	3.28	0.23
8560	55	4.71	5.08	4.39	4.73	0.34
8608	56	3.76	4.01	3.60	3.79	0.21
8610	57	1.80	2.08	2.81	2.23	0.52
8619	58	2.20	2.63	2.35	2.39	0.22
8688	59	3.20	4.06	4.18	3.81	0.54
8713	60	2.50	2.26	2.27	2.34	0.13
8732	61	5.51	5.57	5.28	5.45	0.15
8789	62	1.90	1.87	1.99	1.92	0.06
8795	63	2.70	2.08	1.99	2.26	0.39
8813	64	3.90	3.28	3.09	3.42	0.43
8814	65	3.40	2.63	2.30	2.78	0.57
8821	66	2.40	2.33	1.99	2.24	0.22
8826	67	4.50	4.71	4.56	4.59	0.10
8835	68	3.00	2.91	2.88	2.93	0.06
8950	69	3.86	3.46	3.64	3.65	0.20
9035	70	1.20	1.94	1.71	1.62	0.38
9136	71	3.30	1.87	1.76	2.31	0.86
9266	72	3.50	3.76	4.44	3.90	0.48
9271	73	2.60	1.96	1.48	2.01	0.56
9308	74	0.20	1.02	0.51	0.58	0.41
9309	75	0.70	0.97	1.56	1.08	0.44
9411	76	0.80	1.46	0.95	1.07	0.34
9413	77	0.60	1.11	0.89	0.87	0.26
9414	78	0.50	1.04	0.61	0.72	0.29

Walkley-Black - scooped 0.85 cc						
Using NAPT soil as standard curve						
If OM was above 4.0, then a 1:1 water dilution absorbance was measured						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**Standard deviation**
10430	80	0.90	0.74	0.91	0.85	0.10
10442	81	2.40	2.59	2.22	2.40	0.19
10613	82	1.80	1.61	1.65	1.69	0.10
10615	83	1.50	1.44	1.72	1.55	0.15
10617	84	1.60	2.25	1.60	1.82	0.37
10631	85	3.84	4.01	3.76	3.87	0.12
10670	86	2.50	2.88	2.12	2.50	0.38
10717	87	2.00	1.98	2.17	2.05	0.10
10738	88	2.20	2.10	2.00	2.10	0.10
10744	89	2.30	2.05	2.22	2.19	0.13
10889	90	1.70	1.59	2.12	1.80	0.28
10892	91	2.43	2.30	2.31	2.35	0.07
10897	92	2.53	2.57	2.55	2.55	0.02
10901	93	2.98	2.20	2.43	2.54	0.40
10932	94	3.47	3.76	3.31	3.51	0.23
10937	95	3.00	2.93	3.28	3.07	0.19
10941	96	2.72	1.76	2.34	2.27	0.48
10961	97	3.30	3.27	3.17	3.25	0.07
10985	98	3.40	3.22	3.31	3.31	0.09
11044	99	0.70	1.18	0.61	0.83	0.31
11049	100	0.80	1.25	0.82	0.96	0.25
11050	101	0.90	0.98	1.29	1.06	0.21
11060	102	3.80	3.49	3.83	3.71	0.19

Loss on Ignition						
2 hr at 150C , 15 min cool, 3 hr at 400C, 15 min cool						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8034	1	2.25	2.56	2.61	2.47	0.19
8037	2	1.11	1.15	1.13	1.13	0.02
8321	3	1.64	1.67	1.64	1.65	0.02
8325	4	1.72	1.86	1.89	1.83	0.09
8329	5	1.93	1.96	2.03	1.97	0.05
8546	7	2.93	3.14	3.06	3.04	0.10
8565	9	3.76	4.15	4.03	3.98	0.20
8571	10	2.94	3.18	3.08	3.07	0.12
8598	11	2.65	2.87	2.86	2.79	0.13
8602	12	3.01	3.40	3.48	3.29	0.25
8604	13	3.30	3.62	3.73	3.55	0.22
8620	14	3.71	3.99	3.82	3.84	0.14
8621	15	3.76	4.11	3.97	3.95	0.17
8705	16	2.76	2.95	3.01	2.91	0.13
8728	17	5.34	5.48	5.23	5.35	0.13
8735	18	1.29	1.41	1.48	1.39	0.10
8785	19	3.06	3.35	3.47	3.29	0.21
8836	20	4.80	5.15	5.21	5.05	0.22
8907	21	4.74	4.45	4.54	4.58	0.15
8910	22	4.51	4.40	4.73	4.55	0.17
8911	23	6.74	6.93	6.99	6.89	0.13
8946	24	3.45	3.89	3.89	3.74	0.26
8948	25	5.44	5.54	5.74	5.58	0.15
8951	26	6.62	6.83	6.91	6.79	0.15
8953	27	6.52	6.81	6.77	6.70	0.16

Loss on Ignition						
2 hr at 150C , 15 min cool, 3 hr at 400C, 15 min cool						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8954	28	4.32	4.44	4.54	4.43	0.11
8957	29	1.74	1.98	2.05	1.93	0.16
8961	30	1.56	1.67	1.70	1.64	0.07
9032	31	3.62	3.91	3.87	3.80	0.15
9130	32	2.94	3.34	3.19	3.15	0.20
9142	33	5.02	5.27	5.11	5.13	0.12
9181	34	8.68	8.67	8.81	8.72	0.08
9189	35	5.66	5.43	5.82	5.64	0.19
9264	36	4.93	5.07	5.45	5.15	0.27
9265	37	5.20	5.27	5.22	5.23	0.04
9269	38	2.58	2.77	2.78	2.71	0.11
8037	40	1.10	1.21	1.26	1.19	0.08
8095	41	1.85	2.03	2.03	1.97	0.10
8096	42	1.88	2.14	1.90	1.97	0.14
8098	43	2.00	2.31	2.17	2.16	0.16
8099	44	1.38	2.06	2.07	1.84	0.40
8268	45	5.68	5.94	6.18	5.94	0.25
8270	46	5.43	5.81	5.96	5.73	0.27
8271	47	5.81	6.15	6.24	6.07	0.23
8276	48	2.57	2.77	2.78	2.71	0.12
8280	49	2.39	2.43	2.50	2.44	0.05
8364	50	3.11	3.36	3.21	3.23	0.13
8476	51	2.91	3.21	3.43	3.18	0.26
8545	52	2.43	2.64	2.61	2.56	0.11
8554	53	1.57	1.77	1.67	1.67	0.10

Loss on Ignition						
2 hr at 150C , 15 min cool, 3 hr at 400C, 15 min cool						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
8557	54	3.99	4.26	4.57	4.27	0.29
8560	55	6.33	6.43	6.78	6.51	0.24
8608	56	5.16	5.49	5.37	5.34	0.17
8610	57	2.46	2.79	2.66	2.64	0.17
8619	58	3.12	3.56	3.48	3.39	0.23
8688	59	3.90	4.20	4.22	4.11	0.18
8713	60	2.90	3.21	3.52	3.21	0.31
8732	61	7.14	7.51	7.12	7.26	0.22
8789	62	2.34	2.66	2.59	2.53	0.17
8795	63	2.23	2.45	2.47	2.38	0.14
8813	64	3.90	4.41	4.42	4.25	0.30
8814	65	3.25	3.52	3.62	3.47	0.19
8821	66	2.61	2.72	2.61	2.65	0.06
8826	67	5.51	5.17	5.63	5.44	0.24
8835	68	3.82	4.13	4.34	4.09	0.26
8950	69	4.81	5.11	4.82	4.91	0.17
9035	70	2.37	2.56	2.47	2.47	0.10
9136	71	2.17	2.38	2.59	2.38	0.21
9266	72	4.54	4.87	4.72	4.71	0.17
9271	73	2.52	2.74	2.67	2.64	0.11
9308	74	0.93	1.07	1.11	1.04	0.09
9309	75	1.21	1.47	1.30	1.32	0.13
9411	76	0.89	1.04	1.11	1.01	0.11
9413	77	0.71	0.82	0.68	0.74	0.07
9414	78	0.71	0.89	0.84	0.81	0.09

Loss on Ignition						
2 hr at 150C , 15 min cool, 3 hr at 400C, 15 min cool						
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**
10430	80	1.62	1.73	1.83	1.72	0.11
10442	81	3.22	3.70	3.72	3.55	0.28
10613	82	2.52	2.84	2.98	2.78	0.24
10615	83	2.30	2.72	2.55	2.53	0.21
10617	84	2.49	2.84	2.86	2.73	0.21
10631	85	5.02	5.25	5.10	5.12	0.12
10670	86	5.41	3.07	2.92	3.80	1.40
10717	87	2.58	2.83	2.83	2.75	0.14
10738	88	2.92	3.31	3.15	3.13	0.20
10744	89	2.64	2.65	2.82	2.71	0.10
10889	90	2.61	2.80	2.77	2.73	0.10
10892	91	3.04	3.23	3.32	3.20	0.14
10897	92	2.90	3.19	3.13	3.07	0.15
10901	93	2.85	3.08	3.07	3.00	0.13
10932	94	4.12	4.34	4.42	4.30	0.15
10937	95	3.80	3.98	3.94	3.91	0.09
10941	96	2.88	3.18	3.19	3.09	0.18
10961	97	3.95	4.22	4.33	4.17	0.20
10985	98	3.92	4.04	4.34	4.10	0.22
11044	99	0.84	1.00	0.86	0.90	0.09
11049	100	1.28	1.49	1.49	1.42	0.12
11050	101	1.45	1.53	1.32	1.43	0.11
11060	102	4.20	4.50	4.27	4.32	0.15

Scoop volume weight								
0.85 cc scoop								
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**scoop conversion factor**	**WB scoop converted to weighed**
8034	1	1.01	1.00	1.00	1.00	0.00	1.00	1.97
8037	2	1.16	1.16	1.18	1.17	0.01	0.86	0.99
8321	3	1.01	0.96	1.01	0.99	0.02	1.01	1.45
8325	4	1.05	1.04	1.04	1.04	0.00	0.96	1.51
8329	5	1.03	1.02	1.04	1.03	0.01	0.97	1.56
8546	7	0.92	0.90	0.89	0.90	0.01	1.11	2.44
8565	9	0.84	0.86	0.90	0.87	0.02	1.15	3.32
8571	10	0.86	0.88	0.90	0.88	0.02	1.14	2.48
8598	11	0.94	0.91	0.97	0.94	0.02	1.06	2.08
8602	12	0.88	0.85	0.87	0.87	0.01	1.15	2.66
8604	13	0.93	0.89	0.89	0.90	0.02	1.11	2.66
8620	14	0.88	0.88	0.81	0.86	0.03	1.17	3.21
8621	15	0.90	0.88	0.85	0.88	0.02	1.14	3.53
8705	16	0.85	0.87	0.88	0.87	0.01	1.15	2.63
8728	17	0.75	0.78	0.79	0.77	0.02	1.29	4.78
8735	18	1.08	1.00	0.99	1.02	0.04	0.98	1.28
8785	19	0.89	0.91	0.84	0.88	0.03	1.14	3.02
8836	20	0.80	0.81	0.89	0.83	0.04	1.20	4.29
8907	21	0.90	0.87	0.89	0.89	0.01	1.13	4.41
8910	22	0.97	0.97	0.98	0.97	0.00	1.03	3.67
8911	23	0.84	0.86	0.81	0.84	0.02	1.20	5.99
8946	24	0.97	1.00	0.94	0.97	0.02	1.03	2.98
8948	25	0.77	0.79	0.83	0.80	0.02	1.26	4.70
8951	26	0.79	0.77	0.79	0.78	0.01	1.28	5.45
8953	27	0.83	0.80	0.81	0.81	0.01	1.23	5.73

Scoop volume weight								
0.85 cc scoop								
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**Standard deviation**	**scoop conversion factor**	**WB scoop converted to weighed**
8954	28	0.99	0.96	0.96	0.97	0.01	1.03	3.57
8957	29	0.99	0.98	0.99	0.99	0.00	1.01	1.25
8961	30	1.00	0.98	1.01	1.00	0.01	1.00	1.04
9032	31	0.89	0.87	0.84	0.87	0.02	1.15	2.91
9130	32	0.89	0.86	0.87	0.87	0.01	1.15	2.98
9142	33	0.82	0.82	0.83	0.82	0.00	1.21	4.65
9181	34	0.81	0.77	0.77	0.78	0.02	1.28	7.22
9189	35	0.94	0.96	0.95	0.95	0.01	1.05	4.96
9264	36	0.87	0.83	0.83	0.84	0.02	1.19	4.47
9265	37	0.86	0.94	0.82	0.87	0.05	1.15	4.97
9269	38	0.80	0.78	0.78	0.79	0.01	1.27	2.02
8037	40	1.19	1.15	1.17	1.17	0.02	0.85	1.01
8095	41	0.98	0.96	0.97	0.97	0.01	1.03	1.69
8096	42	0.96	0.92	0.95	0.94	0.02	1.06	1.57
8098	43	0.95	0.90	0.92	0.92	0.02	1.08	1.77
8099	44	0.97	0.88	0.96	0.94	0.04	1.07	1.55
8268	45	0.80	0.82	0.81	0.81	0.01	1.23	4.85
8270	46	0.80	0.75	0.79	0.78	0.02	1.28	5.16
8271	47	0.82	0.78	0.80	0.80	0.02	1.25	5.30
8276	48	1.04	1.04	1.03	1.04	0.00	0.96	2.87
8280	49	0.99	0.95	0.97	0.97	0.02	1.03	2.07
8364	50	0.97	0.95	0.93	0.95	0.02	1.05	2.58
8476	51	0.84	0.87	0.90	0.87	0.02	1.15	2.42
8545	52	0.98	1.01	1.00	1.00	0.01	1.00	2.00
8554	53	1.01	1.02	1.01	1.01	0.00	0.99	1.38

Scoop volume weight								
0.85 cc scoop								
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**scoop conversion factor**	**WB scoop converted to weighed**
8557	54	0.91	0.89	0.90	0.90	0.01	1.11	3.65
8560	55	0.86	0.80	0.79	0.82	0.03	1.22	5.79
8608	56	0.83	0.72	0.77	0.77	0.04	1.29	4.90
8610	57	0.95	0.94	0.94	0.94	0.00	1.06	2.36
8619	58	0.88	0.94	0.88	0.90	0.03	1.11	2.66
8688	59	0.91	0.95	0.91	0.92	0.02	1.08	4.13
8713	60	0.93	0.97	0.97	0.96	0.02	1.05	2.45
8732	61	0.90	0.86	0.90	0.89	0.02	1.13	6.15
8789	62	0.95	0.97	0.96	0.96	0.01	1.04	2.00
8795	63	0.97	0.98	1.03	0.99	0.03	1.01	2.27
8813	64	0.96	0.94	0.92	0.94	0.02	1.06	3.64
8814	65	0.92	0.93	0.91	0.92	0.01	1.09	3.02
8821	66	0.96	0.99	0.95	0.97	0.02	1.03	2.32
8826	67	0.91	0.86	0.94	0.90	0.03	1.11	5.08
8835	68	0.89	0.93	0.89	0.90	0.02	1.11	3.24
8950	69	0.86	0.88	0.87	0.87	0.01	1.15	4.20
9035	70	0.92	0.93	0.89	0.91	0.02	1.09	1.77
9136	71	0.97	0.96	0.94	0.96	0.01	1.05	2.42
9266	72	0.93	0.93	0.90	0.92	0.01	1.09	4.24
9271	73	0.85	0.79	0.85	0.83	0.03	1.20	2.43
9308	74	1.01	0.98	0.98	0.99	0.01	1.01	0.58
9309	75	0.98	0.95	0.92	0.95	0.02	1.05	1.13
9411	76	1.13	1.10	1.06	1.10	0.03	0.91	0.97
9413	77	1.21	1.20	1.19	1.20	0.01	0.83	0.72
9414	78	1.15	1.10	1.11	1.12	0.02	0.89	0.64

Scoop volume weight								
0.85 cc scoop								
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**scoop conversion factor**	**WB scoop converted to weighed**
10430	80	0.88	0.84	0.87	0.86	0.02	1.16	0.99
10442	81	0.94	0.96	0.94	0.95	0.01	1.06	2.54
10613	82	0.85	0.86	0.89	0.87	0.02	1.15	1.95
10615	83	0.90	0.90	0.89	0.90	0.00	1.12	1.73
10617	84	0.84	0.81	0.80	0.82	0.02	1.22	2.22
10631	85	0.99	0.97	0.99	0.98	0.01	1.02	3.94
10670	86	1.00	0.97	0.98	0.98	0.01	1.02	2.54
10717	87	0.91	0.93	0.86	0.90	0.03	1.11	2.28
10738	88	0.99	0.89	0.95	0.94	0.04	1.06	2.23
10744	89	0.99	0.98	0.98	0.98	0.00	1.02	2.23
10889	90	1.10	1.09	1.11	1.10	0.01	0.91	1.64
10892	91	1.01	1.01	1.02	1.01	0.00	0.99	2.32
10897	92	1.01	1.03	1.04	1.03	0.01	0.97	2.48
10901	93	1.01	1.02	0.99	1.01	0.01	0.99	2.52
10932	94	0.99	0.97	0.99	0.98	0.01	1.02	3.57
10937	95	0.98	0.97	0.96	0.97	0.01	1.03	3.17
10941	96	1.03	1.03	0.99	1.02	0.02	0.98	2.23
10961	97	0.98	0.95	0.94	0.96	0.02	1.05	3.39
10985	98	1.03	1.03	1.02	1.03	0.00	0.97	3.22
11044	99	1.10	1.03	1.01	1.05	0.04	0.96	0.79
11049	100	1.11	1.07	1.09	1.09	0.02	0.92	0.88
11050	101	1.11	1.15	1.11	1.12	0.02	0.89	0.94
11060	102	0.99	0.97	0.95	0.97	0.02	1.03	3.82

Dry combustion Total C								
Percent								
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Average x 1.72**	**standard deviation x 1.72**
8034	1	1.29	1.32	1.29	1.30	0.02	2.24	0.03
8037	2	0.59	0.59	0.55	0.57	0.02	0.99	0.03
8321	3	0.88	0.92	0.84	0.88	0.04	1.51	0.07
8325	4	0.86	0.87	0.91	0.88	0.03	1.51	0.05
8329	5	1.00	0.97	0.99	0.99	0.02	1.70	0.03
8546	7	1.58	1.59	1.59	1.59	0.01	2.73	0.01
8565	9	2.16	2.15	2.19	2.16	0.02	3.72	0.03
8571	10	1.74	1.72	1.73	1.73	0.01	2.98	0.02
8598	11	1.43	1.38	1.41	1.41	0.03	2.42	0.05
8602	12	1.69	1.69	1.69	1.69	0.00	2.91	0.01
8604	13	2.06	1.98	2.01	2.01	0.04	3.47	0.07
8620	14	2.19	2.04	2.11	2.11	0.07	3.63	0.12
8621	15	2.12	2.13	2.17	2.14	0.03	3.68	0.04
8705	16	1.50	1.48	1.42	1.46	0.04	2.52	0.07
8728	17	2.99	3.09	3.00	3.03	0.06	5.20	0.10
8735	18	0.60	0.81	0.74	0.71	0.11	1.23	0.19
8785	19	1.79	1.82	1.72	1.78	0.05	3.06	0.08
8836	20	2.87	2.82	2.72	2.80	0.08	4.82	0.13
8907	21	2.53	3.00	2.60	2.71	0.25	4.66	0.43
8910	22	2.39	2.56	2.53	2.50	0.09	4.29	0.16
8911	23	3.99	4.12	3.74	3.95	0.19	6.79	0.33
8946	24	2.10	2.15	1.99	2.08	0.08	3.58	0.14
8948	25	3.27	3.18	3.17	3.21	0.05	5.51	0.09
8951	26	3.43	3.45	3.30	3.40	0.08	5.84	0.14
8953	27	3.70	3.62	3.51	3.61	0.09	6.21	0.16

Dry combustion Total C								
Percent								
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation	Average x 1.72	standard deviation x 1.72
8954	28	2.26	2.21	2.26	2.24	0.03	3.86	0.05
8957	29	0.86	0.87	0.87	0.87	0.00	1.49	0.01
8961	30	0.71	0.70	0.71	0.71	0.00	1.22	0.01
9032	31	2.24	2.10	2.18	2.17	0.07	3.74	0.12
9130	32	1.70	1.71	1.66	1.69	0.03	2.91	0.05
9142	33	2.93	2.83	2.83	2.87	0.06	4.93	0.10
9181	34	5.44	5.20	5.16	5.27	0.15	9.06	0.26
9189	35	3.38	3.25	3.65	3.42	0.20	5.89	0.35
9264	36	3.89	3.79	3.51	3.73	0.20	6.42	0.34
9265	37	4.08	4.14	4.01	4.08	0.07	7.01	0.12
9269	38	1.41	1.39	1.36	1.39	0.02	2.38	0.04
8037	40	0.56	0.63	0.52	0.57	0.06	0.98	0.10
8095	41	1.09	0.98	1.08	1.05	0.06	1.80	0.11
8096	42	0.93	1.00	1.02	0.98	0.04	1.69	0.08
8098	43	1.14	1.17	1.17	1.16	0.01	1.99	0.02
8099	44	0.97	0.98	0.99	0.98	0.01	1.68	0.02
8268	45	3.29	3.30	3.17	3.25	0.07	5.60	0.12
8270	46	3.20	3.20	3.16	3.19	0.02	5.48	0.04
8271	47	3.33	3.37	3.35	3.35	0.02	5.76	0.04
8276	48	1.67	1.60	1.65	1.64	0.04	2.82	0.06
8280	49	1.26	1.30	1.28	1.28	0.02	2.20	0.03
8364	50	1.56	1.53	1.55	1.55	0.02	2.66	0.03
8476	51	1.62	1.57	1.55	1.58	0.03	2.71	0.06
8545	52	1.25	1.18	1.22	1.22	0.04	2.09	0.07
8554	53	0.82	0.83	0.86	0.84	0.02	1.44	0.03

Dry combustion Total C								
Percent								
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	Standard deviation	Average x 1.72	standard deviation x 1.72
8557	54	2.37	2.34	2.26	2.32	0.06	3.99	0.10
8560	55	4.07	3.96	3.98	4.00	0.06	6.88	0.10
8608	56	2.73	2.60	2.84	2.73	0.12	4.69	0.21
8610	57	1.33	1.30	1.32	1.32	0.01	2.26	0.03
8619	58	1.64	1.62	1.59	1.62	0.03	2.78	0.04
8688	59	2.28	2.27	2.25	2.27	0.01	3.90	0.02
8713	60	1.49	1.51	1.51	1.50	0.01	2.59	0.02
8732	61	4.46	4.57	4.47	4.50	0.06	7.73	0.10
8789	62	1.25	1.19	1.26	1.23	0.04	2.12	0.06
8795	63	1.27	1.22	1.26	1.25	0.02	2.15	0.04
8813	64	2.22	2.20	2.22	2.22	0.01	3.81	0.02
8814	65	1.69	1.69	1.72	1.70	0.02	2.92	0.03
8821	66	1.48	1.48	1.51	1.49	0.02	2.56	0.03
8826	67	3.68	3.45	3.37	3.56	0.16	6.13	0.28
8835	68	2.07	2.00	2.04	2.04	0.03	3.50	0.06
8950	69	2.54	2.63	2.64	2.58	0.06	4.44	0.10
9035	70	1.37	1.40	1.38	1.38	0.01	2.38	0.02
9136	71	1.12	1.18	1.14	1.15	0.03	1.98	0.06
9266	72	2.86	3.03	2.99	2.95	0.08	5.07	0.15
9271	73	1.31	1.29	1.30	1.30	0.01	2.23	0.02
9308	74	0.49	0.46	0.46	0.47	0.02	0.81	0.03
9309	75	0.67	0.74	0.76	0.72	0.05	1.24	0.08
9411	76	0.49	0.55	0.53	0.52	0.03	0.90	0.05
9413	77	0.39	0.44	0.37	0.40	0.04	0.69	0.07
9414	78	0.47	0.43	0.42	0.44	0.02	0.76	0.04

Dry combustion Total C								
Percent								
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation	Average x 1.72	standard deviation x 1.72
10430	80	0.80	0.79	0.77	0.79	0.02	1.36	0.03
10442	81	1.80	1.82	1.77	1.79	0.02	3.08	0.04
10613	82	1.38	1.43	1.40	1.40	0.02	2.41	0.04
10615	83	1.24	1.23	1.29	1.25	0.03	2.15	0.05
10617	84	1.34	1.37	1.39	1.37	0.02	2.35	0.04
10631	85	2.71	2.70	2.70	2.70	0.01	4.65	0.02
10670	86	1.56	1.60	1.62	1.59	0.03	2.73	0.05
10717	87	1.34	1.37	1.30	1.34	0.03	2.30	0.06
10738	88	1.60	1.61	1.61	1.60	0.01	2.76	0.01
10744	89	1.34	1.37	1.36	1.36	0.02	2.34	0.03
10889	90	1.14	1.08	1.13	1.12	0.03	1.92	0.06
10892	91	1.47	1.45	1.46	1.46	0.01	2.51	0.01
10897	92	1.47	1.50	1.47	1.48	0.02	2.55	0.03
10901	93	1.52	1.53	1.56	1.53	0.02	2.64	0.03
10932	94	2.33	2.30	2.32	2.32	0.02	3.99	0.03
10937	95	2.08	2.08	2.08	2.08	0.00	3.58	0.00
10941	96	1.47	1.47	1.48	1.47	0.01	2.53	0.01
10961	97	2.21	2.21	2.24	2.22	0.02	3.81	0.03
10985	98	2.09	2.09	2.11	2.10	0.01	3.61	0.02
11044	99	0.38	0.39	0.40	0.39	0.01	0.67	0.02
11049	100	0.52	0.55	0.55	0.54	0.02	0.93	0.03
11050	101	0.55	0.52	0.55	0.54	0.02	0.93	0.04
11060	102	2.19	2.23	2.20	2.21	0.02	3.79	0.03

Dry combustion organic C								
Samples with a pH >7.1 were acid treated								
Percent								
Lab ID #	OM study #	pH	rep 1	rep 2	rep 3	average	standard deviation	Average x 1.72
8034	1	7.4	1.11	1.20	1.17	1.16	0.04	1.99
8037	2	4.9	0.59	0.59	0.55	0.57	0.02	0.99
8321	3	6.8	0.88	0.92	0.84	0.88	0.04	1.51
8325	4	6.8	0.86	0.87	0.91	0.88	0.03	1.51
8329	5	6.3	1.00	0.97	0.99	0.99	0.02	1.70
8546	7	6.5	1.58	1.59	1.59	1.59	0.01	2.73
8565	9	6.6	2.16	2.15	2.19	2.16	0.02	3.72
8571	10	7.7	1.60	1.59	1.59	1.59	0.01	2.74
8598	11	6.9	1.43	1.38	1.41	1.41	0.03	2.42
8602	12	6.7	1.69	1.69	1.69	1.69	0.00	2.91
8604	13	8.1	1.80	1.80	1.80	1.80	0.00	3.09
8620	14	6.3	2.19	2.04	2.11	2.11	0.07	3.63
8621	15	6.3	2.12	2.13	2.17	2.14	0.03	3.68
8705	16	6.6	1.50	1.48	1.42	1.46	0.04	2.52
8728	17	6.6	2.99	3.09	3.00	3.03	0.06	5.20
8735	18	7.0	0.60	0.81	0.74	0.71	0.11	1.23
8785	19	6.0	1.79	1.82	1.72	1.78	0.05	3.06
8836	20	6.5	2.87	2.82	2.72	2.80	0.08	4.82
8907	21	7.0	2.53	3.00	2.60	2.71	0.25	4.66
8910	22	7.9	2.22	2.49	2.53	2.41	0.17	4.15
8911	23	5.8	3.99	4.12	3.74	3.95	0.19	6.79
8946	24	7.2	1.67	1.77	1.73	1.72	0.05	2.96
8948	25	7.1	3.03	2.89	3.01	2.97	0.08	5.11
8951	26	5.7	3.43	3.45	3.30	3.40	0.08	5.84
8953	27	6.1	3.70	3.62	3.51	3.61	0.09	6.21

Dry combustion organic C Samples with a pH >7.1 were acid treated Percent								
Lab ID #	**OM study #**	**pH**	**rep 1**	**rep 2**	**rep 3**	**average**	**Standard deviation**	**average x 1.72**
8954	28	6.5	2.26	2.21	2.26	2.24	0.03	3.86
8957	29	7.0	0.86	0.87	0.87	0.87	0.00	1.49
8961	30	6.6	0.71	0.70	0.71	0.71	0.00	1.22
9032	31	5.8	2.24	2.10	2.18	2.17	0.07	3.74
9130	32	6.4	1.70	1.71	1.66	1.69	0.03	2.91
9142	33	5.8	2.93	2.83	2.83	2.87	0.06	4.93
9181	34	7.5	4.90	4.75	4.83	4.83	0.07	8.30
9189	35	7.4	2.99	3.34	3.43	3.25	0.23	5.59
9264	36	8.0	2.95	2.86	2.86	2.89	0.05	4.97
9265	37	8.5	2.96	2.99	3.06	3.00	0.05	5.16
9269	38	6.1	1.41	1.39	1.36	1.39	0.02	2.38
8037	40	4.9	0.56	0.63	0.52	0.57	0.06	0.98
8095	41	6.5	1.09	0.98	1.08	1.05	0.06	1.80
8096	42	6.5	0.93	1.00	1.02	0.98	0.04	1.69
8098	43	6.8	1.14	1.17	1.17	1.16	0.01	1.99
8099	44	6.6	0.97	0.98	0.99	0.98	0.01	1.68
8268	45	4.9	3.29	3.30	3.17	3.25	0.07	5.60
8270	46	4.8	3.20	3.20	3.16	3.19	0.02	5.48
8271	47	6.0	3.33	3.37	3.35	3.35	0.02	5.76
8276	48	8.3	1.54	1.58	1.56	1.56	0.02	2.68
8280	49	6.2	1.26	1.30	1.28	1.28	0.02	2.20
8364	50	6.0	1.56	1.53	1.55	1.55	0.02	2.66
8476	51	6.5	1.62	1.57	1.55	1.58	0.03	2.71
8545	52	6.5	1.25	1.18	1.22	1.22	0.04	2.09
8554	53	6.9	0.82	0.83	0.86	0.84	0.02	1.44

Dry combustion organic C								
Samples with a pH >7.1 were acid treated								
Percent								
Lab ID #	**OM study #**	**pH**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Average x 1.72**
8557	54	7.8	2.26	2.35	2.26	2.29	0.05	3.94
8560	55	8.1	3.96	3.91	3.93	3.94	0.03	6.77
8608	56	5.9	2.73	2.60	2.84	2.73	0.12	4.69
8610	57	5.7	1.33	1.30	1.32	1.32	0.01	2.26
8619	58	6.1	1.64	1.62	1.59	1.62	0.03	2.78
8688	59	7.0	2.28	2.27	2.25	2.27	0.01	3.90
8713	60	6.5	1.49	1.51	1.51	1.50	0.01	2.59
8732	61	5.9	4.46	4.57	4.47	4.50	0.06	7.73
8789	62	6.0	1.25	1.19	1.26	1.23	0.04	2.12
8795	63	5.7	1.27	1.22	1.26	1.25	0.02	2.15
8813	64	6.6	2.22	2.20	2.22	2.22	0.01	3.81
8814	65	6.6	1.69	1.69	1.72	1.70	0.02	2.92
8821	66	8.0	1.29	1.32	1.32	1.31	0.02	2.26
8826	67	7.2	3.00	3.04	3.03	3.02	0.02	5.19
8835	68	6.7	2.07	2.00	2.04	2.04	0.03	3.50
8950	69	5.4	2.54	2.63	2.64	2.58	0.06	4.44
9035	70	5.8	1.37	1.40	1.38	1.38	0.01	2.38
9136	71	6.9	1.12	1.18	1.14	1.15	0.03	1.98
9266	72	7.8	2.47	2.65	2.68	2.60	0.12	4.47
9271	73	7.1	1.30	1.30	1.30	1.30	0.00	2.24
9308	74	6.9	0.49	0.46	0.46	0.47	0.02	0.81
9309	75	8.0	0.69	0.75	0.77	0.74	0.04	1.27
9411	76	5.5	0.49	0.55	0.53	0.52	0.03	0.90
9413	77	5.5	0.39	0.44	0.37	0.40	0.04	0.69
9414	78	5.6	0.47	0.43	0.42	0.44	0.02	0.76

Dry combustion organic C Samples with a pH >7.1 were acid treated Percent								
Lab ID #	**OM study #**	**pH**	**rep 1**	**rep 2**	**rep 3**	**average**	**Standard deviation**	**Average x 1.72**
10430	80	6.2	0.80	0.79	0.77	0.79	0.02	1.36
10442	81	6.2	1.80	1.82	1.77	1.79	0.02	3.08
10613	82	5.8	1.38	1.43	1.40	1.40	0.02	2.41
10615	83	6.6	1.24	1.23	1.29	1.25	0.03	2.15
10617	84	6.1	1.34	1.37	1.39	1.37	0.02	2.35
10631	85	7.1	2.65	2.69	2.64	2.66	0.03	4.57
10670	86	6.2	1.56	1.60	1.62	1.59	0.03	2.73
10717	87	5.9	1.34	1.37	1.30	1.34	0.03	2.30
10738	88	6.4	1.60	1.61	1.61	1.60	0.01	2.76
10744	89	7.2	1.32	1.40	1.39	1.37	0.05	2.36
10889	90	7.0	1.14	1.08	1.13	1.12	0.03	1.92
10892	91	6.8	1.47	1.45	1.46	1.46	0.01	2.51
10897	92	6.5	1.47	1.50	1.47	1.48	0.02	2.55
10901	93	6.9	1.52	1.53	1.56	1.53	0.02	2.64
10932	94	7.5	2.26	2.27	2.29	2.27	0.02	3.91
10937	95	6.2	2.08	2.08	2.08	2.08	0.00	3.58
10941	96	7.4	1.33	1.42	1.44	1.40	0.06	2.40
10961	97	5.8	2.21	2.21	2.24	2.22	0.02	3.81
10985	98	6.1	2.09	2.09	2.11	2.10	0.01	3.61
11044	99	5.2	0.38	0.39	0.40	0.39	0.01	0.67
11049	100	5.5	0.52	0.55	0.55	0.54	0.02	0.93
11050	101	5.6	0.55	0.52	0.55	0.54	0.02	0.93
11060	102	5.4	2.19	2.23	2.20	2.21	0.02	3.79

Walkley-Black 1 g weighed							
Using sugar standard curve							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**Standard deviation**	**Measured C recovery**
8034	1	0.90	0.90	0.87	0.89	0.01	76.77
8037	2	.	.	.		.	
8321	3	.	.	.		.	
8325	4	.	.	.		.	
8329	5	.	.	.		.	
8546	7	.	.	.		.	
8565	9	.	.	.		.	
8571	10	1.25	1.16	1.25	1.22	0.05	76.81
8598	11	.	.	.		.	
8602	12	.	.	.		.	
8604	13	1.28	1.30	1.32	1.30	0.02	72.15
8620	14	.	.	.		.	
8621	15	.	.	.		.	
8705	16	.	.	.		.	
8728	17	.	.	.	.	.	
8735	18	.	.	.		.	
8785	19	.	.	.		.	
8836	20	.	.	.		.	
8907	21	.	.	.		.	
8910	22	2.04	1.97	1.94	1.98	0.05	82.26
8911	23	2.90	2.78	2.87	2.85	0.06	72.08
8946	24	1.33	1.35	1.29	1.33	0.03	77.03
8948	25	.	.	.		.	
8951	26	.	.	.		.	
8953	27	2.89	2.72	2.75	2.79	0.09	77.22

Walkley-Black 1 g weighed							
Using sugar standard curve							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Measured C recovery**
8954	28	.	.	.		.	
8957	29	.	.	.		.	
8961	30	0.48	0.56	0.47	0.50	0.05	70.92
9032	31	1.61	1.59	1.58	1.60	0.01	73.35
9130	32	1.20	1.27	1.33	1.27	0.06	74.91
9142	33	2.32	2.32	2.35	2.33	0.02	81.33
9181	34	3.23	3.12	3.15	3.17	0.06	65.59
9189	35	2.23	2.27	2.19	2.23	0.04	68.61
9264	36	2.32	2.25	2.33	2.30	0.04	79.55
9265	37	2.55	2.45	2.34	2.45	0.11	81.56
9269	38	0.93	1.08	1.04	1.01	0.08	73.26
8037	40	0.39	0.53	0.44	0.45	0.07	78.96
8095	41	0.77	0.86	0.93	0.86	0.08	81.68
8096	42	0.73	0.84	0.83	0.80	0.06	81.19
8098	43	0.90	0.93	0.92	0.92	0.02	79.19
8099	44	0.76	0.92	0.87	0.85	0.08	86.94
8268	45	2.50	2.47	2.51	2.49	0.02	76.58
8270	46	2.55	2.63	2.58	2.59	0.04	81.19
8271	47	2.65	2.52	2.57	2.58	0.06	77.02
8276	48	1.25	1.20	1.30	1.25	0.05	80.28
8280	49	0.99	1.04	1.04	1.02	0.03	79.91
8364	50	1.21	1.19	1.26	1.22	0.04	78.97
8476	51	1.26	1.20	1.31	1.26	0.06	79.72
8545	52	0.95	0.93	1.01	0.96	0.04	79.19
8554	53	0.62	0.68	0.71	0.67	0.05	80.20

Walkley-Black 1 g weighed							
Using sugar standard curve							
Lab ID #	**OM study #**	**rep 1**	**rep 2**	**rep 3**	**average**	**standard deviation**	**Measured C recovery**
8557	54	1.92	1.89	1.97	1.92	0.04	84.10
8560	55	2.80	2.77	2.81	2.80	0.02	71.01
8608	56	2.37	2.36	2.49	2.41	0.07	88.34
8610	57	0.98	1.00	1.10	1.03	0.07	77.97
8619	58	1.16	1.20	1.22	1.19	0.03	73.86
8688	59	1.82	1.66	1.82	1.77	0.09	78.06
8713	60	1.21	1.07	1.16	1.15	0.07	76.18
8732	61	3.20	3.09	3.13	3.14	0.05	69.79
8789	62	0.90	1.00	1.07	0.99	0.09	80.25
8795	63	0.94	0.97	0.99	0.96	0.02	77.04
8813	64	1.63	1.55	1.67	1.62	0.06	73.04
8814	65	1.27	1.31	1.33	1.30	0.03	76.76
8821	66	1.00	1.03	1.11	1.05	0.06	79.80
8826	67	2.38	2.29	2.45	2.37	0.08	78.59
8835	68	1.55	1.45	1.64	1.55	0.10	75.91
8950	69	1.96	1.96	2.06	1.99	0.06	77.20
9035	70	1.04	1.05	1.09	1.06	0.03	76.58
9136	71	0.89	0.84	0.87	0.87	0.02	75.32
9266	72	2.07	2.01	2.04	2.04	0.03	78.54
9271	73	1.02	0.97	1.06	1.02	0.05	78.02
9308	74	0.29	0.29	0.34	0.31	0.03	65.22
9309	75	0.41	0.44	0.48	0.44	0.04	60.20
9411	76	0.37	0.37	0.37	0.37	0.00	70.73
9413	77	0.24	0.26	0.27	0.26	0.01	64.41
9414	78	0.25	0.32	0.34	0.31	0.05	69.58

Walkley-Black 1 g weighed							
Using sugar standard curve							
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation	Measured C recovery
10430	80	0.52	0.53	0.53	0.53	0.01	67.15
10442	81	1.36	1.35	1.38	1.36	0.02	75.81
10613	82	1.08	1.01	1.08	1.06	0.04	75.32
10615	83	0.94	0.87	0.87	0.89	0.04	71.50
10617	84	1.02	0.99	1.06	1.02	0.03	74.75
10631	85	1.99	2.03	1.90	1.97	0.07	74.32
10670	86	1.22	1.25	1.19	1.22	0.03	76.93
10717	87	1.01	1.07	1.06	1.04	0.03	78.19
10738	88	1.21	1.22	1.27	1.24	0.03	77.01
10744	89	1.04	1.10	1.07	1.07	0.03	78.09
10889	90	0.98	0.88	0.90	0.92	0.05	82.47
10892	91	1.29	1.08	1.12	1.16	0.11	79.85
10897	92	1.07	1.13	1.09	1.10	0.03	74.22
10901	93	1.15	1.16	1.10	1.14	0.03	74.22
10932	94	1.62	1.72	1.63	1.65	0.05	72.75
10937	95	1.34	1.53	1.48	1.45	0.10	69.70
10941	96	1.02	1.07	1.04	1.04	0.03	74.44
10961	97	1.57	1.72	1.63	1.64	0.08	73.77
10985	98	1.48	1.58	1.43	1.50	0.08	71.31
11044	99	0.36	0.33	0.30	0.33	0.03	84.73
11049	100	0.51	0.38	0.47	0.45	0.07	83.27
11050	101	0.47	0.41	0.50	0.46	0.05	85.78
11060	102	1.78	1.75	1.75	1.76	0.02	79.83

Dry combustion Total N						
Percent						
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation
8034	1	0.12	0.14	0.12	0.13	0.01
8037	2	0.07	0.08	0.05	0.07	0.01
8321	3	0.09	0.12	0.08	0.10	0.02
8325	4	0.08	0.09	0.08	0.08	0.01
8329	5	0.10	0.10	0.10	0.10	0.00
8546	7	0.14	0.16	0.15	0.15	0.01
8565	9	0.16	0.18	0.18	0.17	0.01
8571	10	0.15	0.15	0.15	0.15	0.00
8598	11	0.12	0.13	0.12	0.12	0.01
8602	12	0.14	0.16	0.15	0.15	0.01
8604	13	0.15	0.17	0.16	0.16	0.01
8620	14	0.19	0.20	0.20	0.19	0.01
8621	15	0.18	0.21	0.21	0.20	0.01
8705	16	0.13	0.15	0.13	0.14	0.01
8728	17	0.26	0.28	0.26	0.26	0.01
8735	18	0.06	0.09	0.08	0.07	0.02
8785	19	0.16	0.18	0.16	0.17	0.01
8836	20	0.23	0.24	0.23	0.23	0.01
8907	21	0.19	0.22	0.20	0.20	0.02
8910	22	0.22	0.25	0.24	0.24	0.01
8911	23	0.33	0.34	0.32	0.33	0.01
8946	24	0.17	0.18	0.19	0.18	0.01
8948	25	0.26	0.26	0.28	0.26	0.01
8951	26	0.30	0.32	0.32	0.32	0.01
8953	27	0.34	0.33	0.33	0.33	0.01

Dry combustion Total N						
Percent						
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation
8557	54	0.22	0.22	0.21	0.22	0.01
8560	55	0.34	0.33	0.33	0.34	0.01
8608	56	0.24	0.24	0.22	0.23	0.01
8610	57	0.14	0.14	0.14	0.14	0.00
8619	58	0.16	0.17	0.17	0.17	0.01
8688	59	0.22	0.21	0.21	0.21	0.00
8713	60	0.17	0.16	0.17	0.17	0.00
8732	61	0.36	0.35	0.34	0.35	0.01
8789	62	0.14	0.12	0.15	0.14	0.02
8795	63	0.12	0.11	0.14	.	0.02
8813	64	0.23	0.20	0.22	.	0.02
8814	65	0.17	0.16	0.18	.	0.01
8821	66	0.14	0.13	0.14	.	0.01
8826	67	0.36	0.35	.	0.35	0.01
8835	68	0.21	0.45	.	0.33	0.17
8950	69	0.21	0.23	.	0.22	0.02
9035	70	0.15	0.21	.	0.18	0.04
9136	71	0.12	0.12	.	0.12	0.00
9266	72	0.26	0.30	.	0.28	0.03
9271	73	0.16	0.23	.	0.20	0.05
9308	74	0.08	0.08	.	0.08	0.00
9309	75	0.10	0.14	.	0.12	0.03
9411	76	0.09	0.11	.	0.10	0.02
9413	77	0.08	0.08	.	0.08	0.00
9414	78	0.08	0.08	.	0.08	0.00

Dry combustion Total N						
Percent						
Lab ID #	OM study #	rep 1	rep 2	rep 3	average	standard deviation
10430	80	0.11	0.11	.	0.11	0.01
10442	81	0.18	0.20	.	0.19	0.01
10613	82	0.14	0.15	.	0.14	0.01
10615	83	0.12	0.12	.	0.12	0.00
10617	84	0.13	0.15	.	0.14	0.02
10631	85	0.22	0.23	.	0.23	0.00
10670	86	0.15	0.17	.	0.16	0.01
10717	87	0.15	0.14	.	0.15	0.00
10738	88	0.14	0.15	.	0.14	0.01
10744	89	0.13	0.15	.	0.14	0.01
10889	90	0.13	0.14	.	0.14	0.01
10892	91	0.14	0.18	.	0.16	0.03
10897	92	0.16	0.17	.	0.17	0.01
10901	93	0.15	0.16	.	0.15	0.01
10932	94	0.19	0.21	.	0.20	0.02
10937	95	.	0.04	.	0.04	.
10941	96	.	0.05	.	0.05	.
10961	97	.	0.02	.	0.02	.
10985	98	0.19	.	.	0.19	.
11044	99	0.07	.	.	0.07	.
11049	100	0.09	.	.	0.09	.
11050	101	0.09	.	.	0.09	.
11060	102	0.20	.	.	0.20	.

Appendix B - Lime and buffer pH raw data

Study 1- Part 1

Table B-1. Raw data for study 1 part 1 of the lime and buffer pH chapter.

Ashland					
Treatment	**Replication**	**moisture**	**lime rate**	**PH after 28 days**	**PH after 50 days**
		% wt/wt	Mg ha-1		
1	1	10	0	4.40	4.42
1	2	10	0	4.42	4.42
1	3	10	0	4.42	4.43
2	1	20	0	4.45	4.52
2	2	20	0	4.47	4.52
2	3	20	0	4.47	4.51
3	1	30	0	4.55	4.66
3	2	30	0	4.58	4.63
3	3	30	0	4.59	4.64
4	1	40	0	4.60	4.67
4	2	40	0	4.60	4.67
4	3	40	0	4.60	4.68
5	1	10	1.12	6.20	6.23
5	2	10	1.12	6.12	6.16
5	3	10	1.12	6.24	6.14
6	1	20	1.12	6.09	5.95
6	2	20	1.12	6.12	5.88
6	3	20	1.12	6.08	5.92
7	1	30	1.12	6.49	6.55
7	2	30	1.12	6.52	6.60
7	3	30	1.12	6.43	6.79
8	1	40	1.12	6.74	6.58
8	2	40	1.12	6.69	6.67
8	3	40	1.12	6.70	6.71

Ashland					
Treatment	**Replication**	**moisture**	**lime rate**	**PH after 28 days**	**PH after 50 days**
		% wt/wt	Mg ha-1		
9	1	10	2.24	7.21	7.50
9	2	10	2.24	7.25	7.42
9	3	10	2.24	7.21	7.20
10	1	20	2.24	7.49	7.55
10	2	20	2.24	7.50	7.48
10	3	20	2.24	7.35	7.72
11	1	30	2.24	7.78	7.59
11	2	30	2.24	7.64	7.48
11	3	30	2.24	7.45	7.55
12	1	40	2.24	7.87	7.66
12	2	40	2.24	7.75	7.86
12	3	40	2.24	7.86	7.75

Smolan					
Treatment	**Replication**	**moisture**	**lime rate**	**PH after 28 days**	**PH after 50 days**
		% wt/wt	Mg ha^{-1}		
1	1	10	0	4.57	4.69
1	2	10	0	4.56	4.64
1	3	10	0	4.56	4.64
2	1	20	0	4.56	4.71
2	2	20	0	4.64	4.73
2	3	20	0	4.6	4.68
3	1	30	0	4.7	4.71
3	2	30	0	4.73	4.68
3	3	30	0	4.72	4.78
4	1	40	0	4.9	5.01
4	2	40	0	4.86	4.95
4	3	40	0	4.91	4.97
5	1	10	1	5.24	5.33
5	2	10	1	5.46	5.3
5	3	10	1	5.35	5.27
6	1	20	1	5.28	5.31
6	2	20	1	5.4	5.28
6	3	20	1	5.31	5.38
7	1	30	1	5.23	5.13
7	2	30	1	5.36	5.17
7	3	30	1	5.58	5.17
8	1	40	1	5.74	5.78
8	2	40	1	5.66	5.71
8	3	40	1	5.88	5.87

Smolan					
Treatment	**Replication**	**moisture**	**lime rate**	**PH after 28 days**	**PH after 50 days**
		% wt/wt	Mg ha^{-1}		
9	1	10	2	6.03	5.92
9	2	10	2	5.94	6.04
9	3	10	2	5.96	5.93
10	1	20	2	5.99	5.89
10	2	20	2	5.88	5.85
10	3	20	2	5.89	5.82
11	1	30	2	5.77	5.76
11	2	30	2	5.83	5.88
11	3	30	2	5.76	5.82
12	1	40	2	6.35	6.25
12	2	40	2	6.48	6.18
12	3	40	2	6.51	6.65

Study 1 - Part 2

Table B-2. Raw data for study 1 part 2 of the lime and buffer pH chapter, looking at lime response of 19 soils at three moisture and three lime rates.

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	**Mg ECC ha^{-1}**	**1:1 soil:water**	
6260	1	15	0.0	5.15	5.24
6260	4	15	3.4	5.15	6.82
6260	7	15	6.7	5.15	7.18
6260	2	30	0.0	5.15	4.92
6260	5	30	3.4	5.15	6.06
6260	8	30	6.7	5.15	7.12
6260	3	45	0.0	5.15	5.14
6260	6	45	3.4	5.15	6.7
6260	9	45	6.7	5.15	7.78
6262	1	15	0.0	5.64	5.58
6262	4	15	3.4	5.64	7
6262	7	15	6.7	5.64	7.65
6262	2	30	0.0	5.64	5.45
6262	5	30	3.4	5.64	6.99
6262	8	30	6.7	5.64	7.5
6262	3	45	0.0	5.64	5.64
6262	6	45	3.4	5.64	7.23
6262	9	45	6.7	5.64	7.94
6274	1	15	0.0	5.6	5.61
6274	4	15	3.4	5.6	6.69
6274	7	15	6.7	5.6	7.14
6274	2	30	0.0	5.6	5.43
6274	5	30	3.4	5.6	6.37
6274	8	30	6.7	5.6	7.18
6274	3	45	0.0	5.6	5.67
6274	6	45	3.4	5.6	6.7
6274	9	45	6.7	5.6	7.42

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	Mg ECC ha^{-1}	1:1 soil:water	
6283	1	15	0.0	5.46	5.5
6283	4	15	3.4	5.46	6.03
6283	7	15	6.7	5.46	6.74
6283	2	30	0.0	5.46	5.13
6283	5	30	3.4	5.46	5.89
6283	8	30	6.7	5.46	6.74
6283	3	45	0.0	5.46	5.26
6283	6	45	3.4	5.46	6.29
6283	9	45	6.7	5.46	6.99
6342	1	15	0.0	5.89	5.89
6342	4	15	3.4	5.89	6.45
6342	7	15	6.7	5.89	6.96
6342	2	30	0.0	5.89	5.2
6342	5	30	3.4	5.89	5.96
6342	8	30	6.7	5.89	6.86
6342	3	45	0.0	5.89	5.13
6342	6	45	3.4	5.89	5.93
6342	9	45	6.7	5.89	6.83
6344	1	15	0.0	5.37	5.71
6344	4	15	3.4	5.37	6.47
6344	7	15	6.7	5.37	6.95
6344	2	30	0.0	5.37	5.44
6344	5	30	3.4	5.37	6.3
6344	8	30	6.7	5.37	7.06
6344	3	45	0.0	5.37	5.67
6344	6	45	3.4	5.37	6.41
6344	9	45	6.7	5.37	7.27

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	Mg ECC ha^{-1}	1:1 soil:water	
6345	1	15	0.0	4.9	5.52
6345	4	15	3.4	4.9	6.33
6345	7	15	6.7	4.9	6.8
6345	2	30	0.0	4.9	5.29
6345	5	30	3.4	4.9	5.89
6345	8	30	6.7	4.9	6.59
6345	3	45	0.0	4.9	5.45
6345	6	45	3.4	4.9	6.11
6345	9	45	6.7	4.9	6.86
6351	1	15	0.0	5.48	5.52
6351	4	15	3.4	5.48	6.4
6351	7	15	6.7	5.48	7.01
6351	2	30	0.0	5.48	5.14
6351	5	30	3.4	5.48	5.95
6351	8	30	6.7	5.48	6.93
6351	3	45	0.0	5.48	5.38
6351	6	45	3.4	5.48	6.03
6351	9	45	6.7	5.48	6.9
6398	1	15	0.0	5.38	5.28
6398	4	15	3.4	5.38	5.85
6398	7	15	6.7	5.38	6.25
6398	2	30	0.0	5.38	5.03
6398	5	30	3.4	5.38	5.51
6398	8	30	6.7	5.38	5.97
6398	3	45	0.0	5.38	5.2
6398	6	45	3.4	5.38	5.56
6398	9	45	6.7	5.38	6.79

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	Mg ECC ha^{-1}	1:1 soil:water	
6433	1	15	0.0	5.18	5.26
6433	4	15	3.4	5.18	5.69
6433	7	15	6.7	5.18	6.41
6433	2	30	0.0	5.18	4.86
6433	5	30	3.4	5.18	5.42
6433	8	30	6.7	5.18	6.13
6433	3	45	0.0	5.18	5.11
6433	6	45	3.4	5.18	5.53
6433	9	45	6.7	5.18	6.11
6436	1	15	0.0	4.99	5.03
6436	4	15	3.4	4.99	5.91
6436	7	15	6.7	4.99	6.59
6436	2	30	0.0	4.99	4.87
6436	5	30	3.4	4.99	5.52
6436	8	30	6.7	4.99	6.36
6436	3	45	0.0	4.99	4.81
6436	6	45	3.4	4.99	5.55
6436	9	45	6.7	4.99	6.4
6441	1	15	0.0	5.62	5.58
6441	4	15	3.4	5.62	6.28
6441	7	15	6.7	5.62	6.74
6441	2	30	0.0	5.62	5.22
6441	5	30	3.4	5.62	6.01
6441	8	30	6.7	5.62	6.69
6441	3	45	0.0	5.62	5.26
6441	6	45	3.4	5.62	6.08
6441	9	45	6.7	5.62	6.72

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	Mg ECC ha^{-1}	1:1 soil:water	
6462	1	15	0.0	5.47	5.43
6462	4	15	3.4	5.47	6.03
6462	7	15	6.7	5.47	6.87
6462	2	30	0.0	5.47	5.27
6462	5	30	3.4	5.47	5.92
6462	8	30	6.7	5.47	6.9
6462	3	45	0.0	5.47	5.31
6462	6	45	3.4	5.47	6.41
6462	9	45	6.7	5.47	7.21
6561	1	15	0.0	5.8	5.9
6561	4	15	3.4	5.8	6.75
6561	7	15	6.7	5.8	7.1
6561	2	30	0.0	5.8	5.61
6561	5	30	3.4	5.8	6.52
6561	8	30	6.7	5.8	7.15
6561	3	45	0.0	5.8	5.35
6561	6	45	3.4	5.8	6.03
6561	9	45	6.7	5.8	7
6646	1	15	0.0	5.7	5.65
6646	4	15	3.4	5.7	8.38
6646	7	15	6.7	5.7	8.66
6646	2	30	0.0	5.7	5.39
6646	5	30	3.4	5.7	8.58
6646	8	30	6.7	5.7	8.87
6646	3	45	0.0	5.7	5.34
6646	6	45	3.4	5.7	8.36
6646	9	45	6.7	5.7	8.84

Lab ID	Treatment #	Moisture content	lime rate	Initial pH	Final pH 40 days after application
		percent gravimetric	Mg ECC ha^{-1}	1:1 soil:water	
6780	1	15	0.0	4.8	4.8
6780	4	15	3.4	4.8	5.2
6780	7	15	6.7	4.8	5.68
6780	2	30	0.0	4.8	4.91
6780	5	30	3.4	4.8	5.28
6780	8	30	6.7	4.8	5.59
6780	3	45	0.0	4.8	4.98
6780	6	45	3.4	4.8	5.13
6780	9	45	6.7	4.8	5.33

Study 2

Table B-3. Raw data for comparing Shoemaker-Mclean-Pratt (SMP), Sikora, and modified-Mehlich buffer to each other and to observed lime requirements to pHs 6.0, 6.3 and 6.6.

			Buffer value after 40 minutes			Lime required target pH		
Study ID	Lab ID	pH	Sikora	SMP	Modified-Mehlich	6	6.3	6.6
#	#	1:1 soil:water	Buffer pH			Mg ECC lime ha^{-1}		
1	7168	4.74	6.22	6.37	5.74	4.96	6.47	8.23
2	7167	5.23	6.29	6.43	5.74	2.98	4.35	5.89
3	6987	5.00	6.58	6.80	5.99	2.29	3.06	3.90
4	7123	5.59	6.83	7.04	6.17	1.08	1.93	2.85
5	8043	4.82	6.39	6.61	5.83	4.01	5.23	6.60
6	7084	5.50	6.95	7.11	6.23	1.19	1.96	2.79
7	8062	5.25	6.93	7.05	6.20	1.78	2.57	3.43
8	8122	5.02	6.28	6.52	5.78	3.53	4.81	6.24
9	8119	4.83	6.18	6.42	5.69	4.49	5.87	7.39
10	7462	4.37	6.04	6.33	5.60	7.24	8.90	10.73
11	7759	4.62	6.26	6.50	5.70	5.10	6.50	8.10
12	7852	4.89	6.54	6.78	5.93	3.14	4.14	5.25
13	6965	5.64	6.19	6.54	5.72	1.27	2.41	3.65
15	8110	5.57	6.49	6.63	5.91	1.42	2.49	3.66
16	7960	5.66	7.00	7.10	6.27	0.91	1.79	2.75
17	8098	5.19	6.23	6.32	5.71	3.01	4.28	5.68
18	7925	5.73	6.58	6.82	6.01	1.08	2.38	3.81
19	6962	5.75	6.24	6.44	5.72	1.00	2.29	3.68
20	6824	5.13	6.26	6.50	5.74	3.17	4.44	5.83
21	7171	5.48	6.43	6.69	5.87	1.72	2.82	4.04

			Buffer value after 40 minutes			Lime required target pH		
Study ID	Lab ID	pH	Sikora	SMP	Modified-Mehlich	6.0	6.3	6.6
#	#	1:1 soil:water	Buffer pH			Mg ECC lime ha^{-1}		
22	7172	5.59	6.54	6.86	5.95	1.45	2.62	3.91
23	7349	5.53	6.39	6.60	5.82	2.10	3.60	5.25
24	7401	5.24	6.35	6.60	5.81	2.88	4.18	5.61
25	7402	5.13	6.38	6.62	5.76	3.10	4.33	5.71
26	6823	5.24	6.37	6.63	5.81	2.80	4.08	5.51
27	8121	4.79	6.03	6.34	5.61	5.15	6.64	8.26
28	8140	4.84	6.70	6.88	6.05	2.52	3.26	4.06
29	6988	4.25	6.66	6.77	5.97	3.68	4.43	5.24
31	7459	4.56	6.26	6.50	5.77	4.68	5.90	7.28
32	7461	4.57	6.18	6.41	5.73	5.73	7.18	8.77
33	8143	5.03	6.08	6.31	5.63	6.04	7.93	9.84
34	6904	4.92	6.41	6.66	5.88	2.75	3.63	4.58
35	7460	4.57	6.26	6.42	5.75	5.20	6.56	8.08
36	7455	5.48	6.60	6.78	6.01	1.81	2.98	4.28
37	7004	5.55	6.57	6.77	5.95	1.35	2.34	3.42
38	8115	5.52	6.38	6.64	5.88	1.67	2.83	4.11
45	8070	5.56	6.54	6.64	5.95	1.59	2.79	4.13

Appendix C - Soybean P correlation and calibration raw data

2011

Table C-1. Raw data for soybean yield, and trifoliate analysis at various soil phosphorus levels and phosphorus fertilizer application rates.

Woodson County							
		Block soil P	Fertilizer	Yield	R4 Trifoliate analysis		
		Mehlich-3	P	at 13 % moisture	N	P	K
Plot	Treatment	0-15 cm	k ha^{-1}	Mg ha^{-1}	%		
101	4	5	29	2.5	3.79	0.34	1.69
102	1	5	0	1.9	3.71	0.33	1.83
103	2	5	10	2.6	3.48	0.31	1.89
104	3	5	20	2.7	3.97	0.39	1.92
105	5	5	39	2.6	4.21	0.35	1.65
201	1	4	0	2.1	3.87	0.34	1.78
202	5	4	39	2.5	3.77	0.40	1.86
203	3	4	20	2.5	4.11	0.36	1.75
204	2	4	10	2.5	4.01	0.36	1.83
205	4	4	29	2.6	4.06	0.39	1.89
301	3	5	20	2.0	4.17	0.35	1.67
302	2	5	10	2.6	4.01	0.35	1.90
303	4	5	29	2.5	4.16	0.37	1.71
304	5	5	39	2.4	4.62	0.35	1.48
305	1	5	0	2.1	4.45	0.31	1.56
401	2	4	10	2.5	4.02	0.33	1.58
402	3	4	20	2.7	4.51	0.34	1.55
403	1	4	0	2.4	3.84	0.31	1.61
404	4	4	29	2.4	4.11	0.35	1.66
405	5	4	39	2.3	4.12	0.34	1.70

Cherokee County							
		Block soil P	Fertilizer	Yield	R4 Trifoliate analysis		
		Mehlich-3	P	at 13 % moisture	N	P	K
Plot	Treatment	0-15 cm	k ha^{-1}	Mg ha^{-1}	%		
101	4	13	29	1.3	4.83	0.35	1.18
102	1	13	0	1.4	4.91	0.32	1.01
103	2	13	10	1.1	4.65	0.33	1.14
104	3	13	20	1.0	5.43	0.33	0.95
105	5	13	39	1.0	5.03	0.32	1.07
201	1	12	0	1.6	4.68	0.33	1.18
202	5	12	39	1.7	4.39	0.34	1.10
203	3	12	20	1.8	4.94	0.33	1.11
204	2	12	10	1.8	4.92	0.36	1.12
205	4	12	29	1.7	4.69	0.33	1.05
301	3	20	20	2.6	4.46	0.35	1.26
302	2	20	10	2.2	3.98	0.32	1.39
303	4	20	29	2.4	5.20	0.37	1.20
304	5	20	39	2.7	4.72	0.38	1.43
305	1	20	0	2.3	5.25	0.36	1.17
401	2	17	10	1.9	5.30	0.35	1.25
402	3	17	20	2.2	5.03	0.33	1.18
403	1	17	0	2.2	5.27	0.37	1.25
404	4	17	29	2.3	4.80	0.34	1.32
405	5	17	39	2.6	4.57	0.34	1.38

2012

Treatments

Table C-2. Treatments for the 2012 sites and their respective plot number.

Saline County - Dryland								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	14	20	10	0	0	0	0	0
108	1	0	0	0	0	0	0	0
109	8	39	0	0	0	0	0	0
110	7	20	10	0	0	0	0	0
111	9	29	10	0	0	0	0	0
112	12	20	10	22	0	0	0	0
113	11	39	10	0	0	0	0	0
114	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	14	20	10	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0
214	2	10	0	0	0	0	0	0

Saline County - Dryland								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	14	20	10	0	0	0	0	0
306	9	29	10	0	0	0	0	0
307	6	29	0	0	0	0	0	0
308	10	49	0	0	0	0	0	0
309	1	0	0	0	0	0	0	0
310	13	20	10	22	11	11	11	1
311	2	10	0	0	0	0	0	0
312	8	39	0	0	0	0	0	0
313	12	20	10	22	0	0	0	0
314	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0
414	14	20	10	0	0	0	0	0

Saline County - Flood irrigated								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	14	20	10	0	0	0	0	0
108	1	0	0	0	0	0	0	0
109	8	39	0	0	0	0	0	0
110	7	20	10	0	0	0	0	0
111	9	29	10	0	0	0	0	0
112	12	20	10	22	0	0	0	0
113	11	39	10	0	0	0	0	0
114	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	14	20	10	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0
214	2	10	0	0	0	0	0	0

Saline County - Flood irrigated								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	14	20	10	0	0	0	0	0
306	9	29	10	0	0	0	0	0
307	6	29	0	0	0	0	0	0
308	10	49	0	0	0	0	0	0
309	1	0	0	0	0	0	0	0
310	13	20	10	22	11	11	11	1
311	2	10	0	0	0	0	0	0
312	8	39	0	0	0	0	0	0
313	12	20	10	22	0	0	0	0
314	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0
414	14	20	10	0	0	0	0	0

Woodson County - lynx								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	8	39	0	0	0	0	0	0
109	7	20	10	0	0	0	0	0
110	9	29	10	0	0	0	0	0
111	12	20	10	22	0	0	0	0
112	11	39	10	0	0	0	0	0
113	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	2	10	0	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0

Woodson County - lynx								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	9	29	10	0	0	0	0	0
306	6	29	0	0	0	0	0	0
307	10	49	0	0	0	0	0	0
308	1	0	0	0	0	0	0	0
309	13	20	10	22	11	11	11	1
310	2	10	0	0	0	0	0	0
311	8	39	0	0	0	0	0	0
312	12	20	10	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0

Woodson County - meadow								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	8	39	0	0	0	0	0	0
109	7	20	10	0	0	0	0	0
110	9	29	10	0	0	0	0	0
111	12	20	10	22	0	0	0	0
112	11	39	10	0	0	0	0	0
113	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	2	10	0	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0

Woodson County - meadow								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	9	29	10	0	0	0	0	0
306	6	29	0	0	0	0	0	0
307	10	49	0	0	0	0	0	0
308	1	0	0	0	0	0	0	0
309	13	20	10	22	11	11	11	1
310	2	10	0	0	0	0	0	0
311	8	39	0	0	0	0	0	0
312	12	20	10	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0

Riley County - Manhattan								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	14	20	10	0	0	0	0	0
108	1	0	0	0	0	0	0	0
109	8	39	0	0	0	0	0	0
110	7	20	10	0	0	0	0	0
111	9	29	10	0	0	0	0	0
112	12	20	10	22	0	0	0	0
113	11	39	10	0	0	0	0	0
114	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	14	20	10	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0
214	2	10	0	0	0	0	0	0

Riley County - Manhattan								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	14	20	10	0	0	0	0	0
306	9	29	10	0	0	0	0	0
307	6	29	0	0	0	0	0	0
308	10	49	0	0	0	0	0	0
309	1	0	0	0	0	0	0	0
310	13	20	10	22	11	11	11	1
311	2	10	0	0	0	0	0	0
312	8	39	0	0	0	0	0	0
313	12	20	10	22	0	0	0	0
314	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0
414	14	20	10	0	0	0	0	0

Riley County - Leonardville								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	8	39	0	0	0	0	0	0
109	7	20	10	0	0	0	0	0
110	9	29	10	0	0	0	0	0
111	12	20	10	22	0	0	0	0
112	11	39	10	0	0	0	0	0
113	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	2	10	0	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0

Riley County - Leonardville								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	9	29	10	0	0	0	0	0
306	6	29	0	0	0	0	0	0
307	10	49	0	0	0	0	0	0
308	1	0	0	0	0	0	0	0
309	13	20	10	22	11	11	11	1
310	2	10	0	0	0	0	0	0
311	8	39	0	0	0	0	0	0
312	12	20	10	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0

Nemaha County								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
101	13	20	10	22	11	11	11	1
102	2	10	0	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	49	0	0	0	0	0	0
105	4	20	0	0	0	0	0	0
106	6	29	0	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	8	39	0	0	0	0	0	0
109	7	20	10	0	0	0	0	0
110	9	29	10	0	0	0	0	0
111	12	20	10	22	0	0	0	0
112	11	39	10	0	0	0	0	0
113	3	0	10	0	0	0	0	0
201	7	20	10	0	0	0	0	0
202	11	39	10	0	0	0	0	0
203	6	29	0	0	0	0	0	0
204	12	20	10	22	0	0	0	0
205	8	39	0	0	0	0	0	0
206	3	0	10	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	5	10	10	0	0	0	0	0
209	13	20	10	22	11	11	11	1
210	10	49	0	0	0	0	0	0
211	2	10	0	0	0	0	0	0
212	4	20	0	0	0	0	0	0
213	9	29	10	0	0	0	0	0

Nemaha County								
		Broadcast P	Banded P	S	Zn	Fe	Mn	B
Plot	Treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	0
302	4	20	0	0	0	0	0	0
303	11	39	10	0	0	0	0	0
304	7	20	10	0	0	0	0	0
305	9	29	10	0	0	0	0	0
306	6	29	0	0	0	0	0	0
307	10	49	0	0	0	0	0	0
308	1	0	0	0	0	0	0	0
309	13	20	10	22	11	11	11	1
310	2	10	0	0	0	0	0	0
311	8	39	0	0	0	0	0	0
312	12	20	10	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	49	0	0	0	0	0	0
403	8	39	0	0	0	0	0	0
404	3	0	10	0	0	0	0	0
405	12	20	10	22	0	0	0	0
406	13	20	10	22	11	11	11	1
407	11	39	10	0	0	0	0	0
408	6	29	0	0	0	0	0	0
409	2	10	0	0	0	0	0	0
410	4	20	0	0	0	0	0	0
411	7	20	10	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	29	10	0	0	0	0	0

Soil

Table C-3. Soil results for 2012 by site.

	Walkley-Black	**soil: water**	**SMP**	**Mehlich-3**	**1 N Ammonium Acetate**	**DTPA**			**Hot water**
	OM			**P**	**K**	**Fe**	**Mn**	**Zn**	**Boron**
Block	**%**	**pH**		**mg kg^{-1}**					
		0-15 cm							
Nemaha									
1	2.1	6.32	6.65	3.3	174	46.7	10	0.5	
2	2.0	6.12	6.61	2.3	185	42.9	10	0.4	
3	2.0	6.04	6.57	2.3	191	45.9	12	0.3	
4	2.3	5.76	6.31	4.1	216	53.0	16	0.7	
Riley - Leonardville									
1	2.3	5.3	6.2	15.6		64.6	19.8	0.4	0.85
2	2.3	5.3	6.2	15.6		65.3	19.0	0.4	0.86
3	2.2	5.3	6.1	16.5		72.6	22.1	0.5	0.96
4	2.3	5.3	6.2	24.0		69.4	21.6	0.4	0.85
Woodson - lynx									
1	1.8	5.6	7.0	9.9	91	72.5	20.5	1.3	
2	1.6	5.8	7.0	5.4	65	77.2	22.3	1.2	
3	1.7	6.0	7.1	4.6	60	62.7	20.5	1.0	
4	1.6	6.0	7.1	8.8	77	60.7	20.9	1.0	

	Walkley-Black	soil: water	SMP	Mehlich-3	1 N Ammonium Acetate	DTPA			Hot water
	OM			**P**	**K**	**Fe**	**Mn**	**Zn**	**Boron**
Block	**%**	**pH**		**mg kg^{-1}**					
		0-15 cm							
Woodson - meadow									
1	2.0	5.5	6.6	6.5	80	81.6	28.2	0.9	
2	2.0	5.5	6.7	29.0	98	107.9	27.8	1.6	
3	2.0	5.7	6.7	9.1	85	100.3	27.3	1.4	
4	2.3	5.8	6.8	13.7	88	110.1	28.3	1.7	
Riley - Randolph									
1	2.0	7.5		11.8		20.0	7.9	0.7	0.61
2	2.0	6.9		8.9		19.2	9.0	0.7	0.67
3	2.0	7.2		7.1		15.7	8.1	0.7	0.65
4	2.0	7.7		8.1		12.0	6.4	0.6	0.45
Saline - dryland									
1	3.0	7.9		51.4	468.0	6.9	4.0	1.1	
2	2.9	8.1		38.6	410.0	3.6	2.6	0.9	
3	2.9	8.1		43.3	527.0	4.2	3.2	1.1	
4	2.9	8.2		37.2	465.0	4.1	2.9	1.2	
Saline - flood Irrigated									
1	3.4	8.0		64.6	476	9.7	4.9	1.1	
2	3.2	8.0		74.4	442	9.9	4.2	2.1	
3	3.2	8.0		40.3	380	8.6	4.0	0.9	
4	3.3	8.0		44.7	394	8.8	3.9	0.9	

V4 to V6 whole plants

Table C-4. V4 to V6 whole plant analysis for 2012 by site.

Saline County - dryland - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	15.2	3.55	0.28	2.25	0.25	144	177	40	40
102	13.2	3.47	0.26	2.49					
103	13.2	3.65	0.25	2.04					
104	15.3	3.38	0.25	2.41					
105	16.3	3.51	0.25	2.16					
106	13.3	3.48	0.24	2.05					
107	14	3.99	0.26	2.15					
108	14.3	3.39	0.24	2.06	0.25	142	174	30	42
109	15.4	3.40	0.25	2.28					
110	15.7	3.77	0.28	2.18	0.24	145	200	37	39
111	16.3	3.35	0.25	2.28					
112	16.5	3.44	0.27	2.24	0.24	200	205	32	38
113	13.1	3.47	0.23	2.01					
114	13.2	3.17	0.24	2.25					
201	9.6	3.77	0.25	2.22	0.25	161	202	35	38
202	8.4	3.66	0.25	2.10					
203	9.4	3.66	0.25	2.04					
204	8.5	3.75	0.25	2.09	0.28	179	218	31	38
205	10.5	3.63	0.24	2.14					
206	7.7	3.15	0.23	1.96					
207	7.6	3.48	0.24	2.26	0.25	136	169	30	39
208									
209	11.9	3.65	0.26	2.23	0.26	163	182	35	38
210	9.3	3.55	0.25	2.20					
211	9.2	3.59	0.24	2.15					
212	10.5	3.37	0.25	2.22					
213	11.1	3.54	0.23	2.28					
214	7.8	3.43	0.24	2.50					

Saline County - dryland - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
301	15.9	3.46	0.26	2.57					
302	14.3	3.51	0.26	2.46					
303	12.9	3.45	0.26	2.40					
304	13.9	3.55	0.26	2.41	0.26	183	207	38	43
305	13.5	3.61	0.27	2.59					
306	17.4	3.28	0.27	2.90					
307	17.6	3.60	0.26	2.53					
308	18	3.24	0.24	2.72					
309	21.2	3.30	0.26	2.67	0.25	130	178	36	40
310	21.9	3.66	0.28	2.66	0.25	214	190	38	40
311	20.8	3.78	0.31	2.86					
312	15.5	3.71	0.30	2.66					
313	19.9	3.42	0.27	2.70	0.23	156	197	37	38
314	17.8	3.40	0.27	2.71					
401	14.3	3.34	0.24	2.52	0.24	131	169	36	39
402	14.1	3.59	0.27	2.59					
403	16.8	3.45	0.27	2.62					
404	20	3.83	0.29	2.66					
405	20.7	3.39	0.30	2.95	0.22	121	169	34	37
406	19.1	3.72	0.28	2.77	0.25	241	236	42	42
407	20.5	3.67	0.28	2.68					
408	11.1	3.72	0.29	2.71					
409	10.6	3.67	0.25	2.35					
410	9.3	3.40	0.26	2.54					
411	10.2	3.50	0.26	2.49	0.24	142	180	37	39
412	11.7	3.48	0.27	2.46					
413	17.1	3.52	0.28	2.70					
414	11.3	3.83	0.27	2.44					

Saline County - flood irrigated - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g $plant^{-1}$	%				mg kg^{-1}			
101	10.3	3.49	0.26	1.94	0.25	181	149	33	42
102	12.5	3.11	0.29	2.34					
103	11.1	3.50	0.28	2.02					
104	11.2	3.39	0.27	1.99					
105	11.4	3.52	0.28	1.96					
106	13	3.24	0.27	2.06					
107	13.7	3.22	0.29	2.28					
108	12.4	3.42	0.27	1.87	0.25	158	147	31	44
109	12.5	3.39	0.29	2.28					
110	13.0	3.50	0.29	2.12	0.24	130	134	30	40
111	12.9	3.41	0.28	1.94					
112	13.0	3.54	0.30	1.99	0.24	151	172	37	41
113	12.9	3.42	0.27	2.06					
114	12.6	3.29	0.28	2.23					
201	9.4	3.53	0.28	1.94	0.25	324	128	31	44
202	10.7	3.16	0.28	2.37					
203	9.1	3.56	0.27	1.86					
204	9.6	3.68	0.30	2.06	0.26	152	133	47	45
205	9.7	3.62	0.29	1.96					
206	10.8	3.64	0.29	1.91					
207	10.3	3.36	0.29	1.90	0.25	147	149	36	41
208	8.4	3.43	0.28	1.80					
209	8.9	3.38	0.29	2.18	0.24	135	137	37	45
210	9.8	3.40	0.28	2.23					
211	8.2	3.60	0.26	1.75					
212	7.5	2.84	0.25	1.93					
213	9.7	3.66	0.28	1.86					
214	7.4	3.49	0.28	2.02					

Saline County - flood irrigated - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g $plant^{-1}$	%				mg kg^{-1}			
301	7.1	3.29	0.23	1.74					
302	11.8	3.32	0.29	2.10					
303	8.5	3.23	0.26	2.06					
304	14.0	3.32	0.29	2.24	0.23	268	147	49	40
305	9.9	3.28	0.28	2.08					
306	13.1	3.31	0.30	2.09					
307	13.2	3.10	0.27	1.95					
308	10.8	3.32	0.28	2.10					
309	10.7	3.57	0.27	1.69	0.25	154	158	31	41
310	10.7	3.30	0.30	2.10	0.24	130	143	34	41
311	11.5	3.34	0.27	2.14					
312	11.4	3.30	0.26	1.96					
313	12.5	3.47	0.27	2.00	0.26	129	137	32	40
314	9.3	3.53	0.27	1.92					
401	8.6	3.40	0.23	1.85	0.24	194	127	39	44
402	12.3	3.73	0.29	2.12					
403	12.2	3.62	0.27	1.94					
404	11.3	3.96	0.28	2.06					
405	11.2	3.39	0.26	2.08	0.24	208	125	34	45
406	13.8	3.55	0.27	1.97	0.26	171	134	30	43
407	13.9	3.18	0.29	2.35					
408	14.6	3.86	0.27	1.87					
409	12.6	3.37	0.26	1.86					
410	10.3	3.53	0.27	2.05					
411	13.5	3.52	0.27	1.96	0.26	156	142	36	42
412	12.5	3.60	0.28	2.03					
413	11.6	3.13	0.25	1.74					
414	14.7	3.75	0.29	1.88					

Woodson County - lynx - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	32.7	3.27	0.30	2.23	0.24	710	78	50	72
102	28.6	3.88	0.30	1.43					
103	29.9	3.97	0.34	1.79					
104	36.1	4.00	0.34	2.10					
105	32.5	3.63	0.29	1.75					
106	27.8	3.95	0.33	1.73					
107	27.2	3.92	0.31	1.54	0.25	1528	105	49	49
108	25.1	3.98	0.35	1.72					
109	31.5	4.20	0.32	1.72	0.27	1180	124	48	48
110	27.2	3.92	0.33	1.68					
111	32.6	2.65	0.20	2.33	0.25	864	78	49	45
112	30.2	3.80	0.31	2.22					
113	30.1	3.71	0.32	1.77					
201	27.9	3.80	0.27	1.66	0.27	806	68	44	47
202	28.5	3.71	0.32	1.62					
203	28.6	4.31	0.35	1.70					
204	39.3	4.00	0.34	1.84	0.26	695	61	42	48
205	28.2	4.21	0.29	1.51					
206	25.4	3.88	0.26	1.64					
207	25.3	3.79	0.27	1.48	0.25	646	72	48	48
208	33.5	3.97	0.32	1.49					
209	34.1	3.80	0.30	1.68	0.28	968	105	60	82
210	26.8	3.91	0.32	1.74					
211	21.9	4.04	0.29	1.58					
212	26	3.92	0.31	2.38					
213	32.3	3.96	0.30	1.98					

Woodson County - lynx - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
301	30.2	4.08	0.29	1.64					
302	34.1	3.87	0.30	1.98					
303	27.7	3.97	0.31	1.97					
304	27.9	4.03	0.30	1.60	0.25	749	65	39	49
305	29.7	3.61	0.29	2.18					
306	31.8	3.96	0.29	1.43					
307	24	4.18	0.31	1.85					
308	33.2	3.77	0.28	1.92	0.23	683	65	45	45
309	28.8	3.93	0.28	2.11	0.27	402	68	55	82
310	31.7	3.75	0.27	1.71					
311	30.8	4.05	0.30	1.97					
312	30.9	3.95	0.30	2.03	0.26	609	79	49	49
313	23.5	4.08	0.28	1.94					
401	31.7	3.74	0.27	1.99	0.25	788	58	42	43
402	31.8	3.48	0.28	2.18					
403	37.7	3.59	0.27	2.23					
404	36.5	3.86	0.27	1.77					
405	40.7	3.90	0.30	2.29	0.26	547	66	40	40
406	30.1	4.09	0.31	1.99	0.25	834	87	52	71
407	33.7	4.22	0.31	2.15					
408	32	3.43	0.28	2.38					
409	40.2	4.22	0.28	1.77					
410	32.6	4.03	0.28	1.70					
411	33.3	3.89	0.30	2.42	0.25	335	62	43	45
412	24.7	4.01	0.32	1.99					
413	26.5	4.31	0.34	1.73					

Woodson County - meadow - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	21.8	4.11	0.32	1.54	0.27	657	127	66	67
102	24.9	4.09	0.30	1.59					
103	23.7	4.26	0.31	1.42					
104	25.4	4.36	0.35	1.71					
105	26	4.41	0.29	1.36					
106	23.4	4.32	0.30	1.44					
107	21.5	4.16	0.28	1.53	0.25	991	97	49	55
108	18.5	4.35	0.34	1.65					
109	20	4.28	0.32	1.49	0.24	1293	198	51	56
110	20.6	4.08	0.33	1.74					
111	17.6	4.41	0.32	1.69	0.29	748	101	56	54
112	16.4	3.96	0.36	1.51					
113	15.3	4.45	0.33	1.79					
201	26.9	4.43	0.33	1.87	0.27	525	102	48	48
202	22.1	4.48	0.36	1.78					
203	22	4.50	0.33	2.03					
204	21.7	4.31	0.31	1.96	0.25	734	100	47	50
205	28	4.34	0.34	2.03					
206	21.3	4.35	0.30	1.82					
207	23.4	4.22	0.29	2.24	0.24	326	71	50	53
208	22.2	4.56	0.33	1.84					
209	26.6	4.51	0.34	2.50	0.26	816	121	74	91
210	21.4	4.54	0.35	1.48					
211	22.4	4.38	0.33	1.59					
212	15.9	4.37	0.37	2.11					
213	19.3	4.39	0.37	1.85					

Woodson County - meadow - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g $plant^{-1}$	%				mg kg^{-1}			
301	20.9	4.66	0.34	1.41					
302	15.2	4.26	0.30	1.60					
303	19.5	4.44	0.33	1.69					
304	21.6	4.40	0.31	1.73	0.24	745	97	51	52
305	24.2	4.55	0.30	1.79					
306	28.7	4.01	0.31	2.68					
307	26	4.69	0.38	2.25					
308	26.5	3.86	0.36	2.21	0.22	638	96	52	55
309	20.3	4.35	0.39	2.01	0.28	631	117	76	75
310	23	3.84	0.35	2.11					
311	19.6	4.38	0.35	2.03					
312	18.9	4.13	0.33	2.17	0.27	626	107	55	49
313	18.6	4.29	0.32	1.78					
401	18.8	4.30	0.29	1.15	0.26	533	78	55	54
402	26	4.18	0.31	1.78					
403	16.1	4.18	0.30	1.73					
404	27.2	4.48	0.32	1.68					
405	21.7	4.50	0.37	2.03	0.25	365	106	45	50
406	26.2	4.31	0.33	1.54	0.27	686	91	68	72
407	24.4	4.21	0.37	1.96					
408	28.2	4.35	0.38	1.84					
409	21	4.19	0.36	1.80					
410	23.3	4.12	0.35	1.96					
411	19.9	4.30	0.36	2.19	0.25	588	85	55	47
412	23	4.17	0.35	1.64					
413	19.5	4.49	0.39	1.82					

Riley County - Manhattan - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	59	3.49	0.35	1.91	0.27	377	56	32	49
102	57	3.75	0.32	1.80					
103	58.5	3.88	0.34	1.44					
104	57.5	3.74	0.39	1.93					
105	54	4.13	0.39	1.33					
106	55.5	3.71	0.36	1.59					
107	56.5	4.12	0.36	1.58					
108	57	4.32	0.38	1.72	0.27	337	50	32	53
109	53.5	3.63	0.33	1.58					
110	59.5	3.86	0.33	1.72	0.28	354	53	34	54
111	56	3.89	0.32	1.05					
112	58.5	3.90	0.33	1.40	0.26	381	46	36	53
113	59	3.79	0.35	1.42					
114	53.5	3.88	0.32	1.15					
201	55	3.61	0.35	1.65	0.27	372	50	27	44
202	57	3.90	0.34	1.47					
203	58.5	3.61	0.32	1.29					
204	56.5	4.00	0.35	1.28	0.29	465	50	41	58
205	51.5	3.83	0.34	1.21					
206	51.5	3.57	0.32	1.28					
207	53	3.74	0.32	1.22	0.27	388	41	36	57
208	53	3.10	0.30	1.39					
209	54.5	3.76	0.30	1.23	0.25	550	59	39	63
210	50.5	4.06	0.32	1.06					
211	52	3.93	0.33	1.08					
212	47	3.80	0.31	0.96					
213	46.5	3.81	0.35	0.93					
214	48.5	3.81	0.34	1.12					

Riley County - Manhattan - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g $plant^{-1}$	%				mg kg^{-1}			
301	59.5	3.44	0.33	1.79					
302	55	3.56	0.29	2.22					
303	55.5	3.94	0.39	1.79					
304	58	3.34	0.35	2.25	0.27	353	57	30	49
305	61.5	2.93	0.30	2.02					
306	60.5	3.74	0.34	1.52					
307	55.5	3.78	0.32	1.07					
308	56.5	4.38	0.37	1.40					
309	56	4.05	0.32	1.54	0.27	331	51	36	53
310	52.5	3.97	0.33	1.91	0.28	390	59	40	53
311	56	4.17	0.31	1.36					
312	58	3.15	0.29	2.09					
313	57	3.24	0.30	1.90	0.27	255	50	35	47
314	52.5	3.57	0.34	2.17					
401	57.5	3.42	0.33	1.69	0.25	508	59	30	47
402	57	3.30	0.36	2.04					
403	57	3.43	0.36	2.18					
404	56.5	3.34	0.32	1.71					
405	58	3.85	0.34	1.74	0.28	474	66	31	47
406	60	4.17	0.37	1.66	0.28	965	77	37	58
407	53	4.05	0.35	1.43					
408	58	3.96	0.37	1.35					
409	55	3.77	0.34	1.33					
410	55.5	3.63	0.33	1.64					
411	60.5	4.14	0.34	1.66	0.26	688	67	32	50
412	57.5	4.36	0.34	2.13					
413	54	3.24	0.31	1.93					
414	58.5	3.54	0.32	2.23					

Riley County - Leonardville - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	21.3	3.91	0.26	1.26	0.28	844	104	54	57
102	21.5	3.55	0.27	1.28					
103	23.1	3.45	0.26	1.35					
104	22.3	4.14	0.30	1.10					
105	22.1	4.04	0.29	1.43					
106	23.6	3.50	0.27	1.37					
107	20	3.80	0.26	1.30	0.26	651	77	47	49
108	20.5	3.93	0.30	1.35					
109	19.3	4.02	0.30	1.43	0.26	457	79	41	49
110	23.8	3.91	0.28	1.27					
111	20.5	3.95	0.27	1.56	0.26	441	72	41	45
112	20.8	3.87	0.25	1.56					
113	18.5	4.11	0.29	1.27					
201	16.1	4.01	0.27	1.58	0.27	441	82	42	46
202	17.4	4.00	0.28	1.22					
203	17.6	3.84	0.27	1.22					
204	19.6	3.60	0.25	1.40	0.25	493	80	41	43
205	17.3	3.28	0.25	1.24					
206	20.5	3.18	0.25	1.48					
207	18.1	3.45	0.24	1.24	0.25	754	72	46	45
208	18.8	3.57	0.25	1.34					
209	20.5	3.53	0.27	1.40	0.26	558	82	54	49
210	19.9	3.53	0.26	1.17					
211	19.3	2.84	0.24	1.43					
212	16.3	3.85	0.26	1.34					
213	15.9	3.54	0.26	1.03					

Riley County - Leonardville - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g $plant^{-1}$	%				mg kg^{-1}			
301	15.5	3.31	0.23	1.18					
302	19.4	3.70	0.27	1.37					
303	21.3	3.83	0.27	1.16					
304	17.8	3.31	0.23	1.29	0.25	751	84	39	44
305	20.6	3.70	0.26	1.33					
306	21.7	3.69	0.27	1.40					
307	16.9	3.39	0.27	1.26					
308	18.8	3.63	0.24	1.17	0.26	527	78	45	48
309	19.5	3.55	0.27	1.40	0.27	327	93	51	52
310	23.2	3.65	0.26	1.18					
311	20	3.91	0.28	1.52					
312	20.2	3.83	0.25	1.41	0.26	470	81	41	45
313	15.1	3.72	0.27	1.26					
401	18	3.11	0.23	1.41	0.22	439	64	40	42
402	21.5	3.62	0.27	1.56					
403	23.5	4.26	0.28	1.21					
404	22.4	3.50	0.24	1.39					
405	19.9	3.48	0.24	1.64	0.26	607	77	47	46
406	20.6	3.42	0.25	1.62	0.27	388	81	50	47
407	23.5	3.62	0.27	1.46					
408	21.6	3.54	0.27	1.60					
409	22	3.79	0.28	1.46					
410	25.3	3.70	0.28	1.41					
411	23.8	3.25	0.23	1.48	0.24	771	82	41	45
412	18.4	3.48	0.24	1.36					
413	17.6	3.76	0.29	1.28					

Nemaha County - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
101	19.3	3.71	0.27	1.46	0.26	1179	65	52	49
102	20.4	3.31	0.24	1.46					
103	22.5	3.35	0.23	1.22					
104	21.2	3.47	0.24	1.40					
105	21.3	3.63	0.24	1.30					
106	20.7	3.53	0.27	1.42					
107	18.8	3.46	0.22	1.26	0.22	2592	83	42	49
108	22.3	3.10	0.25	1.60					
109	21	3.59	0.28	1.71	0.24	1330	49	42	50
110	26.2	3.71	0.30	1.65					
111	16.1	3.79	0.30	1.21	0.25	1565	63	47	51
112	22.8	3.64	0.28	1.72					
113	18.2	3.44	0.24	1.39					
201	17.6	3.34	0.25	1.76	0.24	1264	60	41	53
202	20.8	4.04	0.30	1.67					
203	17.2	3.74	0.25	1.50					
204	21.4	3.59	0.26	1.87	0.24	1759	83	46	47
205	15.9	3.47	0.28	1.81					
206	15.1	3.34	0.27	1.40					
207	15.2	3.21	0.25	1.54	0.24	797	48	43	50
208	20.2	3.24	0.25	1.42					
209	20.1	3.18	0.29	1.52	0.25	1275	59	49	52
210	21.1	3.49	0.28	1.92					
211	12.9	3.25	0.25	1.30					
212	17.8	3.54	0.25	1.40					
213	14.3	3.30	0.25	1.68					

Nemaha County - V4 to V6 whole plant sample results									
Plot	weight	N	P	K	S	Fe	Mn	Zn	B
	g plant^{-1}	%				mg kg^{-1}			
301	18.8	3.63	0.26	1.91					
302	16.1	3.44	0.27	1.76					
303	19.9	3.62	0.25	1.65					
304	18.4	3.49	0.26	1.64	0.23	991	57	41	50
305	17.8	3.35	0.25	1.80					
306	21.5	3.29	0.26	1.56					
307	15.2	3.33	0.22	1.71					
308	18.6	3.21	0.23	1.63	0.21	3229	100	46	53
309	14.9	3.60	0.26	1.51	0.23	1304	62	44	56
310	21.4	3.46	0.25	1.82					
311	14.1	3.61	0.24	1.21					
312	19.9	3.44	0.25	2.05	0.22	1773	65	43	54
313	17	3.32	0.24	1.37					
401	20.8	3.52	0.26	1.93	0.24	1173	89	41	49
402	21	3.41	0.28	1.92					
403	19.3	3.03	0.23	1.72					
404	19.4	3.09	0.26	1.86					
405	17.5	3.55	0.28	2.09	0.23	1272	78	41	46
406	19	3.27	0.26	1.83	0.22	977	77	46	44
407	13.8	3.68	0.26	1.59					
408	17.5	3.65	0.29	1.70					
409	13.1	3.66	0.26	1.36					
410	16.5	3.50	0.26	1.73					
411	11.2	3.40	0.23	1.25	0.22	1311	56	40	55
412	13.3	3.11	0.21	1.23					
413	15.8	3.11	0.21	1.21					

R4 Trifoliates

Table C-5. Trifoliate analysis at R4 for 2012 by site.

Saline County - flood irrigated - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.42	5.15	0.32	1.92
102	0.46	5.36	0.30	1.87
103	0.48	5.60	0.33	1.90
104	0.46	5.28	0.34	2.14
105	0.51	5.62	0.34	1.90
106	0.48	5.38	0.33	1.92
107	0.48	5.47	0.32	1.88
108	0.50	5.46	0.34	1.83
109	0.35	5.33	0.34	1.97
110	0.45	5.26	0.32	1.80
111	0.53	5.35	0.30	1.84
112	0.44	5.47	0.36	2.04
113	0.44	5.31	0.34	1.93
114	0.44	5.62	0.34	1.93
201	0.44	5.70	0.38	2.16
202	0.49	5.59	0.32	1.94
203	0.52	5.48	0.32	1.83
204	0.48	5.66	0.31	1.82
205	0.47	5.49	0.33	1.91
206	0.49	5.48	0.32	1.71
207	0.38	5.68	0.36	1.89
208	0.44	5.62	0.33	1.75
209	0.46	5.50	0.34	1.77
210	0.45	5.69	0.34	1.63
211	0.47	5.51	0.31	1.67
212	0.46	5.26	0.33	1.75
213	0.48	5.34	0.32	1.76
214	0.47	5.51	0.33	1.78

Saline County - flood irrigated - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.47	6.15	0.35	1.75
302	0.51	5.53	0.32	1.87
303	0.51	5.39	0.33	1.71
304	0.51	4.98	0.33	1.98
305	0.49	5.67	0.32	1.70
306	0.48	5.51	0.32	1.76
307	0.50	5.40	0.31	1.45
308	0.46	5.69	0.36	1.80
309	0.51	5.52	0.32	1.68
310	0.50	5.94	0.38	1.84
311	0.44	5.77	0.35	1.81
312	0.51	5.50	0.34	1.85
313	0.49	5.25	0.33	1.80
314	0.52	5.48	0.33	1.78
401	0.42	5.84	0.38	2.12
402	0.48	5.75	0.34	1.89
403	0.48	5.76	0.36	1.96
404	0.56	5.20	0.36	2.02
405	0.55	5.01	0.34	2.14
406	0.53	5.46	0.35	2.08
407	0.53	5.67	0.36	1.94
408	0.39	5.49	0.35	1.98
409	0.49	5.40	0.33	1.91
410	0.51	5.79	0.37	2.07
411	0.52	5.36	0.35	2.02
412	0.50	5.45	0.35	2.01
413	0.51	5.57	0.33	1.84
414	0.50	4.83	0.32	2.03

Saline County - dry land - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.53	4.32	0.25	1.67
102	0.45	4.79	0.26	1.63
103	0.57	4.55	0.25	1.58
104	0.54	4.54	0.26	1.88
105	0.49	4.45	0.25	1.71
106	0.51	4.56	0.26	1.71
107	0.51	4.44	0.27	1.74
108	0.51	5.10	0.29	1.74
109	0.55	4.82	0.27	1.72
110	0.50	4.88	0.28	1.64
111	0.58	4.40	0.28	1.94
112	0.47	4.58	0.27	1.88
113	0.51	4.48	0.27	1.76
114	0.47	4.47	0.25	1.92
201	0.58	4.32	0.28	2.02
202	0.59	4.71	0.28	1.78
203	0.59	4.82	0.28	1.81
204	0.57	4.62	0.27	1.89
205	0.58	4.66	0.27	1.75
206	0.55	4.73	0.26	1.59
207	0.49	4.48	0.27	1.84
208	0.61	4.69	0.26	1.67
209	0.65	4.62	0.26	1.82
210	0.58	4.75	0.28	1.85
211	0.53	4.30	0.26	1.87
212	0.57	4.87	0.28	1.83
213	0.56	4.43	0.25	1.75
214	0.54	4.58	0.24	1.67

Saline County - dry land - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.49	4.10	0.25	1.86
302	0.39	4.06	0.26	2.10
303	0.41	4.18	0.25	1.88
304	0.49	4.00	0.24	2.07
305	0.54	3.89	0.23	1.90
306	0.56	3.94	0.23	1.86
307	0.56	3.84	0.23	1.91
308	0.57	3.42	0.22	2.34
309	0.67	3.62	0.21	2.12
310	0.52	3.62	0.22	2.23
311	0.54	3.48	0.22	2.25
312	0.59	3.75	0.23	2.06
313	0.64	3.51	0.22	1.95
314	0.69	3.59	0.23	2.15
401	0.61	3.77	0.23	2.16
402	0.61	3.82	0.22	1.93
403	0.54	4.26	0.23	1.81
404	0.54	4.30	0.23	1.83
405	0.49	3.89	0.23	2.00
406	0.51	4.19	0.23	1.76
407	0.50	3.97	0.22	1.85
408	0.64	4.20	0.24	2.05
409	0.56	3.56	0.23	2.14
410	0.57	3.85	0.21	1.73
411	0.43	3.87	0.22	1.66
412	0.48	4.50	0.24	1.61
413	0.43	4.55	0.25	1.64
414	0.46	4.31	0.23	1.68

Nemaha County - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.79	3.74	0.17	1.36
102	0.71	3.55	0.16	1.27
103	0.52	3.55	0.18	1.42
104	0.61	3.57	0.17	1.32
105	0.57	3.75	0.17	1.34
106	0.52	3.41	0.14	1.23
107	0.59	3.44	0.14	1.20
108	0.43	3.50	0.18	1.42
109	0.57	4.05	0.17	1.23
110	0.59	3.57	0.19	1.37
111	0.49	3.44	0.20	1.45
112	0.73	3.47	0.16	1.19
113	0.69	3.38	0.16	1.08
201	0.71	3.49	0.14	1.38
202	0.58	3.63	0.16	1.24
203	0.55	3.63	0.16	1.34
204	0.52	3.75	0.16	1.28
205	0.43	3.37	0.15	1.32
206	0.47	3.34	0.15	1.16
207	0.47	3.48	0.17	1.21
208	0.55	3.52	0.17	1.22
209	0.58	3.58	0.18	1.25
210	0.59	3.61	0.17	1.33
211	0.49	3.33	0.16	1.25
212	0.55	3.41	0.15	1.35
213	0.56	3.45	0.15	1.23

Nemaha County - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.57	3.56	0.17	1.40
302	0.67	3.64	0.17	1.25
303	0.68	3.46	0.17	1.39
304	0.66	3.89	0.19	1.35
305	0.63	3.58	0.17	1.25
306	0.48	3.20	0.15	1.27
307	0.67	3.30	0.15	1.28
308	0.62	3.31	0.16	1.25
309	0.54	3.44	0.20	1.37
310	0.52	3.40	0.16	1.21
311	0.47	3.59	0.17	1.24
312	0.57	3.48	0.16	1.30
313	0.62	3.31	0.15	1.22
401	0.73	3.73	0.18	1.36
402	0.69	3.54	0.18	1.31
403	0.65	3.50	0.18	1.39
404	0.74	3.58	0.17	1.30
405	0.53	3.69	0.17	1.31
406	0.72	3.39	0.15	1.25
407	0.68	3.43	0.17	1.31
408	0.63	3.53	0.17	1.23
409	0.51	3.57	0.17	1.38
410	0.54	3.12	0.17	1.38
411	0.48	3.21	0.17	1.42
412	0.57	3.27	0.17	1.22
413	0.64	3.56	0.17	1.15

Riley County - Manhattan - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.78	4.52	0.26	1.30
102	0.80	4.39	0.25	1.31
103	0.97	4.08	0.24	1.03
104	1.09	4.21	0.24	0.88
105	1.04	3.98	0.25	0.72
106	0.94	4.20	0.24	0.75
107	0.92	4.04	0.22	0.94
108	0.95	3.71	0.21	0.99
109	1.01	3.64	0.20	0.81
110	0.96	3.91	0.21	0.93
111	0.91	3.85	0.21	0.94
112	0.97	4.70	0.19	0.86
113	0.80	3.81	0.21	0.94
114	0.86	3.49	0.20	0.78
201	0.84	4.21	0.24	1.06
202	0.58	4.29	0.25	1.08
203	0.70	4.23	0.24	0.88
204	0.68	4.50	0.24	1.01
205	0.60	3.91	0.22	0.97
206	0.73	3.73	0.20	0.90
207	0.60	3.44	0.21	1.11
208	0.69	3.66	0.22	1.09
209	0.75	3.74	0.22	1.01
210	0.63	3.51	0.22	1.08
211	0.72	3.50	0.22	1.05
212	0.40	3.75	0.23	1.28
213	0.39	3.46	0.23	1.11
214	0.31	3.65	0.23	1.21

Riley County - Manhattan - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.74	4.46	0.26	1.18
302	0.87	4.27	0.25	1.14
303	1.09	3.91	0.24	0.97
304	1.04	4.11	0.23	1.08
305	1.04	3.76	0.22	1.02
306	0.94	4.13	0.23	0.84
307	1.03	4.26	0.26	0.74
308	1.12	4.16	0.25	0.84
309	0.91	4.03	0.23	0.93
310	0.90	3.91	0.22	1.09
311	0.86	4.10	0.20	0.95
312	0.95	4.05	0.22	1.09
313	0.96	3.83	0.21	1.01
314	0.93	3.93	0.21	0.94
401	0.69	4.45	0.26	1.06
402	0.79	4.71	0.28	1.19
403	0.87	4.82	0.28	1.14
404	0.90	4.59	0.25	1.05
405	0.79	4.24	0.26	1.16
406	0.90	4.40	0.25	1.17
407	0.97	4.38	0.25	1.01
408	1.01	4.08	0.25	0.86
409	0.99	3.94	0.24	0.72
410	0.92	3.87	0.22	0.98
411	0.90	4.36	0.22	1.08
412	0.97	4.31	0.23	1.20
413	1.03	4.37	0.24	1.05
414	0.98	3.86	0.20	1.01

Riley County - Leonardville - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.59	3.73	0.21	1.04
102	0.52	3.63	0.21	0.98
103	0.62	3.85	0.20	1.03
104	0.53	3.97	0.23	1.22
105	0.63	3.73	0.21	1.08
106	0.59	3.87	0.22	1.09
107	0.54	3.55	0.21	1.23
108	0.55	4.15	0.24	1.22
109	0.57	3.95	0.22	1.10
110	0.54	3.98	0.24	1.30
111	0.63	3.76	0.22	1.26
112	0.49	4.08	0.26	1.61
113	0.60	4.00	0.22	1.09
201	0.65	3.63	0.21	1.07
202	0.55	3.93	0.23	1.13
203	0.52	4.04	0.22	1.07
204	0.64	3.59	0.22	1.18
205	0.58	3.98	0.22	1.18
206	0.62	3.58	0.21	1.24
207	0.57	3.93	0.23	1.29
208	0.69	3.82	0.22	1.25
209	0.57	3.91	0.23	1.30
210	0.59	4.01	0.22	1.04
211	0.62	3.84	0.20	1.23
212	0.69	3.71	0.22	1.31
213	0.54	3.94	0.22	1.15

Riley County - Leonardville - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.57	3.86	0.21	1.05
302	0.60	3.93	0.22	1.11
303	0.60	3.92	0.22	1.09
304	0.64	3.82	0.21	1.16
305	0.61	3.84	0.22	1.17
306	0.61	3.96	0.23	1.17
307	0.59	4.07	0.25	1.21
308	0.35	3.98	0.23	1.31
309	0.77	3.85	0.23	1.11
310	0.80	3.79	0.20	1.08
311	0.89	3.67	0.20	1.09
312	0.88	3.82	0.23	1.50
313	0.78	3.84	0.22	1.23
401	0.74	3.96	0.21	1.18
402	0.75	3.66	0.21	1.14
403	0.93	3.90	0.22	1.13
404	0.99	3.77	0.21	1.27
405	0.96	3.88	0.22	1.34
406	0.73	4.00	0.22	1.30
407	1.00	3.87	0.21	1.00
408	1.09	3.48	0.21	1.09
409	0.97	4.09	0.23	1.14
410	0.75	3.96	0.21	1.03
411	0.99	3.96	0.22	1.22
412	0.90	3.45	0.20	1.32
413	0.93	4.10	0.23	1.20

Woodson County - meadow - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.25	3.55	0.18	0.96
102	0.27	3.91	0.17	0.81
103	0.22	3.68	0.18	1.01
104	0.51	3.56	0.16	1.13
105	0.50	3.46	0.17	1.05
106	0.53	3.68	0.17	1.02
107	0.18	3.27	0.16	1.09
108	0.24	3.54	0.16	1.01
109	0.28	3.89	0.19	0.98
110	0.25	3.83	0.22	1.05
111	0.30	4.39	0.26	1.12
112	0.27	3.88	0.24	1.27
113	0.33	4.16	0.22	1.12
201	0.46	4.11	0.18	0.74
202	0.44	3.91	0.18	0.73
203	0.41	3.66	0.14	0.72
204	0.43	3.62	0.12	0.66
205	0.41	3.44	0.12	0.96
206	0.36	3.53	0.13	1.10
207	0.42	3.58	0.16	1.06
208	0.48	3.53	0.19	0.88
209	0.49	4.41	0.24	0.90
210	0.60	4.51	0.28	0.90
211	0.55	4.16	0.25	0.77
212	0.58	4.13	0.26	0.99
213	0.59	4.30	0.31	1.16

Woodson County - meadow - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.33	4.12	0.20	0.92
302	0.32	4.19	0.22	1.12
303	0.32	4.16	0.20	1.04
304	0.32	3.92	0.18	0.85
305	0.38	4.78	0.32	1.48
306	0.39	4.08	0.19	1.14
307	0.45	4.45	0.25	1.13
308	0.49	4.58	0.30	1.15
309	0.41	4.55	0.30	1.28
310	0.38	4.33	0.28	1.46
311	0.51	4.49	0.29	1.44
312	0.44	4.21	0.27	1.46
313	0.50	3.46	0.14	0.95
401	0.34	4.28	0.20	0.99
402	0.43	3.63	0.15	0.71
403	0.37	3.76	0.15	0.83
404	0.41	4.03	0.15	0.86
405	0.49	3.85	0.17	0.81
406	0.56	4.06	0.21	0.75
407	0.55	4.55	0.28	0.87
408	0.54	4.25	0.25	0.95
409	0.51	4.21	0.27	1.17
410	0.55	4.08	0.25	1.10
411	0.62	4.48	0.27	1.21
412	0.51	4.41	0.29	0.99
413	0.59	4.65	0.27	0.89

Woodson County - lynx - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
101	0.49	4.54	0.28	1.20
102	0.39	5.01	0.30	1.14
103	0.55	4.07	0.32	1.29
104	0.47	4.51	0.30	1.01
105	0.40	4.54	0.29	1.13
106	0.39	4.77	0.28	1.06
107	0.42	4.38	0.26	1.14
108	0.41	4.09	0.30	1.19
109	0.38	3.67	0.29	1.05
110	0.38	4.70	0.31	0.92
111	0.44	4.56	0.32	1.02
112	0.43	4.71	0.34	1.35
113	0.44	4.42	0.29	1.33
201	0.59	4.70	0.26	0.97
202	0.53	4.62	0.27	1.14
203	0.65	4.25	0.26	0.97
204	0.62	4.44	0.28	0.85
205	0.59	4.13	0.25	0.86
206	0.53	3.86	0.23	0.80
207	0.53	3.79	0.20	0.77
208	0.53	4.18	0.23	0.79
209	0.52	3.89	0.22	0.80
210	0.49	4.30	0.26	0.70
211	0.54	3.92	0.24	0.80
212	0.55	4.30	0.27	1.01
213	0.62	4.07	0.25	0.92

Saline County - lynx - trifoliate analysis				
	Weight	N	P	K
Plot	g trifoliate^{-1}	%		
301	0.52	4.59	0.28	1.13
302	0.47	4.38	0.28	1.50
303	0.56	4.52	0.32	1.37
304	0.55	5.00	0.33	1.25
305	0.47	4.64	0.33	1.33
306	0.51	4.92	0.32	1.14
307	0.40	4.85	0.34	1.36
308	0.43	4.31	0.30	1.20
309	0.41	4.72	0.31	1.14
310	0.43	4.64	0.28	0.98
311	0.37	4.17	0.25	1.01
312	0.40	4.34	0.28	1.18
313	0.45	4.35	0.28	1.24
401	0.67	4.63	0.27	1.32
402	0.68	5.14	0.32	1.26
403	0.65	4.65	0.30	1.46
404	0.64	4.66	0.29	1.28
405	0.66	4.68	0.30	1.36
406	0.65	4.73	0.30	1.37
407	0.69	4.86	0.32	1.38
408	0.67	5.12	0.32	1.34
409	0.70	4.72	0.29	1.13
410	0.59	4.87	0.32	1.04
411	0.46	4.36	0.25	0.91
412	0.46	4.25	0.23	0.93
413	0.31	4.39	0.29	1.28

Grain yield and analysis

Table C-6. Grain and yield analysis for 2012 by site.

Saline County - dry land - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	20.1	0.74	0.59
102	22.1	0.63	0.60
103	24.6	0.52	0.61
104	30.5	0.51	0.59
105	35.8	0.46	0.63
106	26.8	0.61	0.57
107	26.4	0.63	0.58
108	25.3	0.47	0.59
109	32.0	0.38	0.58
110	41.1	0.25	0.65
111	35.0	0.49	0.60
112	36.6	0.34	0.60
113	20.3	0.83	0.57
114	18.8	0.69	0.52
201	44.3	0.24	0.63
202	30.9	0.38	0.63
203	33.6	0.31	0.61
204	28.1	0.50	0.59
205	49.5	0.24	0.61
206	21.3	0.95	0.58
207	18.9	0.79	0.57
208	59.3	0.16	0.66
209	41.3	0.20	0.62
210	33.6	0.26	0.60
211	21.9	0.77	0.57
212	40.3	0.50	0.62
213	19.1	0.96	0.58
214	20.5	0.77	0.60

Saline County - dry land - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	18.5	0.66	0.56
302	19.6	0.71	0.57
303	15.5	1.02	0.54
304	14.1	1.14	0.50
305	15.5	0.89	0.54
306	16.8	0.94	0.57
307	16.3	0.97	0.55
308	14.7	1.19	0.55
309	12.4	1.35	0.52
310	11.2	1.53	0.52
311	11.7	1.62	0.50
312	12.5	1.58	0.54
313	13.3	1.58	0.52
314	13.5	1.42	0.54
401	14.1	1.39	0.56
402	13.9	1.35	0.58
403	12.5	1.60	0.54
404	11.8	1.70	0.52
405	13.1	1.83	0.55
406	12.1	1.44	0.53
407	11.4	1.39	0.52
408	14.0	1.29	0.60
409	12.9	1.53	0.61
410	11.3	1.88	0.53
411	11.3	1.87	0.55
412	10.7	1.97	0.54
413	12.0	1.60	0.54
414	12.1	1.66	0.53

Saline County - flood irrigated - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	9.5	1.93	0.58
102	9.0	1.80	0.52
103	8.6	2.02	0.53
104	8.6	2.19	0.56
105	8.8	2.29	0.54
106	8.9	2.92	0.51
107	8.7	2.85	0.54
108	8.2	2.21	0.55
109	8.6	2.16	0.57
110	8.4	2.49	0.54
111	8.6	2.36	0.54
112	8.7	2.23	0.52
113	8.3	1.88	0.53
114	8.4	2.46	0.54
201	9.3	1.96	0.55
202	10.6	2.02	0.54
203	9.5	1.72	0.53
204	8.7	2.45	0.62
205	8.7	2.48	0.48
206	8.6	2.53	0.53
207	8.7	2.45	0.55
208	8.8	3.02	0.53
209	8.9	2.58	0.56
210	9.0	2.91	0.57
211	11.3	2.66	0.51
212	8.5	2.31	0.52
213	9.5	1.84	0.48
214	8.3	1.84	0.52

Saline County - flood irrigated - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	10.1	1.73	0.53
302	8.3	2.03	0.53
303	8.9	2.34	0.52
304	9.2	2.79	0.51
305	8.5	2.42	0.53
306	9.2	2.90	0.54
307	8.9	2.66	0.52
308	8.8	2.84	0.57
309	8.7	3.03	0.53
310	8.9	3.29	0.53
311	9.7	2.88	0.52
312	8.9	2.28	0.55
313	8.4	1.64	0.50
314	8.4	1.80	0.50
401	11.8	1.84	0.53
402	8.6	1.95	0.54
403	9.7	2.37	0.50
404	8.8	2.55	0.52
405	8.6	2.53	0.50
406	9.7	3.20	0.55
407	8.8	2.98	0.53
408	8.8	2.75	0.55
409	8.8	2.67	0.50
410	8.9	2.85	0.53
411	8.7	2.16	0.50
412	9.4	1.94	0.51
413	8.1	1.26	0.50
414	8.2	1.98	0.51

Nemaha County - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	12.1	1.74	0.44
102	12.2	1.14	0.40
103	12.2	1.39	0.40
104	12.2	1.43	0.44
105	12.3	1.42	0.43
106	12.2	0.98	0.41
107	11.8	1.59	0.40
108	12.0	1.59	0.44
109	11.9	1.68	0.41
110	12.2	1.53	0.46
111	12.2	1.68	0.41
112	12.0	1.68	0.44
113	11.7	1.83	0.39
201	12.6	1.29	0.43
202	14.2	1.16	0.44
203	12.5	1.34	0.44
204	11.8	1.35	0.42
205	13.2	1.16	0.41
206	12.2	0.81	0.41
207	11.8	1.37	0.45
208	12.2	1.12	0.46
209	12.3	1.32	0.44
210	13.1	1.31	0.47
211	13.0	1.19	0.38
212	11.9	1.35	0.37
213	11.8	1.80	0.40

Nemaha County - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	16.1	1.59	0.28
302	12.4	1.40	0.44
303	12.0	1.43	0.46
304	12.0	1.24	0.44
305	12.0	1.39	0.41
306	12.3	0.86	0.41
307	11.8	1.33	0.41
308	12.5	0.92	0.44
309	11.9	1.40	0.46
310	11.8	1.39	0.42
311	12.7	1.17	0.41
312	11.8	1.25	0.41
313	11.8	1.33	0.40
401	12.4	1.59	0.43
402	12.3	1.34	0.45
403	12.5	1.33	0.42
404	11.9	1.21	0.43
405	12.2	1.16	0.41
406	12.0	0.98	0.43
407	11.8	1.30	0.38
408	12.1	1.08	0.41
409	11.7	1.50	0.39
410	12.2	1.02	0.42
411	11.9	1.14	0.43
412	12.3	1.02	0.43
413	11.7	1.63	0.45

Riley County - Leonardville - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	10.0	1.34	0.51
102	10.8	1.23	0.53
103	9.2	1.95	0.46
104	10.8	1.11	0.49
105	9.9	1.50	0.49
106	11.3	1.08	0.56
107	10.0	1.24	0.53
108	9.8	1.44	0.48
109	9.5	1.66	0.51
110	10.2	1.40	0.52
111	10.5	1.29	0.52
112	12.6	0.95	0.54
113	9.9	1.63	0.49
201	10.7	1.33	0.50
202	11.8	1.05	0.55
203	8.9	1.81	0.51
204	10.9	1.26	0.55
205	10.1	1.59	0.54
206	12.1	0.90	0.56
207	11.5	0.93	0.56
208	10.3	1.35	0.51
209	10.5	1.22	0.53
210	9.4	1.77	0.48
211	10.6	1.30	0.47
212	12.5	0.86	0.53
213	10.6	1.38	0.46

Riley County - Leonardville - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	10.8	1.23	0.47
302	10.5	1.20	0.47
303	9.5	1.88	0.46
304	10.7	1.18	0.49
305	9.6	1.63	0.46
306	11.5	1.09	0.52
307	10.8	1.18	0.48
308	10.2	1.59	0.49
309	9.7	1.66	0.46
310	9.5	1.82	0.45
311	10.0	1.34	0.49
312	14.8	0.72	0.54
313	10.1	1.53	0.48
401	11.2	1.01	0.48
402	11.6	0.98	0.49
403	9.0	2.05	0.46
404	10.6	1.12	0.47
405	10.7	1.15	0.51
406	11.2	0.96	0.52
407	10.4	1.43	0.49
408	9.6	1.90	0.47
409	10.6	1.53	0.49
410	9.6	1.73	0.46
411	10.5	1.36	0.48
412	14.1	0.77	0.52
413	10.8	1.34	0.48

Woodson County - lynx - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	8.6	3.01	0.50
102	8.7	3.55	0.50
103	8.7	3.70	0.52
104	8.7	3.45	0.55
105	8.7	3.39	0.49
106	8.6	3.33	0.51
107	8.8	3.02	0.48
108	8.6	3.22	0.54
109	8.6	2.89	0.50
110	8.7	3.00	0.51
111	8.6	3.20	0.52
112	8.6	3.27	0.53
113	8.7	3.19	0.49
201	8.8	3.47	0.49
202	8.6	3.43	0.50
203	8.7	3.44	0.49
204	8.6	3.44	0.54
205	8.8	3.06	0.53
206	8.6	3.09	0.48
207	8.8	2.98	0.44
208	8.6	3.15	0.50
209	8.6	2.74	0.52
210	8.6	2.82	0.55
211	8.5	2.99	0.46
212	8.6	3.24	0.54
213	8.6	3.16	0.53

Woodson County - lynx - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	8.7	3.55	0.49
302	8.6	3.43	0.47
303	8.6	3.77	0.54
304	8.6	3.70	0.52
305	8.7	3.65	0.50
306	8.5	3.69	0.50
307	8.7	3.25	0.52
308	8.7	3.12	0.48
309	8.5	3.09	0.50
310	8.5	3.09	0.46
311	8.5	3.22	0.50
312	8.5	3.05	0.52
313	8.7	2.92	0.48
401	8.7	3.54	0.46
402	8.5	3.56	0.51
403	8.8	3.74	0.52
404	8.7	3.75	0.49
405	8.6	3.70	0.52
406	8.5	3.64	0.50
407	8.7	3.73	0.53
408	8.4	3.28	0.55
409	8.5	3.64	0.49
410	8.7	3.54	0.50
411	8.5	3.04	0.47
412	8.7	2.91	0.48
413	8.6	2.70	0.52

Woodson County - meadow - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	9.5	1.88	0.51
102	9.3	1.80	0.56
103	9.5	1.89	0.49
104	9.6	1.95	0.51
105	9.4	1.53	0.47
106	9.6	1.48	0.54
107	9.5	1.37	0.47
108	9.5	1.70	0.51
109	9.4	1.87	0.57
110	9.4	1.95	0.56
111	9.4	1.94	0.56
112	9.4	1.93	0.56
113	10.0	1.81	0.52
201	9.5	1.77	0.55
202	9.6	1.84	0.58
203	9.5	1.81	0.53
204	9.2	1.81	0.53
205	9.4	1.67	0.48
206	9.5	1.61	0.46
207	9.4	1.82	0.48
208	9.1	2.21	0.54
209	9.0	2.38	0.59
210	9.1	2.60	0.56
211	9.0	2.60	0.59
212	9.3	2.59	0.63
213	9.3	2.54	0.63

Woodson County - meadow - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	9.4	1.95	0.49
302	9.5	1.77	0.47
303	9.5	1.84	0.49
304	9.5	2.04	0.53
305	9.2	1.97	0.51
306	9.4	2.42	0.52
307	9.3	2.47	0.59
308	9.4	2.26	0.64
309	9.4	2.31	0.67
310	9.2	2.54	0.59
311	9.0	2.55	0.62
312	9.1	2.49	0.60
313	9.2	2.27	0.54
401	9.6	1.90	0.48
402	9.5	1.92	0.61
403	9.5	1.79	0.63
404	9.3	1.78	0.51
405	9.4	2.20	0.65
406	9.2	2.43	0.57
407	9.1	2.42	0.61
408	9.3	2.43	0.66
409	9.2	2.13	0.71
410	9.2	2.41	0.65
411	9.0	2.64	0.63
412	9.0	3.05	0.57
413	9.0	2.97	0.61

Riley County - Manhattan - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
101	8.3	4.63	0.53
102	8.3	4.11	0.56
103	8.4	3.28	0.52
104	9.1	2.90	0.54
105	10.6	2.64	0.57
106	11.2	2.40	0.57
107	11.6	1.78	0.55
108	15.0	1.78	0.62
109	17.8	1.81	0.58
110	19.0	1.67	0.57
111	19.8	1.40	0.59
112	23.5	1.63	0.61
113	22.6	1.49	0.58
114	13.0	1.20	0.54
201	8.2	3.98	0.57
202	8.8	3.48	0.60
203	10.2	2.61	0.53
204	10.9	2.68	0.53
205	12.8	2.20	0.55
206	14.2	1.53	0.53
207	12.8	0.84	0.53
208	26.3	0.60	0.64
209	27.3	0.63	0.63
210	47.9	0.18	0.72
211	27.3	0.36	0.61
212	13.9	1.26	0.56
213	13.1	1.45	0.58
214	17.7	0.96	0.58

Riley County - Manhattan - grain analysis			
Plot	Moisture	Yield at 13 %	P
	%	Mg ha^{-1}	%
301	8.2	3.78	0.52
302	8.4	3.59	0.58
303	8.6	3.03	0.54
304	9.2	2.97	0.51
305	9.9	2.68	0.57
306	8.9	3.06	0.53
307	10.0	2.25	0.58
308	11.5	2.08	0.59
309	10.9	2.27	0.50
310	10.9	1.99	0.54
311	10.1	2.02	0.52
312	10.2	2.34	0.57
313	11.0	2.13	0.54
314	10.7	2.20	0.53
401	8.1	3.25	0.46
402	8.2	3.19	0.57
403	8.1	3.53	0.53
404	8.2	3.36	0.54
405	8.2	3.04	0.54
406	8.1	3.75	0.50
407	8.4	3.18	0.54
408	9.5	2.68	0.58
409	10.9	2.22	0.56
410	11.8	1.95	0.57
411	10.8	2.17	0.52
412	9.0	2.86	0.51
413	9.3	2.57	0.54
414	11.4	2.23	0.56

2013

Treatments

Table C-7. Treatments for the 2013 sites and their respective plot number.

Atchison County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	14	0	0	0	0	0	0	R4 - rained on
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	15	0	0	0	0	0	0	Post R4
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
114	12	0	29	22	0	0	0	0
115	8	0	39	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	15	0	0	0	0	0	0	Post R4
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	14	0	0	0	0	0	0	R4 - rained on
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0
214	5	10	10	0	0	0	0	0

215	2	0	10	0	0	0	0	0

Atchison County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	15	0	0	0	0	0	0	Post R4
305	9	10	29	0	0	0	0	0
306	14	0	0	0	0	0	0	R4 - rained on
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
314	1	0	0	0	0	0	0	0
315	6	0	29	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	15	0	0	0	0	0	0	Post R4
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	14	0	0	0	0	0	0	R4 - rained on
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0
414	3	10	0	0	0	0	0	0
415	8	0	39	0	0	0	0	0

Lyon County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	12	0	29	22	0	0	0	0
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	8	0	39	0	0	0	0	0
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	2	0	10	0	0	0	0	0
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	5	10	10	0	0	0	0	0
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0

Lyon County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	6	0	29	0	0	0	0	0
305	9	10	29	0	0	0	0	0
306	1	0	0	0	0	0	0	0
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	8	0	39	0	0	0	0	0
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	3	10	0	0	0	0	0	0
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0

Riley County - Manhattan								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	14	0	0	0	0	0	0	R4
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	15	0	0	0	0	0	0	V4-6
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
114	12	0	29	22	0	0	0	0
115	8	0	39	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	15	0	0	0	0	0	0	V4-6
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	14	0	0	0	0	0	0	R4
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0
214	5	10	10	0	0	0	0	0
215	2	0	10	0	0	0	0	0

Riley County - Manhattan								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	15	0	0	0	0	0	0	V4-6
305	9	10	29	0	0	0	0	0
306	14	0	0	0	0	0	0	R4
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
314	1	0	0	0	0	0	0	0
315	6	0	29	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	15	0	0	0	0	0	0	V4-6
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	14	0	0	0	0	0	0	R4
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0
414	3	10	0	0	0	0	0	0
415	8	0	39	0	0	0	0	0

Douglas County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	12	0	29	22	0	0	0	0
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	8	0	39	0	0	0	0	0
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	2	0	10	0	0	0	0	0
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	5	10	10	0	0	0	0	0
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0

Douglas County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	6	0	29	0	0	0	0	0
305	9	10	29	0	0	0	0	0
306	1	0	0	0	0	0	0	0
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	8	0	39	0	0	0	0	0
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	3	10	0	0	0	0	0	0
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0

Riley County - Randolph								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	14	0	0	0	0	0	0	R4
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	8	0	39	0	0	0	0	0
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
114	12	0	29	22	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	2	0	10	0	0	0	0	0
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	14	0	0	0	0	0	0	R4
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0
214	5	10	10	0	0	0	0	0

Riley County - Randolph								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	6	0	29	0	0	0	0	0
305	9	10	29	0	0	0	0	0
306	14	0	0	0	0	0	0	R4
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
314	1	0	0	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	8	0	39	0	0	0	0	0
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	14	0	0	0	0	0	0	R4
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0
414	3	10	0	0	0	0	0	0

Woodson County - lowland								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	12	0	29	22	0	0	0	0
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	8	0	39	0	0	0	0	0
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	2	0	10	0	0	0	0	0
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	5	10	10	0	0	0	0	0
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0

Woodson County - Lowland								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	6	0	29	0	0	0	0	0
305	9	10	29	0	0	0	0	0
306	1	0	0	0	0	0	0	0
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	8	0	39	0	0	0	0	0
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	3	10	0	0	0	0	0	0
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0

Woodson County - upland								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	0	29	22	11	11	1	0
102	2	0	10	0	0	0	0	0
103	5	10	10	0	0	0	0	0
104	10	0	49	0	0	0	0	0
105	4	0	20	0	0	0	0	0
106	6	0	29	0	0	0	0	0
107	1	0	0	0	0	0	0	0
108	12	0	29	22	0	0	0	0
109	7	10	20	0	0	0	0	0
110	9	10	29	0	0	0	0	0
111	8	0	39	0	0	0	0	0
112	11	10	39	0	0	0	0	0
113	3	10	0	0	0	0	0	0
201	7	10	20	0	0	0	0	0
202	11	10	39	0	0	0	0	0
203	6	0	29	0	0	0	0	0
204	12	0	29	22	0	0	0	0
205	8	0	39	0	0	0	0	0
206	3	10	0	0	0	0	0	0
207	1	0	0	0	0	0	0	0
208	2	0	10	0	0	0	0	0
209	13	0	29	22	11	11	1	0
210	10	0	49	0	0	0	0	0
211	5	10	10	0	0	0	0	0
212	4	0	20	0	0	0	0	0
213	9	10	29	0	0	0	0	0

Woodson County - upland								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	10	0	0	0	0	0	0
302	4	0	20	0	0	0	0	0
303	11	10	39	0	0	0	0	0
304	6	0	29	0	0	0	0	0
305	9	10	29	0	0	0	0	0
306	1	0	0	0	0	0	0	0
307	10	0	49	0	0	0	0	0
308	7	10	20	0	0	0	0	0
309	13	0	29	22	11	11	1	0
310	2	0	10	0	0	0	0	0
311	8	0	39	0	0	0	0	0
312	12	0	29	22	0	0	0	0
313	5	10	10	0	0	0	0	0
401	1	0	0	0	0	0	0	0
402	10	0	49	0	0	0	0	0
403	8	0	39	0	0	0	0	0
404	2	0	10	0	0	0	0	0
405	12	0	29	22	0	0	0	0
406	13	0	29	22	11	11	1	0
407	11	10	39	0	0	0	0	0
408	6	0	29	0	0	0	0	0
409	3	10	0	0	0	0	0	0
410	4	0	20	0	0	0	0	0
411	7	10	20	0	0	0	0	0
412	5	10	10	0	0	0	0	0
413	9	10	29	0	0	0	0	0

Soil

Table C-8. Soil results for 2013 by site.

Atchison County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	13.6	1.4	78.8	71.7	9.5	3.3
102	9.6					
103	8.6					
104	15.9					
105	11.7					
106	13.3	0.8	57.5	59.3	7.3	3.2
107	11.5	1.1	75.0	69.6	7.0	4.1
108	8.6					
109	9.3					
110	13.0					
111	9.2					
112	10.6					
113	13.3					
114	11.0	0.7	51.6	89.5	6.4	3.2
115	9.5					
201	8.8					
202	10.7					
203	9.7	0.9	60.4	70.0	7.1	4.1
204	10.9	1.0	69.3	44.5	8.7	3.0
205	14.7					
206	9.3					
207	7.3	0.7	71.7	49.5	8.0	2.6
208	10.2					
209	8.9	0.8	63.0	64.4	7.1	2.8
210	10.8					
211	9.3					
212	11.3					
213	11.0					
214	14.9					
215	10.4					

Atchison County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	10.1					
302	9.6					
303	7.9					
304	12.5					
305	12.4					
306	10.4					
307	12.4					
308	11.7					
309	9.5	0.7	55.0	48.3	6.9	3.8
310	9.8					
311	11.6					
312	7.7	0.9	55.7	67.5	6.1	
313	9.2					
314	9.1	0.7	58.5	69.1	6.6	2.8
315	10.2	0.9	65.0	55.4	7.8	4.9
401	7.1	0.6	49.8	50.7	5.3	3.2
402	10.3					
403	7.5					
404	7.0					
405	14.3	0.9	57.0	76.4	7.2	3.3
406	9.4	1.0	56.7	59.8	7.7	3.2
407	5.5					
408	8.6	0.9	65.8	57.7	8.5	4.0
409	10.9					
410	10.3					
411	11.0					
412	14.8					
413	9.8					
414	9.0					
415	10.6					

Lyon County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	10.2	0.8	18.1	15.8	24.3	303.7
102	8.2					
103	7.0					
104	9.1					
105	8.6					
106	8.7	1.2	19.4	23.2	6.1	74.9
107	8.5	1.5	19.3	26.7	5.9	18.8
108	9.4	1.8	29.3	21.9	6.5	7.2
109	10.4					
110	8.1					
111	9.2					
112	9.0					
113	7.2					
201	7.9					
202	6.8					
203	7.8	1.0	23.2	21.5	6.0	34.4
204	8.6	0.9	21.7	20.6	5.8	37.3
205	6.9					
206	6.8					
207	6.7	1.3	22.0	23.5	6.8	46.0
208	6.7					
209	7.8	1.7	29.2	23.8	5.6	29.2
210	8.8					
211	8.7					
212	10.6					
213	8.2					

Lyon County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	6.6					
302	6.7					
303	7.9					
304	7.5	0.9	21.6	22.6	6.4	11.8
305	7.6					
306	5.6	1.0	18.5	19.2	5.4	12.7
307	6.6					
308	6.1					
309	6.3	1.4	24.4	22.4	6.3	74.9
310	7.0					
311	6.2					
312	6.6	1.8	22.2	21.9	5.5	23.9
313	8.0					
401	6.7	0.7	18.3	18.7	5.4	413.0
402	6.3					
403	5.9					
404	6.3					
405	7.6	1.1	25.9	16.2	6.7	11.4
406	6.4	1.1	17.3	18.4	5.0	10.2
407	7.0					
408	6.9	1.1	20.9	20.4	5.2	6.8
409	6.6					
410	7.4					
411	8.8					
412	7.0					
413	8.8					

Riley County - Manhattan -soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	15.5	1.5	56.2	42.3	9.3	5.0
102	13.6					
103	17.4					
104	17.5					
105	22.2					
106	18.1	1.6	54.3	51.0	10.0	5.1
107	20.3	1.7	58.5	52.2	8.3	4.3
108	18.1					
109	18.2					
110	19.4					
111	19.3					
112	22.0					
113	39.0					
114	43.2	1.9	64.0	38.9	10.6	4.3
115	35.0					
201	17.2					
202	22.2					
203	14.8	1.5	55.3	51.3	9.0	3.3
204	27.6	1.8	56.0	51.9	9.4	4.0
205	21.2					
206	35.0					
207	20.9	1.8	53.8	49.2	9.5	5.3
208	18.9					
209	18.9	1.5	55.9	50.8	7.9	4.1
210	24.9					
211	17.2					
212	16.9					
213	30.9					
214	23.8					
215	15.5					

Riley County - Manhattan -soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	16.9					
302	16.9					
303	21.1					
304	21.4					
305	17.3					
306	24.4					
307	17.9					
308	14.2					
309	14.1	1.1	45.2	36.3	7.1	4.1
310	16.4					
311	15.4					
312	19.4	1.1	46.2	42.5	8.5	
314	19.5	1.3	61.4	49.0	7.4	4.4
315	17.8	1.1	58.8	42.0	7.9	5.4
401	16.9	1.3	42.8	31.2	8.0	5.2
402	35.3					
403	34.7					
404	16.4					
405	22.7	1.4	54.0	41.3	6.8	4.0
405	8.8					
406	17.7	1.3	61.8	43.9	8.5	5.6
407	11.6					
408	24.0	1.1	47.9	44.4	7.1	4.2
409	18.8					
410	12.9					
411	20.0					
412	26.5					
413	15.7					
414	29.5					
415	26.6					

Douglas County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	9.0	1.9	45.8	61.7	7.9	3.1
102	8.4					
103	9.9					
104	7.8					
105	6.5					
106	7.8	1.5	34.2	55.2	5.1	3.6
107	11.4	2.7	42.8	57.1	7.0	3.5
108	14.1	2.7	35.0	39.5	8.1	3.5
109	8.6					
110	11.0					
111	7.0					
112	12.6					
113	7.4					
201	11.9					
202	10.4					
203	10.7	2.0	50.5	45.2	7.0	3.9
204	10.6	1.5	41.5	47.4	7.8	2.7
205	10.5					
206	9.5					
207	9.2	2.1	47.0	43.7	8.2	4.3
208	12.7					
209	11.0	3.5	59.8	73.4	7.5	2.8
210	10.1					
211	9.1					
212	9.6					
213	14.2					

Douglas County - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	14.7					
302	10.6					
303	14.0					
304	8.7	1.2	34.0	49.7	7.2	3.3
305	11.4					
306	7.9	2.9	35.7	68.3	6.1	2.1
307	10.2					
308	10.5					
309	8.5	2.6	55.9	94.8	6.4	2.4
310	11.1					
311	12.8					
312	13.3	3.3	47.2	74.5	8.9	3.5
313	9.2					
401	12.1	4.7	36.2	62.2	8.8	3.6
402	12.7					
403	13.7					
404	12.4					
405	11.8	2.8	36.8	80.5	7.0	3.1
406	11.9	2.5	34.8	67.9	7.7	3.3
407	11.9					
408	15.7	3.9	41.3	65.8	8.4	2.9
409	11.1					
410	13.1					
411	11.7					
412	11.8					
413	12.8					

Riley County - Randolph - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	16.5	1.2	84.4	79.2	6.2	5.9
102	20.1					
103	19.9					
104	25.5					
105	27.2					
106	17.3	1.1	82.0	72.2	6.4	3.5
107	24.7	1.2	87.1	69.9	6.9	4.2
108	23.2					
109	18.9					
110	15.7					
111	25.4					
112	16.8					
113	14.7					
114	24.0	1.1	91.1	74.6	6.8	
201	29.9					
202	20.1					
203	24.1	1.1	86.0	62.4	6.1	
204	36.8	1.1	92.7	77.9	6.8	4.5
205	23.7					
206	27.7					
207	35.7	1.0	85.8	69.2	6.3	4.6
208	27.7					
209	12.3	1.0	81.6	70.4	6.0	3.7
210	17.5					
211	23.3					
212	23.9					
213	33.9					
214	29.2					

Riley County - Randolph - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	21.5					
302	22.8					
303	19.5					
304	20.3	1.0	99.1	54.9	7.2	
305	18.0					
306	21.0					
307	21.8					
308	25.3					
309	30.9	1.1	97.1	61.3	7.5	6.6
310	17.6					
311	24.3					
312	39.7	1.3	97.7	66.2	8.3	6.5
313	18.0					
314	28.2	1.3	91.6	81.6	8.2	6.2
401	28.0	1.4	92.6	74.5	7.1	5.3
402	21.4					
403	22.0					
404	20.5					
405	15.6	1.0	93.9	55.9	5.8	5.8
406	18.8	1.1	92.7	52.1	6.4	5.4
407	17.5					
408	18.8	1.3	96.4	73.4	6.4	
409	18.1					
410	20.0					
411	16.0					
412	20.6					
413	15.2					
414	23.4					

Woodson County - lowland - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	8.3	1.7	16.8	22.5	3.9	2.5
102	8.5					
103	14.3					
104	13.7					
105	16.7					
106	17.9	2.1	27.6	25.7	5.3	1.7
107	10.7	1.6	18.0	19.8	3.4	2.8
108	11.7	1.3	14.7	15.2	3.3	3.0
109	17.0					
110	23.6					
111	23.6					
112	23.0					
113	12.6					
201	32.8					
202	20.3					
203	13.3	2.1	33.5	30.0	5.7	2.4
204	19.9	2.4	39.3	46.7	5.1	2.9
205	14.6					
206	18.5					
207	13.9	2.1	29.0	28.6	5.0	2.6
208	16.3					
209	8.5	1.5	19.6	22.1	3.2	2.5
210	13.2					
211	15.2					
212	10.8					
213	16.5					

Woodson County - lowland - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	28.6					
302	21.3					
303	14.3					
304	10.2	1.9	25.3	34.4	4.1	2.9
305	9.1					
306	11.1	2.0	24.5	25.8	4.4	2.6
307	10.1					
308	9.8					
309	11.8	1.3	19.2	21.5	3.5	2.9
310	12.5					
311	9.4					
312	17.4	1.4	26.5	25.1	4.1	2.4
313	27.6					
401	26.3	2.5	31.1	26.2	3.7	2.1
402	25.7					
403	12.5					
404	10.3					
405	7.9	1.6	23.2	29.3	3.6	2.7
406	8.3	1.4	27.5	26.8	3.8	2.5
407	7.1					
408	9.0	1.4	21.5	25.9	3.1	2.6
409	16.9					
410	18.3					
411	31.5					
412	31.0					
413	25.9					

Woodson County - upland - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
101	18.5	1.4	87.6	25.4	7.2	4.8
102	15.8					
103	21.5					
104	22.3					
105	13.2					
106	12.5	1.2	86.2	23.9	7.1	4.6
107	16.3	1.3	95.8	23.5	8.1	4.8
108	22.8	1.4	87.0	25.2	7.7	5.6
109	14.2					
110	21.2					
111	18.5					
112	19.9					
113	13.6					
201	12.9					
202	17.7					
203	23.9	1.4	97.8	21.1	7.1	5.7
204	20.5	1.3	108.9	24.2	6.6	5.2
205	9.6					
206	12.7					
207	12.6	1.3	80.2	23.8	8.0	4.7
208	13.3					
209	17.1	1.4	85.6	37.7	8.0	4.5
210	19.3					
211	13.1					
212	13.8					
213	18.0					

Woodson County - upland - soil results						
	Extract					
	Mehlich-3	DTPA			Ca-PO4	
	P	Zn	Fe	Mn	S	
Plot	0-15 cm				0-15 cm	15 - 61 cm
301	14.0					
302	15.6					
303	23.7					
304	14.2	1.5	82.2	28.2	8.4	3.1
305	11.7					
306	23.0	1.2	82.5	33.7	8.4	7.2
307	21.2					
308	15.4					
309	13.1	1.3	76.3	36.0	7.4	2.9
310	20.5					
311	16.6					
312	14.2	1.2	76.0	39.0	7.7	2.5
313	20.7					
401	9.5	1.0	71.5	32.3	5.0	3.9
402	14.8					
403	23.3					
404	11.6					
405	15.4	1.0	82.9	27.4	5.3	6.2
406	9.4	0.9	72.3	27.2	6.1	6.6
407	10.5					
408	15.5	0.9	78.9	28.1	5.2	7.4
409	13.9					
410	8.3					
411	11.0					
412	10.9					
413	11.9					

V4 to V6 whole plants

Table C-9. V4 to V6 whole plant analysis for 2013 by site.

Atchison County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g $plant^{-1}$	%				mg kg^{-1}		
101	0.73	3.09	0.255	3.05	0.303	560.7	189.8	59.8
102	0.80	4.14	0.301	2.63				
103	0.80	4.00	0.300	2.53				
104	1.00	4.42	0.351	2.72				
105	0.80	4.00	0.270	2.44				
106	0.87	4.35	0.320	2.04	0.319	742.6	152.4	40.7
107	0.80	4.68	0.368	2.62	0.301	580.1	134.7	56.3
108	0.87	4.25	0.372	2.36				
109	1.00	4.34	0.337	2.25				
110	1.00	4.05	0.297	2.87				
111	0.93	3.74	0.275	2.34				
112	1.00	4.29	0.368	2.48				
113	0.87	4.44	0.308	2.72				
114	1.00	4.24	0.285	2.21	0.286	675.2	127.7	42.7
115	1.13	4.79	0.343	2.26				
201	0.87	4.48	0.285	2.01				
202	1.00	3.71	0.294	2.91				
203	0.87	4.19	0.343	2.10	0.313	663.1	202.4	36.4
204	0.93	4.55	0.288	2.31	0.299	623.7	132.8	40.7
205	1.13	4.64	0.344	2.42				
206	0.87	4.23	0.313	2.20				
207	0.87	4.51	0.322	2.36	0.313	622.6	154.7	41.9
208	0.87	4.70	0.345	2.35				
209	1.00	4.79	0.330	1.96	0.320	606.1	204.2	58.8
210	1.33	4.26	0.311	2.37				
211	0.87	4.70	0.343	2.59				
212	1.00	5.12	0.342	2.03				
213	1.13	3.92	0.297	2.46				
214	1.13	4.81	0.357	2.36				
215	0.93	3.25	0.245	2.36				

Atchison County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g $plant^{-1}$	%				mg kg^{-1}		
301	0.80	4.40	0.342	2.47				
302	1.00	4.12	0.304	2.15				
303	1.13	5.19	0.399	1.98				
304	0.80	4.49	0.326	2.14				
305	1.00	4.19	0.293	2.08				
306	0.80	4.98	0.345	1.94				
307	1.13	5.08	0.378	2.14				
308	1.00	4.48	0.297	2.16				
309	1.07	4.67	0.366	2.44	0.337	686.0	158.6	55.5
310	0.93	4.21	0.290	2.49				
311	1.20	4.16	0.302	2.02				
312	0.93	4.27	0.314	2.89	0.308	571.1	198.3	49.1
313	1.00	4.94	0.355	2.03				
314	0.80	4.85	0.318	2.14	0.313	669.4	178.2	41.9
315	0.80	4.97	0.311	2.15	0.320	766.1	187.8	42.8
401	0.80	4.48	0.304	2.27	0.292	683.4	156.4	42.8
402	0.93	4.70	0.352	2.03				
403	0.67	4.62	0.316	2.29				
404	0.87	4.44	0.322	2.23				
405	0.87	4.85	0.329	2.05	0.329	977.6	217.5	48.1
406	0.93	4.66	0.297	2.16	0.323	686.0	310.7	78.7
407	1.00	4.57	0.301	2.15				
408	0.93	5.40	0.349	1.95	0.356	959.6	220.5	45.9
409	0.73	4.40	0.243	2.37				
410	1.00	4.31	0.294	1.82				
411	0.93	5.07	0.348	2.22				
412	0.73	4.58	0.286	2.33				
413	0.87	4.31	0.330	2.18				
414	0.80	4.91	0.313	2.34				
415	1.07	4.03	0.289	2.43				

Lyon County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	1.73	3.99	0.377	1.18	0.302	1100.9	84.5	59.3
102	1.87	4.14	0.385	0.99				
103	2.20	4.37	0.364	1.12				
104	2.47	3.84	0.401	1.19				
105	1.93	4.34	0.418	1.05				
106	2.67	4.04	0.400	1.17	0.278	1304.9	77.7	56.3
107	1.93	3.94	0.401	1.28	0.253	1321.4	70.7	53.1
108	2.40	4.13	0.411	1.16	0.294	2361.5	121.5	47.2
109	1.80	4.39	0.449	1.06				
110	1.73	4.10	0.440	1.08				
111	2.33	4.20	0.433	1.13				
112	2.27	4.29	0.440	1.09				
113	1.67	4.56	0.444	1.07				
201	2.00	3.86	0.329	1.09				
202	1.93	4.05	0.363	0.94				
203	3.00	3.93	0.378	1.23	0.273	1978.0	97.2	50.2
204	2.53	4.09	0.384	1.07	0.261	1491.4	72.5	47.6
205	2.47	4.05	0.410	1.28				
206	2.20	4.14	0.366	1.31				
207	2.07	4.18	0.373	1.37	0.272	1229.2	65.8	59.6
208	1.93	4.16	0.377	1.07				
209	1.53	4.20	0.395	1.00	0.262	1273.6	76.1	64.3
210	2.53	4.16	0.414	1.18				
211	2.07	4.01	0.416	1.26				
212	2.93	4.27	0.411	1.27				
213	2.53	4.26	0.390	1.05				

Lyon County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g $plant^{-1}$	%				mg kg^{-1}		
301	1.80	4.19	0.350	1.17				
302	1.93	4.03	0.336	0.96				
303	2.40	3.89	0.367	1.25				
304	2.07	3.90	0.357	1.07	0.267	1565.7	89.0	57.5
305	2.13	4.10	0.379	1.13				
306	1.93	3.65	0.308	1.45	0.250	1074.0	50.8	60.4
307	2.13	4.16	0.371	1.27				
308	2.13	4.16	0.351	1.08				
309	1.67	4.36	0.388	1.04	0.289	1397.4	81.1	57.0
310	2.53	4.24	0.369	1.23				
311	1.40	4.34	0.413	1.07				
312	2.27	4.07	0.384	1.01	0.293	1455.8	90.8	54.7
313	2.00	4.20	0.402	1.05				
401	1.60	3.83	0.323	1.43	0.260	1173.7	67.0	66.1
402	1.87	3.63	0.338	1.12				
403	2.80	4.17	0.367	1.27				
404	2.33	4.21	0.350	1.35				
405	2.13	4.49	0.381	1.21	0.276	1699.2	70.3	48.1
406	2.27	3.79	0.349	1.50	0.265	1281.3	64.0	56.8
407	2.47	3.80	0.376	1.33				
408	2.00	4.11	0.331	1.03	0.273	1284.9	62.7	65.0
409	1.60	4.15	0.344	1.24				
410	2.80	3.81	0.365	1.48				
411	2.13	4.49	0.404	1.23				
412	2.33	4.04	0.355	1.17				
413	2.00	4.09	0.388	1.00				

Riley County - Manhattan - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	1.40	3.97	0.377	1.88	0.319	1532.1	112.6	64.6
102	1.47	3.82	0.355	1.72				
103	1.40	4.05	0.365	1.83				
104	1.60	3.47	0.388	2.09				
105	1.60	3.71	0.364	1.94				
106	1.33	3.72	0.364	2.13	0.300	1551.2	91.1	44.2
107	1.40	3.61	0.368	2.21	0.303	1188.8	74.3	53.2
108	1.13	3.89	0.366	1.94				
109	1.40	3.85	0.374	2.15				
110	1.33	4.05	0.390	1.89				
111	1.07	4.13	0.357	1.87				
112	1.40	3.79	0.389	2.37				
113	1.47	4.11	0.382	1.94				
114	1.20	3.84	0.366	2.31	0.308	1316.9	80.1	48.5
115	1.53	3.91	0.385	2.22				
201	1.20	3.88	0.388	2.19				
202	1.27	3.49	0.398	2.51				
203	1.47	4.09	0.407	2.05	0.307	985.5	69.3	43.0
204	1.53	3.92	0.396	2.18	0.299	1501.6	94.0	47.8
205	1.60	4.60	0.417	2.34				
206	1.27	4.13	0.387	2.19				
207	1.27	4.14	0.385	2.29	0.305	873.1	70.3	50.2
208	1.33	3.79	0.368	2.42				
209	1.53	4.09	0.369	1.90	0.331	1162.1	95.1	57.1
210	1.40	4.27	0.404	2.01				
211	1.27	3.80	0.363	2.46				
212	1.40	3.56	0.383	2.60				
213	1.53	4.27	0.407	2.18				
214	1.47	3.78	0.365	2.24				
215	1.53	3.81	0.378	2.30				

Riley County - Manhattan - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
301	1.13	3.92	0.370	2.22				
302	1.20	4.15	0.387	2.37				
303	1.40	4.07	0.385	2.08				
304	1.20	4.21	0.370	2.25				
305	1.47	3.90	0.379	2.29				
306	1.13	3.56	0.334	2.62				
307	1.80	3.92	0.426	2.49				
308	1.47	3.44	0.373	2.77				
309	1.53	3.60	0.368	2.41	0.325	1270.6	86.9	50.2
310	1.33	4.14	0.377	1.97				
311	1.40	3.89	0.380	1.83				
312	1.40	4.12	0.370	1.99	0.303	1387.1	95.4	39.6
313	1.40	3.55	0.366	2.32				
314	1.20	3.29	0.355	2.43	0.264	806.0	72.8	42.7
315	1.33	3.68	0.392	2.41	0.281	1044.9	86.5	40.3
401	1.47	3.31	0.319	2.22	0.244	2569.7	110.1	45.3
402	1.20	3.85	0.399	2.25				
403	1.13	4.05	0.362	2.09				
404	1.27	3.94	0.350	2.13				
405	1.47	4.00	0.365	2.04	0.290	1302.3	82.2	38.9
406	1.47	3.79	0.375	2.09	0.278	1022.8	93.7	47.1
407	1.67	3.58	0.380	2.32				
408	1.27	4.08	0.372	1.68	0.274	1171.1	81.8	38.8
409	1.20	3.90	0.345	1.73				
410	1.27	3.33	0.345	2.12				
411	1.47	3.83	0.373	2.12				
412	1.20	3.93	0.362	1.78				
413	1.47	4.26	0.363	1.67				
414	1.40	4.07	0.362	2.11				
415	1.40	4.08	0.389	1.80				

Douglas County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	1.33	3.10955	0.28783	2.15006	0.2615	158.576	60.3112	43.861
102	1.33	3.06095	0.27626	2.06274				
103	1.27	3.90388	0.30506	1.86557				
104	1.33	4.03748	0.32525	1.74065				
105	1.20	3.62527	0.30695	2.04961				
106	1.27	3.62322	0.29905	1.48562	0.27407	194.409	61.9974	45.4203
107	1.27	3.31824	0.31839	1.93452	0.26943	181.076	63.3594	47.0342
108	1.33	3.63947	0.31967	1.58831	0.27545	226.309	58.0316	48.1283
109	1.20	3.79949	0.31602	1.82943				
110	1.27	3.6395	0.3419	1.77738				
111	1.33	3.27207	0.3109	1.87626				
112	1.33	3.50062	0.32667	1.85418				
113	1.27	3.0855	0.2667	1.7302				
201	1.33	3.64159	0.29028	1.95768				
202	1.67	3.63573	0.34345	2.062				
203	1.20	4.08845	0.30272	1.74482	0.27832	225.346	69.9887	44.426
204	1.33	3.53467	0.32872	2.05378	0.27119	181.938	55.8296	44.8411
205	1.07	3.9489	0.32299	1.802				
206	1.20	4.3346	0.3285	1.69347				
207	1.27	3.45349	0.30372	1.66326	0.25678	170.448	51.5953	46.0601
208	1.27	3.92175	0.3513	1.44945				
209	1.07	3.51762	0.29398	1.69483	0.2847	185.748	82.5566	52.269
210	1.20	3.50643	0.31996	1.54366				
211	1.00	3.47415	0.31293	1.70718				
212	1.40	3.63785	0.29664	1.7406				
213	1.13	3.40859	0.28093	1.60657				

Douglas County - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g $plant^{-1}$	%				mg kg^{-1}		
301	1.33	3.74292	0.31156	2.13334				
302	1.27	3.537	0.29812	1.86999				
303	0.93	3.39523	0.29134	2.31383				
304	1.40	3.85152	0.33705	2.04846	0.25243	298.493	63.6457	42.4593
305	1.20	3.29435	0.30115	1.88703				
306	1.13	3.76403	0.30172	1.7297	0.2411	264.684	60.3954	45.1027
307	1.13	4.06385	0.32908	1.79311				
308	1.33	3.28745	0.29768	2.07051				
309	1.07	3.17754	0.27347	1.96981	0.22142	278.31	72.5926	42.3126
310	1.07	3.72237	0.3027	1.84244				
311	1.20	3.2556	0.2934	1.96754				
312	1.40	3.1551	0.282	2.28665	0.21654	309.57	66.8584	40.4834
313	1.07	3.48956	0.27364	1.93527				
401	1.33	2.85637	0.24563	2.27762	0.21847	175.299	51.9898	41.4737
402	1.13	3.47436	0.30222	2.23484				
403	0.93	3.94363	0.31909	1.9912				
404	1.40	3.40844	0.29594	2.35877				
405	1.20	3.18967	0.29841	2.3635	0.22826	244.753	60.0952	41.6811
406	1.27	3.70326	0.29664	1.83234	0.2384	378.061	80.5132	42.5059
407	1.33	3.26252	0.30236	2.29859				
408	1.27	3.28883	0.28577	2.0957	0.2197	287.729	77.5754	36.6205
409	1.07	3.63778	0.30359	2.15892				
410	1.00	3.15352	0.29915	2.37675				
411	1.33	3.65932	0.30845	1.97657				
412	1.20	3.23538	0.30296	2.19019				
413	1.07	3.72209	0.29909	1.90258				

Riley County - Randolph - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	0.93	4.16	0.398	2.79	0.306	349.5	171.3	79.3
102	0.73	3.95	0.378	2.56				
103	0.60	4.21	0.418	3.01				
104	1.00	3.77	0.425	3.45				
105	0.87	4.04	0.405	3.02				
106	0.87	4.47	0.433	3.05	0.320	389.1	128.0	72.4
107	0.53	4.35	0.396	3.05	0.281	297.1	105.3	59.7
108	0.67	4.46	0.395	2.88				
109	0.80	4.18	0.389	2.34				
110	0.93	4.10	0.400	2.65				
111	0.93	4.13	0.424	2.58				
112	0.87	3.69	0.404	2.91				
113	0.53	3.90	0.403	3.04				
114	0.87	3.81	0.391	3.00	0.324	351.2	119.0	57.5
201	0.80	4.19	0.406	3.14				
202	1.13	4.08	0.405	2.78				
203	0.80	3.96	0.403	2.92	0.283	393.9	117.5	58.8
204	0.93	4.02	0.413	3.20	0.298	256.4	144.8	45.1
205	1.00	4.04	0.421	2.76				
206	0.73	4.15	0.421	2.89				
207	0.73	3.61	0.423	3.02	0.269	268.3	113.0	49.4
208	0.87	4.23	0.393	2.74				
209	0.87	3.63	0.352	3.04	0.306	320.8	117.1	65.3
210	0.87	4.01	0.371	2.61				
211	0.73	4.29	0.419	3.28				
212	0.87	4.15	0.405	2.74				
213	0.93	4.32	0.395	2.70				
214	0.80	4.17	0.384	2.56				

Riley County - Randolph - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
301	0.87	3.95	0.399	2.64				
302	0.73	4.17	0.419	2.49				
303	0.93	3.71	0.368	2.44				
304	0.87	3.76	0.399	2.69	0.295	287.0	108.9	52.3
305	1.00	3.89	0.361	2.28				
306	0.80	4.05	0.377	2.61				
307	1.20	3.68	0.339	2.19				
308	0.80	4.37	0.382	2.55				
309	0.93	3.30	0.350	2.34	0.311	516.5	147.8	71.5
310	0.80	4.09	0.368	2.48				
311	0.73	4.24	0.387	2.39				
312	0.60	4.12	0.343	2.43	0.300	369.7	104.9	55.0
313	1.00	4.40	0.357	2.19				
314	0.93	3.88	0.343	2.53	0.308	382.6	93.2	53.0
401	0.67	4.33	0.393	2.42	0.265	448.4	115.1	67.6
402	1.00	3.90	0.364	2.30				
403	0.87	3.87	0.364	2.16				
404	0.67	4.02	0.384	2.50				
405	0.67	4.12	0.404	2.30	0.272	516.0	127.6	63.7
406	0.73	4.46	0.418	2.69	0.312	357.2	126.9	84.2
407	0.87	4.53	0.422	2.70				
408	1.00	4.01	0.369	2.06	0.283	388.6	116.9	57.1
409	0.73	3.91	0.389	2.39				
410	0.87	3.03	0.349	2.26				
411	0.87	3.37	0.374	2.34				
412	0.67	3.37	0.410	2.32				
413	0.67	3.79	0.403	2.31				
414	0.67	3.94	0.417	2.94				

Woodson County - lowland - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	1.33	3.86	0.395	1.81	0.289	166.0	66.9	54.1
102	1.27	3.81	0.372	1.52				
103	1.07	3.86	0.394	1.38				
104	1.20	3.97	0.389	1.42				
105	1.27	3.90	0.379	1.53				
106	1.33	4.28	0.394	1.38	0.313	425.2	80.7	66.4
107	1.13	3.95	0.390	1.62	0.296	184.2	63.3	54.9
108	1.13	4.01	0.392	1.60	0.296	223.5	68.9	52.4
109	1.13	3.73	0.403	1.76				
110	0.93	3.84	0.404	1.63				
111	0.93	3.95	0.399	1.48				
112	1.00	4.18	0.401	1.31				
113	1.00	4.21	0.411	1.56				
201	1.20	3.76	0.393	1.66				
202	1.20	3.80	0.409	1.39				
203	1.33	3.59	0.356	1.62	0.279	155.7	60.3	50.7
204	1.07	3.92	0.385	1.60	0.303	206.2	105.0	60.9
205	1.27	3.75	0.361	1.65				
206	1.13	3.87	0.378	1.49				
207	1.07	3.71	0.354	1.43	0.295	224.9	63.1	56.3
208	1.07	3.95	0.396	1.25				
209	1.00	3.55	0.360	1.35	0.299	182.6	60.3	66.5
210	1.07	3.72	0.360	1.37				
211	1.07	3.95	0.396	1.29				
212	0.93	3.95	0.372	1.20				
213	1.07	3.98	0.384	1.57				

Woodson County - lowland - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g $plant^{-1}$	%				mg kg^{-1}		
301	1.33	3.95	0.409	1.90				
302	1.07	3.88	0.397	1.79				
303	1.07	3.96	0.401	1.34				
304	1.00	4.32	0.420	1.18	0.316	278.9	81.6	63.6
305	1.20	3.74	0.378	1.13				
306	0.93	4.16	0.393	1.18	0.302	218.8	68.7	54.4
307	1.07	3.85	0.361	1.21				
308	0.87	3.87	0.368	1.03				
309	1.07	3.68	0.348	1.29	0.292	238.5	65.1	72.8
310	1.07	3.79	0.362	1.44				
311	1.13	3.83	0.371	1.45				
312	0.93	3.85	0.387	1.40	0.301	169.7	47.0	54.5
313	0.93	4.05	0.379	1.48				
401	1.20	3.89	0.409	1.40	0.289	214.8	65.0	47.5
402	0.93	4.04	0.436	1.28				
403	0.93	4.04	0.388	1.31				
404	1.13	3.95	0.385	1.33				
405	1.07	3.65	0.355	1.19	0.290	229.7	63.6	52.0
406	1.07	3.59	0.341	1.33	0.284	234.8	71.9	54.9
407	1.07	3.79	0.352	1.39				
408	1.13	3.74	0.366	1.47	0.272	193.8	52.4	47.5
409	0.93	3.87	0.373	1.57				
410	1.20	4.13	0.393	1.73				
411	0.93	4.33	0.411	1.68				
412	0.80	4.13	0.407	1.33				
413	1.07	4.44	0.405	1.22				

Woodson County - upland - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
101	1.13	4.59	0.486	1.02	0.290	414.1	68.0	79.7
102	1.33	4.83	0.486	0.91				
103	1.40	4.32	0.506	0.95				
104	1.33	4.80	0.432	0.95				
105	1.27	4.85	0.469	0.85				
106	1.40	4.24	0.417	0.93	0.274	373.6	54.3	54.1
107	1.40	4.55	0.437	0.94	0.306	527.8	66.2	62.4
108	1.27	4.35	0.417	1.03	0.363	308.1	55.2	52.3
109	1.20	3.88	0.454	1.35				
110	1.33	4.11	0.503	0.98				
111	1.40	4.31	0.436	0.90				
112	1.27	4.37	0.440	0.88				
113	1.20	4.08	0.446	0.97				
201	1.00	4.63	0.473	0.74				
202	1.40	4.24	0.425	0.85				
203	1.20	4.54	0.460	1.16	0.338	312.3	53.7	56.0
204	1.13	4.36	0.411	0.75	0.321	413.7	58.4	60.2
205	1.13	4.59	0.448	0.84				
206	1.40	4.57	0.442	0.88				
207	1.33	4.14	0.402	0.79	0.343	333.6	56.4	57.4
208	1.33	4.60	0.444	1.03				
209	1.47	4.14	0.417	0.95	0.314	332.2	59.7	63.1
210	1.33	4.08	0.428	1.05				
211	1.27	4.33	0.435	0.77				
212	1.27	4.13	0.427	0.87				
213	1.20	4.68	0.425	0.76				

Woodson County - upland - V4 to V6 whole plant analysis								
plot	weight	N	P	K	S04-S	Fe	Mn	Zn
	g plant^{-1}	%				mg kg^{-1}		
301	1.13	4.53	0.475	0.90				
302	1.20	3.97	0.476	1.15				
303	1.47	4.72	0.527	1.21				
304	1.13	4.04	0.436	1.32	0.326	296.0	64.6	60.0
305	1.07	4.35	0.479	1.00				
306	1.27	4.44	0.429	0.83	0.261	295.1	50.9	55.0
307	1.33	4.40	0.438	0.88				
308	1.20	4.64	0.480	0.85				
309	1.27	4.19	0.445	0.95	0.331	414.1	71.4	71.2
310	1.20	4.34	0.488	1.04				
311	1.13	4.26	0.446	0.84				
312	1.13	4.32	0.450	0.85	0.306	313.6	52.2	53.0
313	1.13	4.01	0.441	0.89				
401	1.13	4.08	0.452	0.95	0.303	174.6	49.0	51.9
402	1.07	4.23	0.481	1.20				
403	1.13	4.43	0.487	1.15				
404	1.13	4.61	0.465	1.09				
405	1.13	4.14	0.474	1.08	0.307	310.0	54.6	51.8
406	1.00	4.64	0.480	0.90	0.329	457.3	93.6	75.1
407	1.13	4.52	0.448	0.80				
408	1.13	4.59	0.421	0.76	0.332	393.2	73.7	63.8
409	1.13	4.42	0.468	0.80				
410	1.07	4.70	0.529	0.99				
411	1.13	4.70	0.449	0.83				
412	1.13	4.13	0.476	0.85				
413	1.07	4.28	0.486	0.74				

R4 Trifoliates

Table C-10. Trifoliate analysis at R4 for 2013 by site.

Atchison County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.40	5.05	0.258	1.15
102	0.33	4.85	0.248	1.19
103	0.33	4.63	0.243	1.17
104	0.47	5.17	0.270	1.24
105	0.33	4.93	0.252	1.25
106	0.40	4.68	0.245	1.20
107	0.40	4.98	0.267	1.25
108	0.40	4.79	0.231	1.11
109	0.40	4.71	0.237	1.15
110	0.47	5.23	0.270	1.36
111	0.40	4.71	0.225	1.16
112	0.53	4.89	0.247	1.28
113	0.53	5.03	0.257	1.31
114	0.53	4.98	0.267	1.22
115	0.47	4.68	0.247	1.25
201	0.33	5.17	0.265	1.24
202	0.47	5.02	0.273	1.33
203	0.40	5.01	0.251	1.06
204	0.40	4.99	0.241	1.17
205	0.47	5.02	0.268	1.34
206	0.33	4.53	0.228	1.07
207	0.33	5.02	0.235	1.11
208	0.40	4.86	0.223	1.17
209	0.40	5.12	0.239	1.04
210	0.47	4.89	0.245	1.16
211	0.47	4.86	0.245	1.22
212	0.47	4.76	0.228	1.05
213	0.40	4.88	0.257	1.06
214	0.47	5.10	0.270	1.39
215	0.47	4.96	0.270	1.17

Atchison County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.33	4.96	0.248	1.05
302	0.40	5.24	0.261	1.08
303	0.40	5.11	0.264	1.09
304	0.40	4.94	0.250	1.14
305	0.47	4.85	0.238	1.04
306	0.47	5.00	0.234	1.10
307	0.40	5.13	0.268	1.09
308	0.33	5.05	0.262	1.08
309	0.40	5.28	0.265	1.05
310	0.40	4.98	0.232	1.03
311	0.40	4.84	0.242	1.04
312	0.47	5.00	0.237	0.97
313	0.33	5.06	0.255	1.03
314	0.33	5.00	0.243	1.17
315	0.47	5.03	0.230	1.00
401	0.40	5.09	0.241	1.19
402	0.47	4.92	0.273	1.18
403	0.40	4.90	0.249	1.22
404	0.40	4.88	0.249	1.22
405	0.47	5.16	0.275	1.16
406	0.27	4.93	0.269	1.17
407	0.40	4.89	0.230	0.98
408	0.33	5.26	0.265	1.00
409	0.33	4.90	0.220	0.98
410	0.40	4.77	0.230	1.04
411	0.40	5.05	0.238	0.93
412	0.33	4.93	0.249	1.12
413	0.33	4.98	0.241	1.02
414	0.40	5.04	0.229	1.04
415	0.40	5.06	0.247	0.97

Lyon County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.40	5.14	0.397	0.83
102	0.40	5.50	0.396	0.70
103	0.53	5.39	0.374	1.00
104	0.53	5.24	0.466	0.90
105	0.40	5.27	0.414	0.94
106	0.40	5.41	0.446	0.88
107	0.53	5.52	0.395	1.02
108	0.60	5.51	0.482	1.00
109	0.47	5.41	0.501	1.08
110	0.33	5.43	0.529	0.87
111	0.33	5.17	0.506	0.92
112	0.40	5.07	0.534	0.94
113	0.40	5.23	0.466	1.24
201	0.33	5.43	0.396	0.89
202	0.27	5.36	0.509	0.69
203	0.33	5.57	0.401	0.83
204	0.40	5.31	0.473	1.17
205	0.40	5.52	0.470	1.08
206	0.33	5.29	0.356	1.12
207	0.33	5.27	0.361	0.96
208	0.33	5.13	0.393	0.82
209	0.33	5.22	0.477	1.00
210	0.33	5.38	0.582	1.02
211	0.40	5.44	0.482	1.17
212	0.33	5.16	0.495	1.07
213	0.40	5.31	0.534	0.96

Lyon County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.40	5.07	0.288	0.90
302	0.40	5.21	0.330	0.78
303	0.40	5.48	0.354	0.70
304	0.40	5.23	0.371	0.98
305	0.40	5.11	0.420	1.03
306	0.40	5.13	0.277	1.08
307	0.40	5.15	0.399	1.02
308	0.47	5.13	0.370	0.97
309	0.47	4.90	0.347	1.00
310	0.40	5.10	0.331	1.13
311	0.53	5.41	0.443	1.13
312	0.47	5.36	0.449	1.10
313	0.47	5.11	0.399	1.09
401	0.33	4.88	0.268	0.82
402	0.33	5.11	0.471	0.90
403	0.40	5.01	0.417	0.98
404	0.40	5.11	0.307	1.06
405	0.33	5.04	0.341	1.06
406	0.40	5.12	0.298	1.06
407	0.40	5.28	0.425	1.12
408	0.40	4.82	0.326	0.98
409	0.40	4.95	0.307	1.26
410	0.40	5.31	0.334	1.13
411	0.47	5.26	0.414	1.15
412	0.40	5.45	0.376	1.21
413	0.47	5.26	0.484	1.11

Riley County - Manhattan- trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.80	4.95	0.319	1.27
102	0.73	5.11	0.316	1.24
103	0.73	5.43	0.345	1.37
104	0.73	5.48	0.365	1.28
105	0.73	5.27	0.340	1.39
106	0.73	5.25	0.343	1.45
107	0.67	5.47	0.317	1.23
108	0.67	5.31	0.309	1.29
109	0.73	4.71	0.324	1.57
110	0.67	5.47	0.356	1.37
111	0.67	5.20	0.319	1.37
112	0.73	5.23	0.367	1.64
113	0.73	5.30	0.358	1.61
114	0.73	5.18	0.313	1.50
115	0.73	5.37	0.336	1.55
201	0.67	5.69	0.389	1.69
202	0.80	5.16	0.350	1.75
203	0.80	5.25	0.331	1.48
204	0.73	5.19	0.349	1.42
205	0.80	5.34	0.320	1.33
206	0.73	5.26	0.319	1.60
207	0.67	5.30	0.312	1.46
208	0.67	5.16	0.287	1.47
209	0.67	5.17	0.334	1.61
210	0.73	5.34	0.326	1.45
211	0.67	5.09	0.300	1.57
212	0.60	5.15	0.316	1.55
213	0.67	5.21	0.342	1.54
214	0.67	4.77	0.301	1.48
215	0.67	5.05	0.295	1.44

Riley County - Manhattan- trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.80	5.35	0.302	1.54
302	0.80	5.49	0.331	1.53
303	0.73	5.50	0.365	1.62
304	0.67	5.31	0.292	1.51
305	0.67	5.05	0.310	1.55
306	0.60	5.50	0.319	1.61
307	0.73	5.16	0.313	1.50
308	0.67	5.11	0.331	1.73
309	0.67	5.08	0.304	1.45
310	0.73	5.04	0.287	1.45
311	0.60	5.13	0.316	1.33
312	0.67	5.28	0.311	1.35
313	0.67	5.18	0.321	1.48
314	0.67	5.14	0.324	1.54
315	0.67	4.92	0.311	1.51
401	0.73	5.05	0.289	1.69
402	0.47	5.08	0.350	1.61
403	0.67	5.22	0.320	1.50
404	0.73	5.17	0.313	1.58
405	0.67	4.97	0.323	1.64
406	0.67	5.09	0.314	1.44
407	0.60	4.98	0.323	1.58
408	0.67	5.14	0.290	1.30
409	0.60	5.37	0.297	1.33
410	0.67	5.01	0.301	1.43
411	0.67	5.47	0.329	1.28
412	0.60	5.39	0.350	1.33
413	0.67	5.22	0.318	1.40
414	0.67	5.21	0.302	1.45
415	0.73	5.48	0.341	1.39

Douglas County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.73	5.32	0.45	2.44
102	0.67	5.79	0.44	2.34
103	0.73	5.76	0.44	2.34
104	0.73	5.89	0.49	2.56
105	0.73	5.80	0.42	2.22
106	0.67	5.78	0.46	2.33
107	0.73	5.74	0.43	2.40
108	0.67	5.77	0.47	2.46
109	0.67	5.70	0.46	2.32
110	0.80	5.65	0.46	2.27
111	0.67	5.59	0.48	2.42
112	0.73	5.82	0.49	2.45
113	0.60	5.66	0.42	2.41
201	0.67	5.57	0.45	2.43
202	0.73	5.61	0.45	2.17
203	0.73	5.69	0.47	2.36
204	0.67	5.53	0.45	2.36
205	0.67	5.28	0.44	2.42
206	0.60	5.31	0.40	2.50
207	0.67	5.60	0.42	2.42
208	0.67	5.59	0.44	2.29
209	0.67	5.37	0.44	2.38
210	0.73	5.64	0.48	2.38
211	0.67	5.01	0.42	2.23
212	0.73	5.66	0.44	2.30
213	0.60	5.71	0.48	2.29

Douglas County - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.73	5.35	0.41	2.30
302	0.67	5.55	0.46	2.46
303	0.67	5.82	0.48	2.43
304	0.80	5.41	0.43	2.23
305	0.80	5.43	0.45	2.44
306	0.67	5.01	0.37	2.59
307	0.73	5.49	0.45	2.34
308	0.67	5.48	0.46	2.34
309	0.67	5.65	0.44	2.34
310	0.67	5.48	0.43	2.45
311	0.67	5.77	0.47	2.32
312	0.67	5.68	0.45	2.49
313	0.67	5.58	0.43	2.32
401	0.60	5.65	0.45	2.67
402	0.67	5.02	0.46	2.60
403	0.73	5.36	0.46	2.57
404	0.73	5.56	0.43	2.38
405	0.60	5.49	0.47	2.45
406	0.67	5.61	0.46	2.39
407	0.67	5.74	0.48	2.51
408	0.67	5.70	0.48	2.53
409	0.67	5.40	0.44	2.64
410	0.67	5.75	0.43	2.40
411	0.67	5.48	0.48	2.53
412	0.67	5.10	0.42	2.75
413	0.67	5.43	0.45	2.59

Riley County - Randolph - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.73	4.95	0.340	1.46
102	0.60	5.48	0.331	1.39
103	0.60	5.38	0.335	1.78
104	0.60	5.32	0.363	1.94
105	0.53	5.50	0.378	2.00
106	0.60	5.17	0.329	1.92
107	0.53	5.37	0.339	1.83
108	0.60	5.83	0.333	1.59
109	0.60	5.55	0.318	1.42
110	0.60	5.38	0.321	1.79
111	0.60	5.15	0.324	1.62
112	0.53	5.18	0.312	1.59
113	0.53	5.58	0.341	2.00
114	0.53	5.08	0.329	1.70
201	0.47	5.56	0.362	2.09
202	0.47	5.25	0.347	1.94
203	0.53	5.45	0.330	1.94
204	0.53	5.05	0.336	1.97
205	0.47	5.25	0.364	1.77
206	0.53	5.37	0.329	1.89
207	0.47	5.35	0.339	1.81
208	0.53	5.55	0.330	2.00
209	0.40	5.22	0.330	2.12
210	0.60	5.37	0.334	2.09
211	0.47	5.30	0.310	2.19
212	0.47	5.03	0.306	1.92
213	0.53	5.54	0.356	2.08
214	0.47	5.24	0.302	1.92

Riley County - Randolph - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.40	5.29	0.299	1.60
302	0.40	5.19	0.294	1.63
303	0.40	5.19	0.275	1.63
304	0.40	4.97	0.259	1.48
305	0.53	4.99	0.276	1.61
306	0.47	4.99	0.228	1.47
307	0.47	5.68	0.260	1.41
308	0.40	5.45	0.274	1.57
309	0.40	5.53	0.266	1.49
310	0.47	5.24	0.254	1.56
311	0.40	5.31	0.264	1.54
312	0.40	5.56	0.282	1.52
313	0.47	5.51	0.279	1.80
314	0.40	5.29	0.263	1.70
401	0.47	5.58	0.270	1.60
402	0.53	5.19	0.257	1.27
403	0.53	5.24	0.255	1.36
404	0.53	5.07	0.254	1.53
405	0.60	5.43	0.302	1.53
406	0.53	5.51	0.320	1.58
407	0.60	5.49	0.366	2.05
408	0.47	5.61	0.304	1.80
409	0.47	4.72	0.254	1.80
410	0.47	5.45	0.282	1.60
411	0.47	5.30	0.303	1.78
412	0.47	5.53	0.293	1.59
413	0.47	5.77	0.339	2.00
414	0.60	5.14	0.346	2.10

Woodson County - lowland - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.47	6.39	0.426	1.91
102	0.47	6.35	0.427	1.79
103	0.40	6.64	0.460	1.91
104	0.53	6.43	0.469	1.95
105	0.47	6.22	0.439	1.84
106	0.47	6.16	0.456	1.82
107	0.40	6.17	0.449	1.96
108	0.53	6.09	0.426	2.02
109	0.47	6.67	0.443	1.78
110	0.53	6.31	0.448	1.97
111	0.53	6.26	0.442	1.83
112	0.47	6.63	0.459	1.88
113	0.47	5.71	0.411	1.85
201	0.47	5.93	0.459	1.80
202	0.47	6.48	0.490	1.83
203	0.40	6.30	0.444	1.78
204	0.53	6.60	0.445	1.94
205	0.47	6.70	0.496	1.86
206	0.47	6.10	0.419	1.76
207	0.53	6.20	0.423	1.80
208	0.53	5.90	0.416	1.87
209	0.47	6.22	0.424	1.86
210	0.47	6.90	0.483	1.97
211	0.53	6.07	0.407	1.88
212	0.47	6.01	0.399	1.80
213	0.40	6.31	0.443	1.96

Woodson County - lowland - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.60	5.79	0.397	1.77
302	0.53	6.45	0.437	1.70
303	0.67	6.38	0.439	1.77
304	0.73	6.19	0.404	1.84
305	0.73	6.06	0.413	1.64
306	0.60	5.96	0.372	1.85
307	0.67	6.43	0.418	1.61
308	0.67	6.08	0.384	1.76
309	0.67	6.31	0.372	1.69
310	0.60	6.14	0.361	1.66
311	0.67	5.82	0.371	1.74
312	0.67	6.64	0.403	1.97
313	0.53	6.50	0.435	2.02
401	0.53	6.08	0.427	1.80
402	0.67	6.12	0.433	1.46
403	0.47	6.22	0.463	1.87
404	0.67	6.48	0.403	1.69
405	0.47	6.98	0.469	1.73
406	0.47	6.67	0.438	1.71
407	0.47	6.33	0.437	1.69
408	0.60	6.35	0.413	1.77
409	0.60	6.13	0.391	1.88
410	0.60	6.02	0.405	2.00
411	0.60	6.80	0.445	1.95
412	0.60	6.25	0.412	1.91
413	0.60	6.29	0.394	1.77

Woodson County - upland - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
101	0.53	5.73	0.401	1.67
102	0.47	6.19	0.404	1.95
103	0.40	5.26	0.370	1.70
104	0.53	5.93	0.387	1.65
105	0.53	6.47	0.383	1.78
106	0.53	6.05	0.372	1.68
107	0.53	5.95	0.337	1.62
108	0.53	5.87	0.375	1.66
109	0.47	5.76	0.376	1.81
110	0.53	5.66	0.382	1.81
111	0.53	5.74	0.387	1.78
112	0.53	6.03	0.399	1.94
113	0.47	6.19	0.396	1.89
201	0.47	5.78	0.403	1.79
202	0.40	6.08	0.411	1.84
203	0.40	5.80	0.435	1.83
204	0.47	6.27	0.415	1.85
205	0.47	6.41	0.440	1.84
206	0.40	6.26	0.429	1.96
207	0.47	6.26	0.382	1.70
208	0.47	5.97	0.401	1.85
209	0.47	6.32	0.434	2.01
210	0.47	6.32	0.429	1.80
211	0.47	6.20	0.413	1.84
212	0.47	6.69	0.441	1.84
213	0.53	6.40	0.400	1.88

Woodson County - upland - trifoliate results				
plot	weight	N	P	K
	g trifoliate^{-1}	%		
301	0.60	6.19	0.354	1.65
302	0.60	5.60	0.345	1.62
303	0.60	5.31	0.388	1.65
304	0.60	5.96	0.370	1.76
305	0.60	5.81	0.381	1.69
306	0.67	5.79	0.340	1.68
307	0.60	6.37	0.387	1.60
308	0.60	6.28	0.385	1.80
309	0.53	5.91	0.372	1.84
310	0.60	5.72	0.370	1.82
311	0.60	6.44	0.394	1.74
312	0.53	6.07	0.396	1.93
313	0.60	5.77	0.359	1.82
401	0.53	6.33	0.368	1.93
402	0.53	5.76	0.398	1.76
403	0.60	5.87	0.398	1.84
404	0.53	5.96	0.364	1.65
405	0.60	6.11	0.386	1.59
406	0.60	5.67	0.384	1.91
407	0.60	6.00	0.387	1.76
408	0.53	6.06	0.377	1.71
409	0.53	6.11	0.371	1.95
410	0.67	5.63	0.359	1.62
411	0.67	5.71	0.368	1.58
412	0.60	5.76	0.377	1.87
413	0.53	5.95	0.380	1.76

Grain yield and analysis

Table C-11. Grain and yield analysis for 2013 by site.

Atchison County - grain yield and analysis										
plot	moisture	test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	11.0	55.3	3.05	6.25	0.45	1.84	0.29	69.08	50.43	47.15
102	10.5	55.9	2.68	6.50	0.39	1.70				
103	10.5	55.8	3.58	6.50	0.42	1.82				
104	11.0	55.8	3.88	6.38	0.47	1.80				
105	10.5	55.5	3.31	6.68	0.41	1.82				
106	10.7	55.7	3.58	6.60	0.44	1.87	0.27	71.88	34.71	38.72
107	10.8	56.4	3.64	6.55	0.39	1.80	0.28	69.42	31.39	39.85
108	10.7	55.9	2.61	6.33	0.34	1.72				
109	10.7	55.3	3.56	6.54	0.44	1.80				
110	11.2	55.8	3.68	6.33	0.46	1.82				
111	10.9	55.5	3.35	6.41	0.39	1.76				
112	10.7	55.5	3.96	6.65	0.46	1.79				
113	10.9	55.3	3.47	6.64	0.43	1.79				
114	10.6	55.3	3.78	6.43	0.45	1.80	0.29	76.20	37.37	43.01
115	10.7	55.6	4.05	6.59	0.46	1.78				
201	10.4	54.9	1.18	6.64	0.41	1.79				
202	10.6	55.5	3.52	6.29	0.46	1.82				
203	10.4	55.3	2.28	6.47	0.45	1.85	0.27	74.57	37.30	34.93
204	10.5	55.3	3.30	6.59	0.40	1.76	0.28	71.49	37.25	35.95
205	10.5	55.8	3.48	6.47	0.44	1.84				
206	10.3	55.8	2.32	6.24	0.39	1.73				
207	10.8	55.8	2.77	6.68	0.32	1.68	0.26	64.46	34.16	37.49
208	10.7	55.1	2.95	6.61	0.40	1.84				
209	10.4	55.5	3.33	6.60	0.43	1.78	0.27	66.49	38.68	43.52
210	10.9	55.5	4.03	6.42	0.46	1.75				
211	10.8	54.9	3.07	6.66	0.40	1.85				
212	10.5	55.8	3.18	6.45	0.43	1.90				
213	10.6	55.3	3.46	6.56	0.44	1.79				
214	10.6	55.3	3.52	6.56	0.44	1.81				
215	10.3	55.4	2.40	6.65	0.42	1.76				

Atchison County - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	10.6	55.5	3.63	6.48	0.40	1.72				
302	10.4	56.0	3.63	6.45	0.39	1.67				
303	10.4	54.9	3.80	6.32	0.46	1.74				
304	10.4	55.4	3.04	6.29	0.38	1.64				
305	10.3	56.0	3.78	6.28	0.41	1.66				
306	10.4	56.2	3.23	6.55	0.39	1.71				
307	10.5	54.8	3.62	6.43	0.44	1.61				
308	10.5	55.4	3.48	6.59	0.42	1.76				
309	10.5	55.3	3.07	6.47	0.42	1.75	0.28	66.98	36.31	45.95
310	10.4	55.4	2.96	6.59	0.38	1.73				
311	10.4	55.4	3.46	6.35	0.40	1.69				
312	10.3	55.6	3.46	6.64	0.44	1.79	0.29	68.29	38.96	39.51
313	10.5	55.5	3.35	6.52	0.40	1.70				
314	10.5	55.1	3.17	6.52	0.35	1.64	0.26	68.12	38.39	34.55
315	10.4	55.4	3.29	6.27	0.40	1.69	0.26	73.45	33.97	37.50
401	10.4	55.6	3.39	6.57	0.38	1.73	0.27	65.87	39.01	43.53
402	10.5	55.5	4.12	6.56	0.46	1.71				
403	10.6	55.7	2.93	6.61	0.37	1.66				
404	10.4	55.2	3.16	6.74	0.39	1.71				
405	10.5	55.3	3.53	6.72	0.45	1.77	0.30	70.97	45.47	40.31
406	10.4	55.2	2.89	6.26	0.42	1.74	0.28	71.58	40.00	47.18
407	10.5	55.4	3.40	6.63	0.47	1.82				
408	10.3	55.3	3.04	6.62	0.45	1.71	0.30	67.36	51.31	41.55
409	10.4	55.3	2.92	6.74	0.38	1.61				
410	10.3	55.7	3.47	6.92	0.42	1.80				
411	10.4	55.2	3.52	6.79	0.43	1.71				
412	10.4	55.4	2.91	6.82	0.40	1.67				
413	10.4	55.4	3.68	6.78	0.43	1.74				
414	10.3	55.1	3.22	6.95	0.40	1.70				
415	10.5	55.2	3.44	6.75	0.45	1.72				

Riley County -Manhattan - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	10.6	55.6	3.16	6.00	0.53	1.76	0.34	81.67	41.27	43.07
102	10.3	55.7	3.51	6.34	0.50	1.73				
103	10.7	55.8	3.23	6.24	0.50	1.72				
104	10.6	55.6	3.40	6.30	0.59	1.75				
105	10.2	56.1	4.09	6.28	0.56	1.78				
106	10.6	55.9	3.66	6.28	0.56	1.80	0.34	77.41	40.79	38.38
107	10.8	55.4	3.88	6.11	0.49	1.73	0.32	88.48	37.66	38.06
108	10.7	55.0	3.73	6.25	0.48	1.72				
109	11.0	55.6	3.67	6.32	0.55	1.81				
110	10.5	55.0	3.46	6.33	0.58	1.82				
111	11.3	55.7	2.60	6.09	0.50	1.73				
112	10.8	56.1	3.66	6.73	0.59	1.90				
113	10.4	55.7	3.52	6.65	0.62	1.89				
114	10.1	56.0	3.21	6.48	0.57	1.87	0.32	82.44	43.18	39.44
115	10.2	55.1	3.52	6.12	0.56	1.82				
201	11.4	55.2	3.71	6.20	0.51	1.75				
202	12.8	54.7	3.62	6.40	0.58	1.88				
203	11.6	55.6	3.53	6.25	0.50	1.75	0.32	84.99	37.03	33.73
204	11.0	55.6	4.25	6.34	0.56	1.87	0.32	80.80	38.26	34.82
205	11.7	55.8	4.19	6.11	0.57	1.81				
206	11.5	55.0	4.22	6.14	0.47	1.74				
207	11.3	55.6	3.97	6.33	0.50	1.86	0.29	87.17	38.17	34.91
208	10.8	55.8	3.85	6.02	0.49	1.70				
209	10.4	55.9	3.72	6.39	0.55	1.89	0.33	79.61	39.94	41.79
210	10.4	55.5	3.91	6.54	0.60	1.90				
211	10.7	55.6	3.80	6.70	0.50	1.85				
212	10.2	55.4	3.58	6.41	0.53	1.84				
213	10.0	55.4	3.54	6.57	0.64	1.99				
214	9.8	56.2	3.67	6.41	0.55	1.84				
215	9.9	56.3	3.31	6.43	0.50	1.80				

Riley County -Manhattan - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	11.4	55.3	3.73	6.08	0.47	1.76				
302	10.6	55.2	3.56	5.86	0.51	1.78				
303	10.6	55.9	3.76	6.13	0.57	1.86				
304	11.5	55.6	3.53	6.12	0.46	1.76				
305	9.9	56.2	3.79	5.99	0.52	1.73				
306	9.7	55.5	3.61	6.11	0.42	1.64				
307	9.6	56.1	3.84	6.08	0.53	1.79				
308	9.8	55.7	3.56	6.15	0.52	1.79				
309	9.5	55.4	3.39	6.44	0.50	1.80	0.33	90.93	43.48	38.26
310	9.9	55.7	3.46	6.35	0.46	1.72				
311	9.5	55.8	3.13	6.29	0.54	1.74				
312	9.7	55.8	3.44	6.48	0.54	1.76	0.33	85.21	43.01	34.28
313	10.7	54.9	3.97	6.16	0.51	1.80				
314	9.5	56.0	3.14	6.19	0.47	1.66	0.31	83.21	43.96	32.88
315	9.8	55.7	3.57	6.27	0.53	1.67	0.31	84.52	38.20	35.20
401	11.6	55.6	3.44	6.10	0.47	1.71	0.31	107.53	35.74	33.88
402	10.5	55.5	4.06	6.03	0.51	1.71				
403	9.5	55.8	2.84	6.18	0.52	1.77				
404	9.8	55.8	3.55	6.28	0.50	1.70				
405	9.6	56.2	3.44	6.41	0.53	1.74	0.32	87.22	36.19	37.05
406	9.4	56.4	3.13	6.59	0.48	1.71	0.31	78.86	41.39	44.30
407	9.6	56.2	3.33	6.07	0.52	1.69				
408	9.5	56.1	3.52	6.16	0.50	1.69	0.29	83.51	39.43	35.13
409	9.2	55.4	3.18	5.96	0.42	1.62				
410	9.9	55.8	3.38	6.19	0.47	1.68				
411	9.5	55.9	3.30	6.26	0.52	1.65				
412	9.3	55.7	2.94	6.47	0.55	1.69				
413	9.9	55.4	3.23	6.59	0.52	1.78				
414	9.4	56.3	3.24	6.70	0.51	1.74				
415	9.4	55.9	2.99	6.43	0.55	1.73				

Lyon County - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	9.6	55.0	0.97	5.70	0.50	1.51	0.27	72.22	31.42	57.07
102	9.5	54.9	1.05	6.31	0.50	1.50				
103	9.5	55.2	0.93	6.13	0.48	1.62				
104	9.4	55.1	1.19	5.72	0.52	1.49				
105	9.4	54.4	1.15	6.11	0.52	1.55				
106	9.3	55.7	1.35	5.82	0.52	1.55	0.26	84.78	29.71	50.31
107	9.3	54.9	1.42	6.17	0.48	1.57	0.26	91.85	30.84	54.07
108	9.2	54.9	1.99	5.88	0.53	1.54	0.25	86.73	30.44	57.07
109	9.3	54.0	1.69	5.89	0.53	1.50				
110	9.4	55.1	1.34	6.12	0.54	1.52				
111	9.4	55.1	1.07	6.11	0.52	1.53				
112	9.4	55.0	1.30	6.09	0.56	1.61				
113	9.4	55.0	1.00	6.01	0.45	1.56				
201	9.7	54.7	1.26	6.08	0.47	1.52				
202	9.4	54.4	1.37	6.04	0.49	1.47				
203	9.4	54.7	1.08	5.93	0.49	1.50	0.26	70.02	27.89	49.39
204	9.5	55.7	1.68	5.75	0.48	1.56	0.27	68.20	28.54	47.23
205	9.4	55.3	1.62	5.78	0.50	1.49				
206	9.7	54.9	1.09	5.88	0.43	1.56				
207	9.7	54.4	1.15	6.03	0.43	1.56	0.27	65.31	25.77	53.62
208	9.6	55.1	1.28	6.20	0.46	1.51				
209	9.5	55.5	1.05	5.98	0.50	1.64	0.27	79.56	29.50	55.29
210	9.4	55.9	1.18	5.96	0.51	1.53				
211	9.2	55.0	1.32	5.80	0.50	1.53				
212	9.3	55.1	1.46	6.30	0.53	1.70				
213	9.3	55.7	1.29	6.28	0.56	1.55				

Lyon County - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	9.7	55.2	1.21	6.15	0.45	1.64				
302	9.5	54.1	1.39	5.87	0.49	1.60				
303	9.4	55.1	1.10	6.17	0.53	1.59				
304	9.5	55.3	1.38	5.97	0.48	1.65	0.27	101.44	28.49	48.63
305	9.6	54.5	1.59	5.97	0.52	1.55	0.27	72.68	27.07	56.62
306	9.8	54.7	1.00	6.07	0.40	1.67				
307	9.6	54.6	1.39	5.96	0.52	1.58				
308	9.5	53.9	1.27	5.99	0.50	1.66				
309	9.5	55.2	1.49	6.01	0.48	1.66	0.26	72.60	27.93	53.91
310	9.6	55.2	1.20	6.12	0.44	1.66				
311	9.4	55.2	1.76	5.87	0.52	1.57				
312	9.3	54.9	1.69	5.74	0.52	1.64	0.26	67.70	28.42	49.95
313	9.4	54.5	1.57	5.97	0.50	1.68				
401	9.9	55.6	1.27	6.20	0.42	1.55	0.28	65.26	33.00	54.95
402	9.6	54.6	1.32	5.88	0.48	1.56				
403	9.6	54.0	0.93	6.14	0.48	1.64				
404	9.7	54.4	1.20	6.16	0.46	1.68				
405	9.6	53.8	1.46	5.91	0.48	1.56	0.28	69.85	28.97	53.93
406	9.5	53.8	1.19	5.93	0.44	1.69	0.31	73.32	28.37	56.58
407	9.5	54.7	1.42	5.91	0.54	1.65				
408	9.6	54.6	1.04	5.98	0.49	1.63	0.30	73.12	28.87	53.32
409	9.7	54.7	1.31	5.68	0.40	1.60				
410	9.6	55.2	1.11	5.87	0.46	1.71				
411	9.5	54.3	1.45	5.90	0.47	1.58				
412	9.4	55.1	1.41	5.89	0.48	1.65				
413	assumed 9.5		2.10							

Douglas County - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	11.4	56.8	3.18	5.86	0.46	1.79	0.29	70.74	30.75	46.71
102	11.3	55.4	2.63	6.14	0.44	1.75				
103	11.4	56.3	3.16	5.96	0.42	1.76				
104	11.3	56.0	3.18	6.15	0.47	1.81				
105	11.2	56.1	2.65	6.03	0.43	1.83				
106	11.3	56.3	2.91	5.93	0.43	1.68	0.29	67.49	30.32	45.45
107	11.3	55.0	3.06	6.15	0.41	1.71	0.29	66.59	30.29	47.08
108	11.4	56.2	3.43	6.34	0.49	1.78	0.31	72.05	30.25	46.14
109	11.2	55.8	3.24	5.93	0.42	1.75				
110	11.1	55.9	3.06	6.42	0.46	1.83				
111	11.3	55.7	3.39	5.90	0.47	1.82				
112	11.1	56.4	3.42	6.32	0.48	1.84				
113	11.3	55.8	3.35	5.98	0.39	1.75				
201	11.5	56.1	3.13	6.36	0.47	1.84				
202	11.3	56.0	2.74	5.95	0.41	1.66				
203	11.3	55.9	2.96	6.32	0.44	1.76	0.29	63.38	30.22	44.95
204	11.2	57.0	2.79	6.18	0.45	1.77	0.29	63.69	29.94	42.47
205	11.1	56.2	3.20	5.85	0.40	1.69				
206	11.2	55.8	2.93	6.18	0.37	1.76				
207	11.4	56.1	3.20	6.28	0.41	1.80	0.27	67.31	27.33	43.81
208	11.2	55.3	3.63	6.03	0.44	1.76				
209	11.1	55.3	3.28	5.78	0.38	1.74	0.27	62.13	28.99	47.98
210	11.3	56.0	3.18	6.27	0.47	1.79				
211	11.1	55.5	3.44	6.36	0.43	1.79				
212	11.1	56.4	3.18	6.26	0.45	1.83				
213	11.2	56.1	3.30	6.05	0.44	1.78				

Douglas County - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	11.3	56.7	3.14	6.36	0.43	1.74				
302	11.3	55.8	2.64	6.45	0.44	1.81				
303	11.4	55.8	3.13	5.98	0.44	1.77				
304	11.3	55.8	3.10	6.23	0.44	1.77	0.28	66.59	28.70	42.27
305	11.1	56.0	3.25	6.10	0.49	1.78				
306	11.2	56.1	2.68	6.44	0.39	1.72	0.28	58.79	30.29	46.16
307	11.2	55.5	3.21	6.14	0.49	1.72				
308	11.2	55.7	3.21	6.50	0.50	1.78				
309	11.3	55.8	3.09	6.07	0.46	1.78	0.28	73.39	32.82	54.47
310	11.2	55.6	2.70	6.43	0.49	1.81				
311	11.0	55.9	3.24	6.42	0.55	1.75				
312	11.1	56.3	3.03	6.20	0.53	1.81	0.28	72.37	32.57	44.21
313	11.2	55.7	3.06	6.29	0.45	1.73				
401	11.1	56.1	3.01	6.59	0.51	1.75	0.29	66.81	31.06	49.13
402	11.2	56.4	2.86	6.34	0.55	1.80				
403	11.2	54.9	2.81	6.37	0.51	1.82				
404	11.1	56.3	2.93	6.53	0.51	1.79				
405	11.1	56.4	2.81	6.14	0.47	1.77	0.27	65.12	29.36	44.79
406	11.2	55.9	2.84	6.29	0.46	1.70	0.27	62.80	28.47	47.54
407	11.3	55.2	2.97	6.27	0.52	1.77				
408	11.3	56.3	3.02	6.50	0.56	1.83	0.28	68.64	32.26	49.55
409	11.4	55.8	2.84	6.47	0.49	1.83				
410	11.2	55.9	2.93	6.45	0.49	1.68				
411	11.4	56.2	2.95	6.71	0.56	1.82				
412	11.1	56.4	2.88	6.35	0.54	1.80				
413	11.2	55.4	3.02	6.20	0.49	1.74				

Riley County -Randolph - grain yield and analysis										
plot	moisture	test_wt	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	10.4	53.4	1.07	6.08	0.52	1.90	0.27	83.32	51.08	47.39
102	10.0	55.4	1.45	6.37	0.47	1.88				
103	10.2	55.3	1.35	6.26	0.51	1.93				
104	10.2	55.8	1.64	6.27	0.54	1.96				
105	10.5	55.5	1.51	6.05	0.50	1.95				
106	10.1	55.3	1.41	6.30	0.54	2.00	0.22	61.78	39.23	38.36
107	10.3	54.6	1.48	6.34	0.51	1.95	0.24	61.93	41.45	38.03
108	10.4	53.7	1.35	6.22	0.48	1.85				
109	10.1	55.3	1.23	6.37	0.49	1.84				
110	10.1	56.1	1.24	6.20	0.50	1.88				
111	10.0	56.2	1.50	6.22	0.50	1.89				
112	9.9	55.4	1.53	6.28	0.53	1.93				
113	9.9	55.6	1.50	6.36	0.48	1.94				
114	9.9	55.8	1.35	6.18	0.54	1.93	0.29	73.12	48.75	39.92
201	10.1	55.1	1.47	6.26	0.53	1.98				
202	10.1	55.0	1.32	6.21	0.54	1.98				
203	10.1	55.1	1.45	6.32	0.55	1.90				
204	10.4	55.2	1.25	6.44	0.56	1.95	0.24	63.78	47.15	38.67
205	10.1	55.4	1.29	6.38	0.53	1.89	0.28	64.30	55.45	38.94
206	10.4	55.3	1.21	6.50	0.50	1.88				
207	10.3	55.2	1.23	6.37	0.48	1.89	0.24	63.80	46.95	39.94
208	9.9	55.4	1.41	6.46	0.48	1.90				
209	9.9	55.4	1.20	6.30	0.52	1.99	0.28	65.68	48.80	47.05
210	10.0	55.9	1.55	6.39	0.55	2.01				
211	10.1	55.0	1.54	6.35	0.49	1.88				
212	9.9	55.8	1.32	6.22	0.49	1.85				
213	10.0	55.3	1.30	6.40	0.54	1.93				
214	10.1	55.5	1.27	6.39	0.52	1.86				

Riley County -Randolph - grain yield and analysis										
plot	moisture	Test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	9.4	56.0	0.90	6.56	0.51	1.91				
302	9.5	55.8	1.11	6.31	0.45	1.82				
303	9.5	56.1	1.10	6.39	0.49	1.91				
304	9.5	54.5	1.17	6.47	0.46	1.86	0.25	68.71	44.49	43.24
305	9.5	56.0	1.16	6.31	0.49	1.88				
306	9.4	56.0	1.14	6.29	0.40	1.83				
307	9.4	55.6	1.17	6.32	0.48	1.85				
308	9.5	55.8	1.18	6.36	0.50	1.87				
309	9.5	55.7	1.15	6.34	0.46	1.87	0.27	65.81	58.76	49.35
310	9.5	55.9	1.11	6.39	0.46	1.84				
311	9.5	55.7	1.17	6.22	0.47	1.87				
312	9.6	55.6	1.18	6.20	0.51	1.83	0.28	70.56	49.40	40.31
313	9.4	55.8	1.10	6.28	0.44	1.83				
314	9.4	55.1	1.10	6.32	0.43	1.81	0.26	64.84	42.59	41.34
401	9.5	55.8	1.18	6.44	0.45	1.86	0.25	62.34	43.24	36.07
402	9.5	55.6	1.11	6.31	0.48	1.83				
403	9.4	55.4	1.21	6.23	0.49	1.85				
404	9.3	55.3	1.26	6.17	0.41	1.80				
405	9.0	55.5	1.25	6.42	0.47	1.81	0.28	66.91	48.82	39.13
406	9.7	55.5	1.33	6.24	0.50	1.83	0.27	598.15	66.77	58.62
407	9.5	55.9	1.52	6.32	0.56	1.95				
408	9.4	56.0	1.23	6.48	0.49	1.89	0.24	75.36	48.67	41.20
409	9.4	55.4	1.18	6.30	0.42	1.83				
410	9.5	55.6	1.13	6.27	0.47	1.77				
411	9.4	55.5	1.29	6.25	0.49	1.85				
412	9.3	55.3	1.26	6.11	0.44	1.72				
413	9.6	55.7	1.43	6.26	0.49	1.85				
414	9.5	56.1	1.53	6.25	0.50	1.87				

Woodson County - lowland - grain yield and analysis										
plot	moisture	Test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	11.9	55.4	1.34	5.65	0.52	1.67	0.28	69.51	31.62	48.14
102	11.6	54.8	1.42	6.04	0.48	1.72				
103	11.7	55.4	1.34	5.82	0.52	1.68				
104	11.5	55.5	1.34	6.06	0.53	1.71				
105	11.5	55.4	1.35	6.01	0.53	1.74				
106	11.4	55.4	1.36	5.99	0.52	1.73	0.25	73.50	28.45	45.91
107	11.3	55.9	1.33	5.96	0.49	1.74	0.25	72.79	26.88	44.95
108	11.6	55.9	1.26	6.34	0.52	1.67	0.29	62.34	28.37	40.91
109	11.7	55.2	1.30	6.06	0.51	1.63				
110	11.3	56.0	1.32	5.86	0.52	1.63				
111	11.7	54.7	1.28	5.92	0.49	1.60				
112	11.3	55.6	1.29	6.10	0.52	1.68				
113	11.2	55.8	1.06	6.13	0.46	1.55				
201	11.7	55.3	1.32	5.77	0.61	1.87				
202	11.7	55.3	1.38	5.98	0.58	1.76				
203	11.6	55.4	1.32	5.96	0.52	1.68	0.27	66.95	30.33	42.28
204	11.5	55.3	1.31	5.94	0.51	1.67	0.28	65.01	31.08	41.53
205	11.5	55.5	1.35	5.94	0.54	1.74				
206	11.3	55.1	1.34	6.04	0.52	1.71				
207	11.3	55.5	1.30	5.96	0.49	1.68	0.24	68.66	27.22	43.07
208	11.4	55.5	1.30	5.98	0.51	1.67				
209	11.4	55.7	1.22	6.04	0.47	1.61	0.29	66.99	27.71	43.18
210	11.4	55.6	0.95	6.10	0.55	1.72				
211	11.4	55.9	1.19	5.72	0.44	1.60				
212	11.2	55.6	1.26	6.12	0.46	1.63				
213	11.3	56.1	1.23	5.08	0.46	1.63				

Woodson County - lowland - grain yield and analysis										
plot	moisture	test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	11.8	55.5	1.25	5.58	0.56	1.78				
302	11.7	55.5	1.41	5.72	0.58	1.76				
303	11.8	55.0	1.38	5.81	0.56	1.69				
304	11.5	56.0	1.40	5.72	0.49	1.60	0.26	81.25	28.46	42.96
305	11.3	55.3	1.30	5.78	0.49	1.66				
306	11.3	55.3	1.30	5.90	0.47	1.68	0.24	104.03	30.02	59.80
307	11.3	55.8	1.36	6.01	0.50	1.69				
308	11.4	55.3	1.25	5.85	0.45	1.60				
309	11.6	56.3	1.20	5.92	0.46	1.63	0.27	69.19	30.19	44.13
310	11.4	55.5	1.29	5.82	0.44	1.65				
311	11.2	56.0	1.28	5.89	0.47	1.62				
312	11.6	55.0	1.39	6.02	0.47	1.66	0.26	69.09	26.05	39.77
313	11.2	55.9	1.19	5.81	0.50	1.73				
401	11.8	55.0	1.40	5.73	0.55	1.76	0.25	155.36	32.20	45.50
402	11.8	55.2	1.39	5.60	0.54	1.64				
403	11.6	55.0	1.40	5.70	0.51	1.60				
404	11.6	54.6	1.38	5.71	0.47	1.62				
405	11.6	54.8	1.30	5.98	0.46	1.67	0.28	70.46	30.16	41.05
406	11.7	55.4	1.13	5.83	0.47	1.61	0.27	71.12	29.92	45.41
407	11.4	55.4	1.33	5.95	0.50	1.68				
408	11.4	55.9	1.39	5.63	0.48	1.67	0.24	74.40	27.33	46.19
409	11.4	54.9	1.36	5.99	0.48	1.69				
410	11.5	54.9	1.39	6.11	0.48	1.70				
411	11.3	55.6	1.40	5.69	0.52	1.72				
412	11.3	55.8	1.39	5.73	0.53	1.71				
413	11.3	55.5	1.32	5.92	0.52	1.67				

Woodson County - upland - grain yield and analysis										
plot	moisture	test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
101	12.0	56.2	0.72	5.99	0.45	1.58	0.29	63.67	23.85	45.42
102	12.1	56.2	0.80	6.41	0.45	1.76				
103	11.9	56.5	0.52	6.31	0.50	1.72				
104	11.9	56.6	0.68	6.45	0.49	1.71				
105	11.9	56.4	0.70	6.70	0.46	1.66				
106	12.1	56.0	0.82	6.42	0.49	1.72	0.28	59.52	29.09	41.62
107	12.0	56.3	0.67	6.53	0.40	1.63	0.29	60.04	24.50	43.15
108	11.9	55.5	0.73	6.35	0.48	1.73	0.29	61.19	29.05	41.30
109	12.0	56.6	0.69	6.31	0.47	1.74				
110	11.8	56.3	0.74	6.38	0.47	1.69				
111	11.9	56.9	0.83	6.36	0.48	1.70				
112	11.9	56.5	0.93	6.29	0.48	1.67				
113	12.0	56.0	0.86	6.44	0.45	1.70				
201	12.0	55.6	0.57	6.71	0.46	1.60				
202	12.3	55.2	0.74	6.36	0.51	1.69				
203	12.2	56.6	0.63	6.28	0.49	1.71	0.29	63.95	25.35	42.73
204	12.1	56.7	0.77	6.43	0.45	1.66	0.29	60.64	25.95	42.78
205	11.9	56.4	0.69	6.46	0.49	1.69				
206	12.0	56.1	0.78	6.28	0.46	1.70				
207	12.0	56.1	0.77	6.68	0.44	1.73	0.28	60.84	26.12	42.27
208	11.9	56.4	0.84	6.35	0.41	1.62				
209	11.9	55.8	0.80	6.52	0.46	1.75	0.28	59.58	28.30	43.16
210	11.9	56.1	0.87	6.40	0.49	1.76				
211	11.9	56.4	0.82	6.33	0.44	1.75				
212	11.9	56.1	0.89	6.43	0.45	1.77				
213	11.9	55.8	0.93	6.38	0.46	1.68				

Woodson County - upland - grain yield and analysis										
plot	moisture	test weight	yield at 13%	N	P	K	S04-S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				mg kg^{-1}		
301	12.3	56.5	0.63	6.51	0.41	1.69				
302	12.2	56.1	0.89	6.55	0.44	1.75				
303	12.3	55.2	0.76	6.20	0.48	1.79				
304	11.9	56.2	0.78	6.47	0.44	1.71	0.28	63.13	25.54	43.60
305	12.1	55.9	0.67	6.46	0.49	1.81				
306	11.9	57.2	0.74	6.85	0.43	1.79	0.29	60.00	26.10	44.45
307	12.0	56.3	0.68	6.68	0.51	1.77				
308	12.0	56.6	0.78	6.46	0.43	1.74				
309	12.2	55.7	0.68	6.34	0.48	1.72	0.28	59.95	29.21	45.44
310	12.0	56.3	0.85	6.47	0.44	1.71				
311	11.8	56.6	0.77	6.29	0.47	1.65				
312	12.1	56.4	0.81	6.19	0.46	1.70	0.29	63.38	26.76	44.61
313	11.8	55.7	0.85	6.22	0.45	1.75				
401	12.0	55.7	0.65	6.22	0.37	1.67	0.28	61.34	26.27	40.68
402	12.1	56.1	0.78	6.58	0.47	1.65				
403	12.2	55.9	0.64	6.07	0.48	1.61				
404	12.0	56.7	0.70	6.46	0.45	1.63				
405	11.7	56.9	0.57	6.43	0.48	1.80	0.28	67.39	24.78	40.54
406	12.0	57.1	0.75	6.39	0.48	1.68	0.28	67.28	26.38	53.54
407	12.0	56.1	0.71	6.52	0.48	1.67				
408	11.9	56.2	0.78	6.35	0.49	1.64	0.28	62.84	27.39	41.48
409	12.1	55.5	0.66	6.06	0.41	1.57				
410	11.9	55.6	0.80	5.78	0.46	1.68				
411	11.9	56.1	0.78	6.61	0.48	1.63				
412	12.1	56.4	0.79	6.44	0.45	1.63				
413	11.9	55.4	0.73	6.24	0.49	1.69				

2014

Treatments

Table C-12. Treatments for the 2014 sites and their respective plot number.

Clay County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	10	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	10	0	0	0	0	no
110	9	29	10	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	10	0	0	0	0	no
113	3	0	10	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	10	0	0	0	0	no
202	11	39	10	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	10	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	10	0	0	0	0	no
214	5	10	10	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Clay County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	10	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	10	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	10	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	10	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	10	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	10	0	0	0	0	no
412	5	10	10	0	0	0	0	no
413	9	29	10	0	0	0	0	no
414	3	0	10	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Jackson County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	0	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	0	0	0	0	0	no
110	9	29	0	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	0	0	0	0	0	no
113	3	0	0	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	0	0	0	0	0	no
202	11	39	0	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	0	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	0	0	0	0	0	no
214	5	10	0	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Jackson County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	0	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	0	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	0	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	0	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	0	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	0	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	0	0	0	0	0	no
412	5	10	0	0	0	0	0	no
413	9	29	0	0	0	0	0	no
414	3	0	0	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Lyon County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	10	49	0	0	0	0	0	no
104	4	20	0	0	0	0	0	no
105	6	29	0	0	0	0	0	no
106	1	0	0	0	0	0	0	no
107	14	29	0	0	0	0	0	early
108	15	29	0	0	0	0	0	both
109	12	29	0	0	0	0	0	no
110	8	39	0	0	0	0	0	no
201	6	29	0	0	0	0	0	no
202	12	29	0	22	0	0	0	no
203	8	39	0	0	0	0	0	no
204	1	0	0	0	0	0	0	no
205	15	29	0	0	0	0	0	both
206	2	10	0	0	0	0	0	no
207	10	49	0	0	0	0	0	no
208	13	29	0	22	11	11	1	no
209	14	29	0	0	0	0	0	early
210	4	20	0	0	0	0	0	no

Lyon County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	4	20	0	0	0	0	0	no
302	15	29	0	0	0	0	0	both
303	14	29	0	0	0	0	0	early
304	10	49	0	0	0	0	0	no
305	13	29	0	22	11	11	1	no
306	2	10	0	0	0	0	0	no
307	8	39	0	0	0	0	0	no
308	12	29	0	22	0	0	0	no
309	1	0	0	0	0	0	0	no
310	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	6	29	0	0	0	0	0	no
408	14	29	0	0	0	0	0	early
409	4	20	0	0	0	0	0	no
410	8	39	0	0	0	0	0	no

Riley County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	10	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	10	0	0	0	0	no
110	9	29	10	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	10	0	0	0	0	no
113	3	0	10	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	10	0	0	0	0	no
202	11	39	10	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	10	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	10	0	0	0	0	no
214	5	10	10	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Riley County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	10	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	10	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	10	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	10	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	10	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	10	0	0	0	0	no
412	5	10	10	0	0	0	0	no
413	9	29	10	0	0	0	0	no
414	3	0	10	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Osage County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	10	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	10	0	0	0	0	no
110	9	29	10	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	10	0	0	0	0	no
113	3	0	10	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	10	0	0	0	0	no
202	11	39	10	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	10	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	10	0	0	0	0	no
214	5	10	10	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Osage County								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	10	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	10	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	10	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	10	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	10	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	10	0	0	0	0	no
412	5	10	10	0	0	0	0	no
413	9	29	10	0	0	0	0	no
414	3	0	10	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Woodson County - meadow								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	10	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	10	0	0	0	0	no
110	9	29	10	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	10	0	0	0	0	no
113	3	0	10	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	10	0	0	0	0	no
202	11	39	10	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	10	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	10	0	0	0	0	no
214	5	10	10	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Woodson County - meadow								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	10	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	10	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	10	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	10	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	10	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	10	0	0	0	0	no
412	5	10	10	0	0	0	0	no
413	9	29	10	0	0	0	0	no
414	3	0	10	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Woodson County - pasture								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
101	13	29	0	22	11	11	1	no
102	2	10	0	0	0	0	0	no
103	5	10	10	0	0	0	0	no
104	10	49	0	0	0	0	0	no
105	4	20	0	0	0	0	0	no
106	6	29	0	0	0	0	0	no
107	1	0	0	0	0	0	0	no
108	14	29	0	0	0	0	0	early
109	7	20	10	0	0	0	0	no
110	9	29	10	0	0	0	0	no
111	15	29	0	0	0	0	0	both
112	11	39	10	0	0	0	0	no
113	3	0	10	0	0	0	0	no
114	12	29	0	0	0	0	0	no
115	8	39	0	0	0	0	0	no
201	7	20	10	0	0	0	0	no
202	11	39	10	0	0	0	0	no
203	6	29	0	0	0	0	0	no
204	12	29	0	22	0	0	0	no
205	8	39	0	0	0	0	0	no
206	3	0	10	0	0	0	0	no
207	1	0	0	0	0	0	0	no
208	15	29	0	0	0	0	0	both
209	13	29	0	22	11	11	1	no
210	10	49	0	0	0	0	0	no
211	14	29	0	0	0	0	0	early
212	4	20	0	0	0	0	0	no
213	9	29	10	0	0	0	0	no
214	5	10	10	0	0	0	0	no
215	2	10	0	0	0	0	0	no

Woodson County - pasture								
		Broadcast P	Banded P	S	Fe	Mn	B	foliar
plot	treatment	kg nutrient ha^{-1}						
301	3	0	10	0	0	0	0	no
302	4	20	0	0	0	0	0	no
303	11	39	10	0	0	0	0	no
304	15	29	0	0	0	0	0	both
305	9	29	10	0	0	0	0	no
306	14	29	0	0	0	0	0	early
307	10	49	0	0	0	0	0	no
308	7	20	10	0	0	0	0	no
309	13	29	0	22	11	11	1	no
310	2	10	0	0	0	0	0	no
311	8	39	0	0	0	0	0	no
312	12	29	0	22	0	0	0	no
313	5	10	10	0	0	0	0	no
314	1	0	0	0	0	0	0	no
315	6	29	0	0	0	0	0	no
401	1	0	0	0	0	0	0	no
402	10	49	0	0	0	0	0	no
403	15	29	0	0	0	0	0	both
404	2	10	0	0	0	0	0	no
405	12	29	0	22	0	0	0	no
406	13	29	0	22	11	11	1	no
407	11	39	10	0	0	0	0	no
408	6	29	0	0	0	0	0	no
409	14	29	0	0	0	0	0	early
410	4	20	0	0	0	0	0	no
411	7	20	10	0	0	0	0	no
412	5	10	10	0	0	0	0	no
413	9	29	10	0	0	0	0	no
414	3	0	10	0	0	0	0	no
415	8	39	0	0	0	0	0	no

Table C-13. Soil results for 2014 by site.

Clay County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	P	Zn	Fe	Mn	0-15 cm S	15-61 cm S
	mg kg-1					
101	36.7	1.0	17.3	10.4	2.5	4.9
102	35.2					
103	45.7					
104	21.8					
105	18.5					
106	25.1	0.6	21.7	12.9	2.0	3.8
107	30.1	0.9	20.4	11.8	2.7	3.9
108	44.2					
109	9.2					
110	12.6					
111	27.7					
112	49.8					
113	51.1					
114	16.5	0.7	24.7	14.6	2.1	3.9
115	11.2					
201	12.5					
202	21.9					
203	16.6	0.5	39.6	18.1	1.6	4.1
204	13.8	0.4	32.9	17.0	2.2	5.5
205	7.0					
206	28.6					
207	12.7	0.5	39.6	16.4	1.1	3.4
208	17.0					
209	11.5	0.3	34.7	17.1	1.7	4.3
210	19.3					
211	12.8					
212	12.9					
213	14.3					
214	20.2					
215	21.7					

Clay County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg-1					
301	25.8					
302	37.2					
303	50.7					
304	31.8					
305	39.8					
306	35.1					
307	37.1					
308	47.3					
309	48.6	1.2	21.9	9.2	2.2	4.6
310	14.0					
311	7.4					
312	18.2	0.8	28.0	14.0	2.4	5.8
313	40.2					
314	28.1	1.0	24.2	12.0	2.7	4.7
315	17.6	0.6	26.2	13.2	1.9	3.0
401	15.5	0.4	34.2	17.8	1.8	4.5
402	8.8					
403	8.6					
404	10.0					
405	10.2	0.4	32.5	14.8	1.5	3.3
406	10.6	0.3	31.9	17.6	1.0	2.8
407	7.7					
408	12.2	0.4	37.2	17.6	1.3	6.1
409	8.9					
410	11.1					
411	20.4					
412	17.9					
413	6.5					
414	11.2					
415	9.7					

Jackson County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg-1					
101	27.5	3.3	120.6	12.9	4.9	7.5
102	55.6					
103	26.2					
104	40.9					
105	15.6					
106	33.9	3.3	106.6	16.6	4.4	8.5
107	36.6	3.3	123.7	13.9	4.9	6.9
108	34.0					
109	55.0					
110	43.3					
111	47.7					
112	42.4					
113	21.2					
114	24.4	2.5	114.1	17.4	4.5	6.7
115	32.2					
201	63.2					
202	47.0					
203	27.5	2.7	110.2	17.7	5.0	7.9
204	32.9	3.4	96.7	16.9	3.6	7.7
205	67.5					
206	60.5					
207	30.9	2.7	97.1	21.9	4.4	6.6
208	24.8					
209	33.6	2.5	114.7	19.7	5.1	8.1
210	38.2					
211	30.8					
212	46.7					
213	27.9					
214	44.5					
215	35.4					

Jackson County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	22.0					
302	52.5					
303	14.3					
304	23.3					
305	50.3					
306	24.4					
307	45.6					
308	23.3					
309	30.3	3.2	111.7	15.1	4.5	5.5
310	42.6					
311	36.6					
312	15.3	1.8	85.6	19.1	3.5	5.3
313	35.0					
314	16.7	2.5	103.4	19.9	3.9	6.4
315	12.9	2.0	90.2	19.3	4.0	6.9
401	33.8	3.9	107.0	15.9	7.4	6.8
402	49.4					
403	39.7					
404	28.3					
405	13.2	2.2	84.1	14.4	4.3	5.9
406	15.1	2.1	87.4	14.1	4.7	7.2
407	27.0					
408	13.9	2.2	91.7	21.1	4.9	7.1
409	34.4					
410	33.9					
411	38.2					
412	43.0					
413	32.5					
414	33.3					
415	32.3					

Lyon County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
101	12.9	0.8	55.1	17.9	3.3	13.1
102	9.7					
103	8.1					
104	7.0					
105	11.9	0.7	60.1	17.1	3.2	21.2
106	7.9	0.7	55.4	20.2	3.0	17.8
107	9.2					
108	5.0					
109	10.9	0.7	57.2	22.9	3.6	21.4
110	6.3					
201	8.0	0.7	64.4	19.9	4.0	15.0
202	10.9	0.8	60.7	17.4	3.5	19.9
203	11.0					
204	11.2	0.7	56.3	17.2	3.1	15.8
205	12.3					
206	4.1					
207	3.1					
208	7.7	0.7	49.9	16.3	3.5	16.1
209	2.7					
210	6.5					

Lyon County soil data

	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	8.9					
302	10.3					
303	10.3					
304	14.4					
305	6.4	0.7	57.1	17.7	3.2	21.8
306	9.3					
307	13.3					
308	6.3	0.6	54.6	18.0	2.8	24.0
309	11.4	0.8	63.1	19.3	3.5	17.5
310	8.7	0.6	55.6	18.0	2.6	16.5
401	7.2	0.7	63.2	17.3	2.4	11.3
402	7.1					
403	5.7					
404	8.5					
405	9.2	0.6	60.8	17.1	3.1	18.0
406	6.0	0.5	53.2	17.1	3.2	18.5
407	10.5	0.6	55.0	20.2	2.8	13.9
408	6.0					
409	12.5					
410	5.2					

Riley County soil data

	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
101	10.8	0.6	46.9	15.1	1.9	4.6
102	19.8					
103	9.4					
104	9.7					
105	8.3					
106	8.8	0.3	54.5	20.5	1.9	4.3
107	7.5	0.3	53.2	19.4	1.0	4.2
108	12.8					
109	9.8					
110	12.8					
111	11.9					
112	13.1					
113	10.6					
114	5.9	0.5	56.6	20.1	0.6	5.1
115	11.9					
201	15.7					
202	12.3					
203	6.2	0.4	52.4	19.2	1.2	4.5
204	7.3	0.4	54.3	21.7	1.2	5.3
205	11.0					
206	9.5					
207	6.3	0.3	56.2	22.2	1.3	3.6
208	9.9					
209	6.3	0.4	58.2	22.4	1.4	4.1
210	11.2					
211	9.5					
212	14.5					
213	11.9					
214	10.3					
215	10.3					

Riley County soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	11.4					
302	11.2					
303	9.7					
304	11.2					
305	11.4					
306	11.2					
307	10.8					
308	13.4					
309	11.0	0.4	63.2	25.2		
310	10.3					
311	12.9					
312	5.5	0.4	65.8	26.6		
313	14.7					
314	7.6	0.5	68.3	28.1		
315	8.0	0.4	64.1	25.4		
401	5.2	0.2	48.4	16.3		
402	13.2					
403	14.9					
404	11.7					
405	9.8	0.4	62.2	24.6		
406	6.8	0.4	58.9	21.4		
407	12.9					
408	11.7	0.4	64.3	25.0		
409	20.8					
410	12.8					
411	14.2					
412	12.9					
413	11.9					
414	16.5					
415	13.2					
Osage County soil data						
	Extract					

	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
101	8.4	2.2	78.1	25.3	4.2	5.3
102	19.2					
103	5.6					
104	9.1					
105	13.1					
106	3.0	2.4	89.1	22.4	5.4	5.8
107	6.3	2.4	97.7	22.4	4.6	5.6
108	13.8					
109	11.2					
110	12.1					
111	18.4					
112	16.1					
113	9.2					
114	11.1	2.5	106.0	22.7	4.9	4.5
115	16.6					
201	18.9					
202	13.3					
203	5.9	2.7	77.2	28.8	5.0	6.9
204	4.1	2.4	93.4	25.6	5.0	5.6
205	17.5					
206	17.1					
207	6.9	2.5	98.0	27.0	4.8	4.7
208	14.9					
209	8.2	2.3	94.1	23.1	4.3	5.9
210	12.2					
211	24.9					
212	14.9					
213	14.4					
214	17.8					
215	7.8					

Osage County soil data

	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	30.2					
302	9.3					
303	20.0					
304	22.7					
305	22.2					
306	18.4					
307	18.1					
308	12.4					
309	9.0	2.4	89.2	25.1	3.9	5.1
310	20.6					
311	18.4					
312	8.7	2.5	96.2	22.5	4.4	5.0
313	10.0					
314	8.7	2.1	103.5	23.0	4.5	4.1
315	7.5	2.1	95.5	19.2	4.3	4.7
401	14.7	1.9	56.3	32.9	4.8	5.9
402	32.9					
403	35.6					
404	19.2					
405	10.6	2.4	61.6	30.1	4.0	5.2
406	9.3	2.0	56.1	30.3	4.1	4.2
407	22.0					
408	10.3	2.3	71.5	24.8	3.9	4.9
409	14.6					
410	15.4					
411	15.9					
412	16.6					
413	13.3					
414	18.6					
415	16.8					

Woodson County - meadow soil data						
	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
101	8.7	0.7	69.5	21.7	3.7	5.5
102	7.3					
103	8.5					
104	10.5					
105	16.5					
106	5.2	0.8	74.1	24.8	2.3	3.9
107	6.0	1.0	85.3	25.8	2.1	5.2
108	12.8					
109	15.1					
110	10.8					
111	8.6					
112	7.8					
113	12.3					
114	6.8	1.6	101.0	38.5	2.2	3.6
115	19.3					
201	6.5					
202	6.8					
203	2.7	0.9	62.3	26.7	2.2	4.8
204	3.8	1.1	68.9	27.6	2.7	2.8
205	16.9					
206	10.4					
207	6.9	1.1	95.1	29.6	3.1	5.7
208	18.4					
209	15.4	1.2	97.9	35.5	2.8	16.3
210	10.8					
211	13.9					
212	8.7					
213	11.6					
214	12.7					
215	12.5					

Woodson County - meadow soil data			
	Extract		
	Mehlich 3	DTPA	CaPO4

plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	8.8					
302	8.2					
303	8.5					
304	9.3					
305	17.7					
306	17.2					
307	13.1					
308	15.9					
309	12.7	1.2	99.1	36.0	4.2	19.2
310	11.6					
311	8.3					
312	6.6	1.5	83.5	39.8	2.6	6.6
313	8.5					
314	6.2	1.1	70.3	33.0	3.9	4.6
315	7.2	0.9	69.8	23.3	2.1	5.6
401	7.5	1.3	96.6	35.5	4.0	5.5
402	12.5					
403	8.7					
404	9.5					
405	9.1	1.3	83.6	33.2	3.2	4.1
406	8.9	1.0	90.2	33.4	2.5	4.6
407	14.9					
408	10.3	1.2	94.7	35.6	2.3	7.8
409	11.0					
410	9.1					
411	7.4					
412	10.1					
413	8.3					
414	9.4					
415	20.0					

Woodson County - pasture soil data

	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
101	7.8	0.9	85.2	30.5	3.0	2.7
102	5.9					
103	5.7					
104	9.5					
105	7.4					
106	4.4	0.7	99.8	22.9	2.5	1.6
107	2.8	0.8	96.4	26.4	2.3	3.5
108	6.3					
109	6.1					
110	5.1					
111	6.4					
112	4.8					
113	5.3					
114	4.5	0.8	105.9	25.8	2.1	4.4
115	6.2					
201	7.3					
202	5.8					
203	3.3	1.0	101.3	28.9	2.1	2.5
204	4.4	1.0	98.4	25.1	3.6	2.9
205	4.8					
206	4.6					
207	2.8	1.0	88.3	25.0	2.6	1.9
208	5.4					
209	5.5	1.0	98.4	25.5	2.7	3.5
210	4.9					
211	6.4					
212	5.3					
213	6.0					
214	7.7					
215	5.6					

Woodson County - pasture soil data

	Extract					
	Mehlich 3	DTPA			CaPO4	
plot	m3p	Zn	Fe	Mn	0-6" S	6-24" S
	mg kg^{-1}					
301	8.0					
302	8.0					
303	5.6					
304	6.8					
305	7.7					
306	7.9					
307	9.0					
308	16.1					
309	6.8	3.0	0.8	93.1	24.6	15.8
310	6.0					
311	6.9					
312	4.7	2.9	1.0	90.3	22.0	3.4
313	7.1					
314	6.8	3.2	0.9	104.6	23.3	6.2
315	4.4	3.3	0.8	94.0	22.4	4.8
401	7.7	3.1	0.9	87.6	26.2	5.0
402	11.4					
403	7.2					
404	9.3					
405	7.4	3.7	0.8	101.2	24.6	8.2
406	10.5	4.0	0.7	96.6	23.2	18.0
407	14.9					
408	10.0	4.5	0.8	104.6	24.1	31.0
409	11.4					
410	10.0					
411	5.9					
412	6.2					
413	6.0					
414	12.3					
415	8.8					

V4 to V6 whole plants

Table C-14. V4 to V6 whole plant analysis for 2014 by site.

Clay County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	3.56	0.400	2.50	0.289	760.3	54.7	53.3
102	3.47	0.388	2.91				
103	3.57	0.720	2.87				
104	3.96	0.449	2.97				
105	3.83	0.398	2.69				
106	3.31	0.365	2.51	0.270	1274.7	58.2	45.0
107	3.47	0.352	2.27	0.233	1067.7	53.0	47.3
108	4.09	0.429	2.23				
109	4.21	0.879	2.59				
110	4.15	0.405	2.67				
111	4.38	0.412	2.56				
112	4.01	0.815	2.84				
113	4.18	0.722	3.12				
114	4.35	0.408	2.93	0.291	527.0	47.4	43.9
115	4.16	0.390	2.34				
201	3.96	0.955	2.75				
202	4.36	0.719	2.35				
203	3.82	0.395	3.05	0.306	1137.5	68.6	52.3
204	3.36	0.399	3.29	0.295	791.6	59.2	47.7
205	4.47	0.373	2.53				
206	3.73	0.754	2.46				
207	3.71	0.376	2.58	0.271	721.9	69.3	49.9
208	3.56	0.351	2.76				
209	3.77	0.405	2.56	0.289	836.3	67.6	51.0
210	3.64	0.397	3.18				
211	3.50	0.395	2.91				
212	3.61	0.349	2.45				
213	3.71	0.386	2.54				
214	4.28	1.010	2.49				
215	4.19	0.364	2.51				

Clay County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	4.11	0.642	2.31				
302	3.50	0.391	2.74				
303	4.75	1.105	2.60				
304	3.65	0.419	3.00				
305	3.54	0.405	3.05				
306	3.62	0.377	2.94				
307	3.88	0.415	2.78				
308	4.31	0.910	2.68				
309	3.19	0.411	3.33	0.294	334.1	46.9	43.7
310	4.28	0.418	2.63				
311	3.95	0.362	2.34				
312	4.24	0.394	2.47	0.267	1038.4	60.6	47.0
313	4.31	0.830	2.49				
314	3.53	0.368	2.91	0.259	390.7	44.9	43.6
315	3.82	0.390	2.73	0.272	571.7	44.8	44.8
401	3.89	0.350	2.50	0.265	1155.2	62.1	51.3
402	4.18	0.466	3.02				
403	4.64	0.414	2.64				
404	3.48	0.386	2.98				
405	4.11	0.419	2.51	0.292	1096.6	64.7	48.4
406	4.06	0.371	2.21	0.279	1283.6	79.6	55.1
407	3.42	0.654	3.22				
408	4.00	0.418	2.66	0.300	643.1	65.4	52.6
409	3.68	0.401	2.89				
410	3.95	0.393	2.51				
411	3.69	0.760	2.84				
412	4.38	0.863	2.46				
413	3.97	0.396	2.57				
414	4.01	0.855	2.75				
415	3.90	0.390	2.56				

Jackson County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	3.28	0.454	3.28	0.257	409.1	73.8	68.9
102	3.04	0.379	3.59				
103	3.01	0.426	3.24				
104	3.43	0.473	3.42				
105	3.29	0.436	3.41				
106	3.22	0.463	3.37	0.240	155.2	42.8	49.6
107	3.12	0.377	3.34	0.231	201.4	39.6	56.5
108	3.17	0.465	3.80				
109	3.18	0.395	3.24				
110	4.14	0.434	3.16				
111	3.77	0.416	3.59				
112	3.59	0.406	3.24				
113	3.58	0.369	3.25				
114	3.86	0.428	3.61	0.247	190.1	35.0	47.6
115	3.41	0.424	3.70				
201	2.56	0.441	3.39				
202	3.10	0.494	3.43				
203	3.24	0.401	3.71	0.236	226.0	45.7	44.1
204	3.39	0.471	3.53	0.231	113.6	47.6	40.7
205	3.57	0.459	3.50				
206	3.36	0.388	3.51				
207	2.47	0.366	3.13	0.230	110.0	54.1	42.3
208	2.41	0.417	3.30				
209	2.87	0.412	3.30	0.226	123.7	51.6	47.3
210	3.63	0.432	3.26				
211	2.93	0.392	3.61				
212	2.94	0.384	3.55				
213	3.41	0.410	3.64				
214	3.02	0.389	3.53				
215	2.43	0.352	3.47				

Jackson County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	3.33	0.367	3.25				
302	3.41	0.445	3.72				
303	3.49	0.443	3.27				
304	2.89	0.438	3.39				
305	2.64	0.467	3.63				
306	3.13	0.465	3.06				
307	2.20	0.429	3.36				
308	2.23	0.371	3.49				
309	2.78	0.474	3.43	0.235	100.4	47.4	52.4
310	2.43	0.392	3.70				
311	2.80	0.448	3.21				
312	2.44	0.373	3.38	0.219	79.2	32.5	35.3
313	2.30	0.359	3.21				
314	2.03	0.316	3.14	0.222	81.8	35.5	38.4
315	2.25	0.364	3.17	0.214	98.9	37.7	36.1
401	2.19	0.320	3.19	0.239	154.4	45.9	55.1
402	2.69	0.409	3.50				
403	2.30	0.399	3.02				
404	2.86	0.386	3.28				
405	2.77	0.361	3.33	0.247	118.1	39.1	46.3
406	2.32	0.342	2.95	0.239	156.9	39.9	46.1
407	2.51	0.401	3.72				
408	2.37	0.382	3.46	0.232	92.9	30.9	36.6
409	2.31	0.415	2.87				
410	2.57	0.403	3.41				
411	2.40	0.392	3.31				
412	2.02	0.331	2.95				
413	2.60	0.366	3.41				
414	2.66	0.325	2.99				
415	2.48	0.373	3.37				

Lyon County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	3.78	0.303	1.88	0.253	184.9	67.8	71.6
102	4.15	0.356	2.21				
103	3.21	0.347	2.91				
104	3.40	0.313	2.75				
105	4.12	0.350	2.29	0.278	203.5	76.9	67.0
106	3.22	0.311	2.51	0.251	219.0	54.8	66.6
107	3.00	0.315	2.89				
108	3.67	0.338	2.36				
109	4.17	0.342	2.16	0.288	295.7	89.5	67.5
110	3.38	0.377	2.61				
201	3.61	0.376	2.67	0.273	129.6	76.6	63.6
202	3.94	0.382	2.59	0.306	218.6	96.0	72.0
203	3.92	0.397	2.70				
204	3.71	0.351	2.41	0.277	149.0	68.4	73.0
205	3.57	0.379	2.41				
206	3.44	0.328	2.52				
207	4.52	0.396	2.17				
208	3.50	0.336	2.27	0.274	248.2	71.1	71.7
209	3.43	0.329	2.67				
210	3.18	0.349	3.17				

Lyon County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	2.87	0.299	2.91				
302	3.72	0.355	2.40				
303	3.44	0.375	2.58				
304	4.22	0.377	2.27				
305	2.97	0.309	2.71	0.266	120.3	53.3	66.4
306	3.75	0.342	2.03				
307	3.45	0.407	2.96				
308	3.81	0.378	2.63	0.278	215.1	85.5	65.8
309	3.15	0.317	2.67	0.260	162.7	63.8	63.3
310	3.48	0.339	2.88	0.267	208.1	89.0	61.3
401	3.08	0.309	2.59	0.265	150.7	83.1	70.7
402	3.53	0.366	2.79				
403	3.79	0.372	2.70				
404	3.47	0.355	2.86				
405	4.01	0.376	2.49	0.297	230.3	98.0	70.9
406	3.07	0.315	2.60	0.274	127.5	58.7	65.3
407	3.52	0.377	2.75	0.285	207.9	83.2	62.6
408	3.73	0.370	2.97				
409	3.81	0.365	2.82				
410	3.93	0.379	2.55				

Riley County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	4.54	0.371	2.47	0.294	2221.2	148.1	56.6
102	4.79	0.358	2.57				
103	4.42	0.349	2.45				
104	4.55	0.345	2.24				
105	4.57	0.352	2.60				
106	4.36	0.350	2.73	0.251	2573.9	149.7	52.3
107	4.61	0.320	2.53	0.275	2273.6	141.0	56.4
108	4.16	0.330	2.25				
109	4.57	0.363	2.47				
110	4.59	0.352	2.49				
111	3.30	0.274	2.18				
112	4.35	0.351	2.25				
113	3.94	0.329	2.55				
114	4.09	0.325	2.24	0.278	2276.6	135.3	51.7
115	4.17	0.321	2.18				
201	4.92	0.388	2.48				
202	4.71	0.394	2.65				
203	4.48	0.350	2.48	0.260	1607.5	109.4	48.1
204	4.25	0.352	2.63	0.281	1481.2	120.2	50.4
205	4.95	0.404	2.60				
206	4.43	0.337	2.68				
207	4.69	0.338	2.70	0.268	1382.8	112.6	55.1
208	4.59	0.375	2.74				
209	4.87	0.375	2.51	0.291	1523.4	126.8	54.2
210	4.74	0.387	2.49				
211	4.62	0.356	2.39				
212	4.59	0.339	2.39				
213	4.51	0.367	2.25				
214	4.91	0.390	2.49				
215	4.77	0.359	2.04				

Riley County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	4.60	0.377	2.56				
302	4.80	0.349	2.42				
303	4.67	0.379	2.54				
304	4.59	0.357	2.38				
305	4.82	0.393	2.71				
306	5.33	0.398	2.42				
307	4.97	0.379	2.77				
308	4.70	0.366	2.70				
309	5.13	0.387	2.51	0.294	654.4	104.5	51.8
310	4.56	0.321	2.60				
311	4.97	0.397	2.43				
312	4.72	0.375	2.58	0.280	1318.3	124.2	50.2
313	5.07	0.406	2.25				
314	4.75	0.350	2.18	0.264	1571.0	127.9	50.6
315	4.46	0.358	2.56	0.284	708.4	102.6	49.1
401	4.42	0.351	2.32	0.252	2532.6	138.8	50.1
402	5.03	0.395	2.33				
403	4.87	0.377	2.35				
404	4.77	0.385	2.57				
405	4.66	0.391	2.50	0.303	962.3	108.9	49.3
406	5.02	0.414	2.66	0.313	1125.6	135.6	58.7
407	4.72	0.411	2.79				
408	5.31	0.409	2.53	0.280	1198.1	129.1	49.8
409	5.17	0.440	2.80				
410	4.30	0.363	2.62				
411	4.57	0.398	2.54				
412	4.72	0.387	2.59				
413	4.88	0.417	2.51				
414	4.86	0.381	2.51				
415	4.70	0.360	2.30				

Osgae County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	4.48	0.359	2.44	0.288	535.7	87.8	54.6
102	3.73	0.342	2.69				
103	4.03	0.336	2.41				
104	4.51	0.411	2.65				
105	4.17	0.375	2.58				
106	4.44	0.366	2.27	0.265	648.3	151.2	52.2
107	3.87	0.346	2.32	0.269	653.4	73.1	59.0
108	3.89	0.330	2.56				
109	4.15	0.361	2.21				
110	4.25	0.380	2.25				
111	4.50	0.371	2.02				
112	4.49	0.437	1.99				
113	4.06	0.355	2.29				
114	4.04	0.400	2.36	0.293	541.4	73.3	48.0
115	4.24	0.398	2.06				
201	3.83	0.369	2.50				
202	4.32	0.388	2.87				
203	4.52	0.387	2.84	0.282	461.7	65.2	53.5
204	4.44	0.360	2.54	0.284	440.5	68.2	53.2
205	3.92	0.390	3.03				
206	4.04	0.358	2.77				
207	4.20	0.350	2.50	0.263	390.4	68.5	49.9
208	4.29	0.339	2.33				
209	4.06	0.372	2.37	0.299	365.5	74.9	60.6
210	4.50	0.379	2.36				
211	4.51	0.354	1.94				
212	4.04	0.384	2.36				
213	4.15	0.365	1.91				
214	4.60	0.373	2.00				
215	4.45	0.380	1.98				

Osgae County - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	4.04	0.338	2.69				
302	4.42	0.328	2.74				
303	4.03	0.354	2.62				
304	3.87	0.354	2.53				
305	4.00	0.376	2.36				
306	4.14	0.346	2.62				
307	4.15	0.367	2.16				
308	3.44	0.347	2.62				
309	4.69	0.399	2.49	0.299	587.1	94.8	61.0
310	4.10	0.350	2.24				
311	4.29	0.380	2.17				
312	3.97	0.365	2.57	0.289	701.0	80.9	55.5
313	4.17	0.354	2.17				
314	4.14	0.347	2.09	0.275	803.5	90.2	62.3
315	4.25	0.371	2.18	0.272	381.6	79.9	49.3
401	4.21	0.343	2.79	0.283	1316.7	116.0	59.0
402	4.51	0.412	2.68				
403	4.19	0.396	2.65				
404	4.31	0.376	2.41				
405	4.71	0.395	2.83	0.300	483.3	85.0	52.7
406	4.13	0.382	2.99	0.279	424.4	84.8	59.8
407	4.17	0.445	2.86				
408	3.49	0.346	2.79	0.261	393.3	70.6	51.8
409	4.88	0.380	2.48				
410	4.48	0.385	2.30				
411	4.14	0.399	2.78				
412	4.32	0.368	2.20				
413	4.14	0.381	2.20				
414	3.78	0.336	2.57				
415	4.09	0.365	2.40				

Woodson County - meadow - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	2.95	0.343	2.24	0.263	578.7	199.8	62.2
102	3.02	0.284	2.13				
103	2.72	0.287	1.99				
104	2.77	0.403	1.87				
105	3.25	0.331	1.96				
106	2.96	0.275	1.82	0.262	608.9	148.7	40.3
107	3.20	0.273	1.89	0.259	643.6	138.2	48.4
108	2.98	0.341	1.73				
109	2.90	0.309	1.68				
110	2.73	0.336	1.75				
111	3.24	0.310	1.67				
112	3.01	0.330	2.16				
113	2.90	0.254	1.78				
114	2.58	0.332	2.06	0.276	534.7	229.2	39.5
115	3.16	0.350	1.37				
201	3.15	0.338	2.11				
202	2.78	0.338	1.93				
203	3.01	0.351	1.90	0.256	437.6	208.1	36.4
204	2.62	0.322	2.01	0.280	428.7	133.3	36.5
205	2.88	0.355	1.94				
206	3.19	0.274	1.68				
207	3.00	0.284	2.14	0.276	393.8	134.6	44.4
208	3.18	0.366	1.75				
209	2.57	0.357	2.38	0.259	336.9	134.2	50.6
210	2.40	0.339	2.07				
211	2.50	0.297	1.92				
212	2.92	0.296	1.83				
213	2.84	0.347	1.75				
214	2.65	0.285	2.63				
215	2.76	0.279	1.97				

Woodson County - meadow - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	2.89	0.274	2.17				
302	3.07	0.319	1.73				
303	3.11	0.387	1.58				
304	2.58	0.286	1.93				
305	3.24	0.365	1.70				
306	2.92	0.339	1.97				
307	2.99	0.377	1.92				
308	2.85	0.363	1.71				
309	2.58	0.324	1.75	0.259	494.2	308.3	58.4
310	2.64	0.295	2.10				
311	2.58	0.373	2.27				
312	3.01	0.349	2.08	0.261	463.5	127.1	36.9
313	2.23	0.250	2.56				
314	2.82	0.251	2.21	0.235	379.7	106.3	39.3
315	2.82	0.334	1.73	0.264	354.0	147.6	34.3
401	3.33	0.297	2.08	0.244	628.0	188.4	46.6
402	2.72	0.360	1.88				
403	3.04	0.322	2.37				
404	2.79	0.314	1.99				
405	3.19	0.369	2.17	0.272	497.1	213.6	44.8
406	3.30	0.402	1.95	0.287	828.6	229.3	75.7
407	2.14	0.346	1.58				
408	2.23	0.259	1.64	0.220	572.1	150.9	29.9
409	2.79	0.302	2.17				
410	3.12	0.261	1.62				
411	3.62	0.356	2.13				
412	4.34	0.349	1.85				
413	3.32	0.312	2.40				
414	3.41	0.365	2.32				
415	3.28	0.398	1.97				

Woodson County - pasture - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
101	2.39	0.297	1.88	0.263	324.1	150.9	65.6
102	2.74	0.298	2.10				
103	2.33	0.265	2.09				
104	2.30	0.356	2.40				
105	2.42	0.337	2.29				
106	2.30	0.336	2.03	0.259	501.9	125.1	38.9
107	2.84	0.246	1.78	0.244	307.2	110.2	47.4
108	2.50	0.302	1.97				
109	2.70	0.311	2.07				
110	2.15	0.284	2.11				
111	2.60	0.294	1.97				
112	2.57	0.291	1.90				
113	2.40	0.246	2.30				
114	2.65	0.314	1.83	0.266	267.4	96.0	39.8
115	2.77	0.328	1.68				
201	2.78	0.273	2.00				
202	2.71	0.324	2.02				
203	2.77	0.294	2.00	0.245	514.1	195.2	46.3
204	2.89	0.339	2.25	0.289	380.3	262.3	46.1
205	2.93	0.353	1.93				
206	2.77	0.256	1.98				
207	2.83	0.246	2.00	0.241	461.0	131.5	49.1
208	2.96	0.340	2.25				
209	2.38	0.306	2.31	0.286	488.4	213.1	65.0
210	2.97	0.306	1.74				
211	2.64	0.289	1.59				
212	2.74	0.292	1.71				
213	2.50	0.290	1.93				
214	2.91	0.268	1.83				
215	2.59	0.264	1.94				

Woodson County - pasture - V4 -V6 whole plant analysis							
	N	P	K	S04-S	Fe	Mn	Zn
plot	%				mg kg^{-1}		
301	3.02	0.274	1.79				
302	2.36	0.258	1.79				
303	2.40	0.319	2.03				
304	2.54	0.324	2.28				
305	2.57	0.318	2.07				
306	2.65	0.326	2.26				
307	2.34	0.347	1.81				
308	2.89	0.338	2.18				
309	2.12	0.305	2.17	0.279	374.0	127.5	54.7
310	2.44	0.249	1.98				
311	2.11	0.277	2.09				
312	2.34	0.273	2.18	0.266	447.9	168.7	43.3
313	2.74	0.272	2.40				
314	2.94	0.305	2.20	0.261	352.9	110.9	51.9
315	3.01	0.317	1.82	0.267	531.2	142.2	49.4
401	2.80	0.304	1.98	0.271	421.3	160.3	53.7
402	2.59	0.327	1.75				
403	2.64	0.332	1.79				
404	2.50	0.305	2.26				
405	2.59	0.314	2.16	0.265	313.9	152.1	44.8
406	2.45	0.299	1.88	0.262	401.9	172.9	68.4
407	2.48	0.309	1.80				
408	2.89	0.311	1.71	0.262	221.7	233.6	43.5
409	2.48	0.294	2.01				
410	2.65	0.281	1.88				
411	2.84	0.259	1.65				
412	2.48	0.238	2.16				
413	2.76	0.297	1.78				
414	2.63	0.264	2.24				
415	2.69	0.333	1.76				

R4 Trifoliate analysis

Table C-15. Trifoliate analysis at R4 for 2014 by site.

Clay County - R4 trifoliate analysis			
	N	P	K
plot	%		
101	5.47	0.327	1.64
102	5.60	0.371	1.82
103	5.39	0.324	1.61
104	5.24	0.303	1.73
105	5.13	0.296	1.65
106	5.15	0.335	1.72
107	5.59	0.370	1.84
108	5.56	0.328	1.60
109	5.33	0.299	1.71
110	5.26	0.300	1.63
111	5.05	0.302	1.78
112	5.28	0.361	2.04
113	5.34	0.322	1.78
114	5.25	0.293	1.78
115	5.17	0.294	1.74
201	5.03	0.292	1.62
202	5.17	0.300	1.76
203	4.50	0.267	1.77
204	5.09	0.264	1.58
205	5.06	0.273	1.80
206	5.12	0.295	1.77
207	4.97	0.271	1.69
208	5.06	0.273	1.59
209	5.15	0.280	1.74
210	5.00	0.255	1.60
211	4.99	0.264	1.64
212	4.86	0.251	1.74
213	4.64	0.226	1.58
214	5.16	0.261	1.59
215	4.82	0.237	1.67

Clay County - R4 trifoliate analysis			
	N	P	K
plot	%		
301	5.06	0.313	1.81
302	4.88	0.318	2.05
303	5.46	0.327	1.76
304	5.44	0.343	1.74
305	5.31	0.333	1.82
306	5.23	0.304	1.63
307	5.42	0.319	1.76
308	5.53	0.332	1.68
309	5.44	0.336	1.80
310	5.38	0.309	1.73
311	5.02	0.303	1.80
312	5.39	0.313	1.78
313	5.52	0.315	1.57
314	5.31	0.314	1.81
315	5.05	0.285	1.82
401	5.09	0.260	1.67
402	5.25	0.265	1.55
403	4.98	0.248	1.59
404	4.51	0.236	1.84
405	4.94	0.269	1.68
406	4.74	0.263	1.65
407	5.10	0.291	1.60
408	5.02	0.265	1.65
409	5.17	0.287	1.45
410	5.33	0.269	1.44
411	5.19	0.268	1.61
412	4.86	0.239	1.57
413	4.95	0.242	1.51
414	5.06	0.270	1.63
415	5.34	0.284	1.69

Jackson County - R4 trifoliate analysis			
	N	P	K
plot		%	
101	3.99	0.333	2.60
102	4.24	0.315	2.33
103	4.27	0.344	2.26
104	4.10	0.347	2.46
105	4.07	0.324	2.43
106	4.22	0.333	2.22
107	4.63	0.334	2.21
108	4.30	0.365	2.26
109	4.53	0.333	2.29
110	3.88	0.335	2.18
111	3.95	0.339	2.21
112	4.23	0.335	2.17
113	4.00	0.317	2.09
114	3.63	0.334	2.17
115	3.99	0.326	2.35
201	4.40	0.341	2.37
202	4.43	0.325	2.23
203	4.01	0.309	2.06
204	3.89	0.345	2.39
205	4.06	0.358	2.33
206	3.76	0.338	2.24
207	4.27	0.354	2.38
208	4.50	0.348	2.35
209	4.06	0.368	2.48
210	4.48	0.338	2.24
211	no sample	no sample	no sample
212	4.63	0.362	2.37
213	4.58	0.342	2.18
214	4.56	0.377	2.29
215	4.38	0.360	2.29

Jackson County - R4 trifoliate analysis			
	N	P	K
plot	%		
301	3.87	0.331	2.17
302	3.75	0.334	1.92
303	4.04	0.368	2.23
304	3.98	0.359	2.18
305	4.31	0.367	2.22
306	4.22	0.353	2.07
307	4.23	0.381	2.29
308	3.88	0.372	2.05
309	3.89	0.337	1.98
310	4.50	0.364	2.09
311	4.59	0.424	2.23
312	3.96	0.354	1.93
313	4.57	0.368	2.24
314	4.84	0.400	2.20
315	4.40	0.388	2.40
401	4.66	0.393	2.43
402	3.88	0.407	2.23
403	4.09	0.369	2.21
404	4.36	0.387	2.34
405	4.21	0.374	2.40
406	4.05	0.388	2.40
407	4.23	0.388	2.11
408	3.85	0.400	2.27
409	4.27	0.353	2.02
410	4.17	0.439	2.32
411	3.96	0.415	2.19
412	3.97	0.412	2.47
413	4.20	0.436	2.28
414	4.13	0.430	2.34
415	3.83	0.387	2.03

Lyon County - R4 trifoliate analysis			
	N	P	K
plot	%		
101	4.36	0.215	1.38
102	3.72	0.172	1.30
103	4.01	0.193	1.34
104	4.38	0.202	1.32
105	4.11	0.200	1.41
106	4.01	0.182	1.39
107	4.11	0.211	1.43
108	4.70	0.239	1.55
109	4.08	0.201	1.42
110	4.46	0.217	1.43
201	4.94	0.253	1.53
202	4.58	0.260	1.69
203	5.02	0.261	1.50
204	5.15	0.231	1.51
205	5.42	0.269	1.51
206	5.03	0.260	1.73
207	5.15	0.266	1.54
208	5.23	0.267	1.69
209	4.85	0.240	1.52
210	4.98	0.238	1.52

Lyon County - R4 trifoliate analysis			
	N	P	K
plot	%		
301	5.39	0.268	1.84
302	4.86	0.224	1.45
303	5.17	0.259	1.34
304	4.59	0.235	1.51
305	4.17	0.184	1.18
306	5.39	0.247	1.53
307	5.51	0.274	1.55
308	4.90	0.231	1.54
309	4.74	0.187	1.32
310	4.75	0.217	1.54
401	4.14	0.169	1.35
402	4.07	0.193	1.37
403	4.58	0.226	1.57
404	3.85	0.172	1.32
405	5.11	0.255	1.57
406	5.31	0.262	1.58
407	4.76	0.243	1.55
408	4.73	0.231	1.53
409	4.49	0.209	1.55
410	5.21	0.253	1.63

Riley County - R4 trifoliate analysis			
	N	P	K
plot	%		
101	5.13	0.321	1.64
102	5.09	0.293	1.72
103	4.92	0.278	1.72
104	4.99	0.288	1.70
105	4.81	0.272	1.66
106	4.90	0.270	1.58
107	4.60	0.251	1.64
108	4.97	0.292	1.48
109	5.06	0.271	1.43
110	5.04	0.279	1.51
111	4.72	0.262	1.61
112	4.76	0.260	1.59
113	4.84	0.259	1.64
114	4.66	0.256	1.74
115	4.72	0.261	1.74
201	5.02	0.280	1.62
202	5.29	0.319	1.72
203	4.69	0.285	1.95
204	4.81	0.271	1.64
205	4.53	0.255	1.81
206	4.58	0.251	1.68
207	4.69	0.232	1.65
208	4.90	0.249	1.57
209	5.02	0.278	1.62
210	4.92	0.280	1.54
211	4.10	0.387	2.15
212	4.89	0.247	1.41
213	4.85	0.242	1.41
214	4.89	0.264	1.48
215	4.91	0.259	1.49

Riley County - R4 trifoliate analysis			
	N	P	K
plot	%		
301	4.94	0.268	1.68
302	5.05	0.263	1.63
303	5.15	0.276	1.62
304	4.83	0.268	1.70
305	5.16	0.267	1.45
306	5.10	0.297	1.60
307	5.14	0.290	1.64
308	5.29	0.305	1.74
309	5.02	0.280	1.77
310	4.81	0.255	1.63
311	4.64	0.269	1.67
312	4.58	0.243	1.44
313	4.54	0.247	1.62
314	5.02	0.269	1.46
315	4.96	0.261	1.49
401	4.77	0.265	1.54
402	4.75	0.280	1.61
403	4.95	0.260	1.44
404	4.91	0.254	1.50
405	4.81	0.276	1.72
406	4.63	0.289	1.76
407	5.09	0.317	1.74
408	5.28	0.330	1.78
409	4.93	0.319	1.78
410	4.90	0.315	1.98
411	4.98	0.297	1.67
412	4.93	0.265	1.57
413	5.10	0.313	1.70
414	4.80	0.268	1.59
415	5.05	0.300	1.74

Osage County - R4 trifoliate analysis			
	N	P	K
plot	%		
101	3.38	0.214	1.19
102	3.83	0.231	1.08
103	4.04	0.184	0.95
104	4.00	0.219	0.93
105	3.85	0.213	1.38
106	3.49	0.172	1.05
107	3.97	0.170	0.95
108	3.83	0.184	0.79
109	3.21	0.174	0.99
110	3.78	0.205	0.98
111	3.98	0.221	0.87
112	3.95	0.232	0.78
113	3.82	0.184	1.06
114	3.36	0.199	0.84
115	3.89	0.216	0.67
201	4.29	0.242	1.30
202	4.46	0.250	1.70
203	3.85	0.220	1.61
204	3.98	0.218	1.34
205	3.69	0.237	1.84
206	3.91	0.216	1.62
207	3.96	0.217	1.24
208	4.20	0.203	1.05
209	3.61	0.225	1.09
210	4.27	0.215	0.90
211	4.26	0.200	0.94
212	3.67	0.194	1.16
213	3.90	0.211	0.98
214	4.14	0.193	1.04
215	4.13	0.188	0.97

Clay - County R4 trifoliate analysis			
	N	P	K
plot	%		
301	3.92	0.192	1.35
302	4.12	0.176	1.04
303	4.36	0.212	1.05
304	3.93	0.212	1.14
305	3.05	0.166	1.11
306	4.15	0.191	0.96
307	3.50	0.202	1.13
308	3.74	0.188	1.01
309	4.07	0.213	1.06
310	3.09	0.162	1.00
311	3.90	0.215	1.02
312	4.08	0.225	1.03
313	4.40	0.202	1.02
314	3.73	0.167	0.97
315	4.22	0.221	0.83
401	4.18	0.223	1.33
402	3.53	0.207	1.28
403	3.74	0.203	1.31
404	3.78	0.188	1.17
405	3.65	0.193	1.14
406	3.26	0.199	1.29
407	3.91	0.220	1.24
408	4.05	0.212	1.12
409	4.19	0.215	1.07
410	3.79	0.190	1.05
411	4.03	0.214	1.07
412	3.33	0.192	1.35
413	3.90	0.220	0.98
414	3.93	0.209	1.21
415	4.06	0.226	1.22

Woodson County - meadow - R4 trifoliate analysis			
	N	P	K
plot	%		
101	4.61	0.254	0.94
102	4.42	0.229	0.81
103	4.49	0.230	0.85
104	4.58	0.272	0.96
105	4.59	0.266	0.82
106	4.66	0.256	0.87
107	4.41	0.237	0.95
108	4.63	0.284	0.94
109	4.92	0.296	0.93
110	4.85	0.290	0.90
111	4.88	0.306	0.99
112	4.77	0.294	1.04
113	4.64	0.270	0.94
114	4.57	0.276	0.85
115	4.54	0.270	0.70
201	4.66	0.245	0.82
202	4.76	0.267	0.92
203	4.95	0.270	0.96
204	5.16	0.281	0.92
205	4.90	0.263	0.85
206	4.91	0.264	0.97
207	4.87	0.266	1.01
208	5.28	0.296	0.88
209	5.03	0.293	0.88
210	4.98	0.291	0.94
211	5.02	0.300	1.06
212	4.92	0.278	0.95
213	4.69	0.260	0.85
214	4.87	0.269	1.00
215	5.12	0.269	0.90

Woodson County - meadow - R4 trifoliate analysis			
	N	P	K
plot	%		
301	4.57	0.229	0.92
302	5.03	0.264	0.97
303	4.89	0.282	0.80
304	5.03	0.279	0.96
305	4.93	0.272	0.76
306	4.91	0.281	1.00
307	5.04	0.284	0.91
308	4.94	0.295	0.91
309	5.01	0.296	0.99
310	4.48	0.245	0.95
311	4.80	0.280	0.89
312	4.79	0.264	0.95
313	4.70	0.233	0.98
314	4.27	0.214	1.10
315	4.91	0.262	0.96
401	5.11	0.254	1.02
402	5.03	0.287	1.05
403	5.07	0.287	1.06
404	5.12	0.298	1.06
405	5.49	0.299	1.03
406	5.07	0.307	1.11
407	4.76	0.305	1.14
408	4.60	0.278	0.92
409	4.66	0.260	0.99
410	4.52	0.265	1.01
411	4.59	0.274	1.00
412	4.69	0.266	1.08
413	4.65	0.275	1.01
414	4.75	0.254	1.12
415	4.97	0.273	0.95

Woodson County - pasture - R4 trifoliate analysis			
	N	P	K
plot	%		
101	4.34	0.293	1.10
102	4.87	0.303	1.18
103	4.83	0.290	1.11
104	5.00	0.338	1.09
105	4.77	0.311	1.11
106	4.71	0.289	1.00
107	4.83	0.268	1.07
108	4.84	0.309	1.15
109	4.66	0.299	1.08
110	4.56	0.272	0.95
111	4.71	0.283	0.90
112	4.65	0.305	1.06
113	4.73	0.276	1.10
114	4.61	0.285	0.94
115	4.61	0.293	0.92
201	4.48	0.280	0.94
202	4.95	0.307	0.96
203	4.68	0.262	0.95
204	4.51	0.265	0.76
205	4.73	0.286	0.85
206	4.76	0.274	0.88
207	4.80	0.260	1.02
208	4.55	0.274	0.98
209	4.38	0.274	0.91
210	4.65	0.279	0.83
211	4.29	0.240	0.83
212	4.66	0.272	0.83
213	4.41	0.266	0.82
214	4.26	0.242	0.96
215	4.88	0.268	0.92

Woodson County - pasture - R4 trifoliate analysis			
	N	P	K
plot	%		
301	4.67	0.276	0.97
302	5.13	0.308	1.08
303	4.85	0.287	1.01
304	4.66	0.268	0.86
305	4.90	0.284	0.76
306	4.84	0.278	0.98
307	4.98	0.295	0.77
308	4.86	0.294	0.82
309	4.66	0.276	0.91
310	4.47	0.240	0.90
311	4.43	0.265	0.78
312	4.19	0.266	0.81
313	4.44	0.261	0.86
314	4.79	0.256	0.77
315	5.04	0.289	0.93
401	5.51	0.344	1.01
402	5.46	0.326	0.95
403	5.26	0.291	0.79
404	4.64	0.264	0.94
405	4.93	0.269	0.79
406	4.76	0.287	0.83
407	4.87	0.288	0.69
408	5.06	0.292	0.71
409	5.02	0.275	0.79
410	4.97	0.253	0.79
411	4.74	0.243	0.76
412	4.80	0.269	0.94
413	4.96	0.278	1.02
414	4.85	0.263	0.94
415	5.03	0.288	0.88

Grain yield and analysis

Table C-16. Grain and yield analysis for 2013 by site.

Clay Center - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	11.1	53.5	2.72	5.73	0.509	1.73	0.264	65.1	30.4	43.3
102	10.1	23.1	2.81	6.01	0.521	1.74				
103	12	54.5	2.58	6.18	0.523	1.74				
104	11.8	54.8	2.71	5.93	0.510	1.68				
105	12	53.8	2.02	5.89	0.446	1.65				
106	11.6	53.8	2.63	5.69	0.500	1.70	0.263	70.8	33.1	42.0
107	12.7	53.8	2.54	5.79	0.498	1.78	0.267	66.0	35.3	43.4
108	11.5	54.1	2.60	5.84	0.526	1.79				
109	12	53.8	2.58	6.06	0.481	1.70				
110	10.2	54.2	2.12	5.65	0.458	1.72				
111	12.1	53.5	1.87	5.65	0.448	1.71				
112	11.7	54.5	2.87	5.93	0.524	1.82				
113	12.4	53.8	2.85	5.75	0.486	1.68				
114	10.5	53.9	2.48	5.95	0.474	1.70	0.266	56.7	32.9	41.8
115	9.8	53.7	1.94	5.94	0.484	1.75				
201	12.1	54	2.01	5.66	0.466	1.67				
202	11.6	54.7	2.31	5.96	0.470	1.69				
203	11.7	54.6	2.30	5.89	0.465	1.63	0.266	62.1	35.4	42.0
204	11.8	53.6	1.94	6.04	0.480	1.70	0.267	63.3	35.7	38.4
205	12.5	53.8	2.39	6.00	0.463	1.73				
206	12.3	54	2.03	5.67	0.480	1.75				
207	12.7	54.1	2.24	5.97	0.455	1.65	0.266	60.6	40.2	40.6
208	11.8	53.7	2.12	6.01	0.463	1.67				
209	11.4	53.4	2.01	5.87	0.463	1.66	0.258	67.7	34.7	40.4
210	11.4	54.3	2.41	5.73	0.433	1.64				
211	9.1	51	2.24	5.94	0.484	1.78				
212	12.3	54.4	1.86	5.85	0.419	1.67				
213	11.5	54.4	1.77	6.04	0.425	1.64				
214	11	53	2.08	5.73	0.454	1.69				
215	12.1	53.2	1.84	5.92	0.451	1.70				

Clay Center - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	12.2	54	2.50	5.95	0.433	1.59				
302	10.6	54.2	3.43	5.74	0.506	1.78				
303	11.8	54.2	3.16	5.64	0.500	1.72				
304	12.5	54.4	2.54	5.66	0.484	1.74				
305	10.5	53	3.29	5.71	0.494	1.74				
306	12.3	54	2.04	6.06	0.430	1.60				
307	12.1	53.9	3.10	5.72	0.497	1.64				
308	10.6	54.8	2.88	5.56	0.482	1.71				
309	9.8	54.3	2.46	5.74	0.513	1.78	0.266	64.6	30.7	37.3
310	8.5	54	2.51	6.02	0.460	1.74				
311	12.4	54.5	2.23	6.04	0.462	1.73				
312	12.4	54.2	2.48	5.82	0.470	1.76	0.257	68.0	35.4	49.3
313	12.4	54.6	2.69	5.68	0.510	1.78				
314	11.8	54.3	3.04	5.92	0.504	1.75	0.263	59.7	30.8	40.6
315	10.3	54.9	3.29	6.07	0.482	1.76	0.261	65.9	29.4	44.1
401	12.5	54.5	2.22	6.02	0.474	1.73	0.279	66.8	34.3	41.7
402	11.9	53.5	2.38	5.71	0.459	1.76				
403	11.9	53.2	2.22	5.56	0.426	1.69				
404	10.2	54.3	2.43	5.94	0.438	1.71				
405	9.6	53.6	3.15	5.91	0.435	1.71	0.268	63.0	32.9	35.1
406	9.2	54	2.49	5.78	0.456	1.75	0.261	67.5	36.4	38.4
407	11.9	54.2	2.87	5.67	0.401	1.62				
408	11.9	53.7	2.13	5.79	0.455	1.75	0.280	67.5	36.0	39.5
409	10.7	53.2	2.80	5.92	0.433	1.74				
410	10.6	54.2	2.98	5.76	0.445	1.70				
411	12.7	53.6	1.73	5.53	0.423	1.64				
412	11.9	53.2	2.11	5.68	0.420	1.67				
413	11.8	54.4	1.86	5.73	0.416	1.69				
414	9.7	54.8	2.47	5.76	0.420	1.69				
415	12	53.2	3.09	6.02	0.425	1.74				

Jackson County - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	7.6	55.3	5.09	5.93	0.592	1.97	0.275	55.4	33.5	51.1
102	10	56.3	4.94	6.08	0.574	1.98				
103	10.4	52.4	5.23	5.82	0.568	1.92				
104	10.8	54.9	4.49	5.98	0.597	1.98				
105	10.1	56.6	3.41	5.93	0.588	1.95				
106	7.4	56.2	4.66	5.99	0.608	2.01	0.257	66.4	30.6	45.4
107	11.6	55.2	4.93	6.11	0.633	2.05	0.280	67.8	32.8	51.8
108	8.6	54.9	4.70	5.89	0.611	1.94				
109	8.5	55.6	4.69	5.97	0.596	1.97				
110	7.1	56.5	3.93	5.65	0.632	2.01				
111	7.4	55.2	4.48	5.75	0.608	1.99				
112	7.1	56	4.53	5.78	0.578	1.94				
113	10.1	55.5	4.55	5.92	0.579	1.96				
114	7.4	56.6	4.69	5.93	0.591	1.95	0.276	62.3	31.8	48.9
115	8.4	53.6	5.01	5.92	0.583	1.90				
201	11.6	56.3	4.26	6.03	0.606	2.03				
202	7.5	55.7	4.64	6.15	0.595	1.98				
203	7.4	57.1	4.31	6.05	0.590	1.99	0.277	82.0	31.0	48.9
204	8.9	56.9	4.24	5.98	0.604	1.95	0.270	66.1	31.8	52.4
205	8.1	56.4	4.43	5.80	0.603	1.95				
206	8.2	55.6	4.17	6.11	0.611	2.01				
207	7.9	56.5	4.40	6.16	0.613	2.00	0.258	62.3	30.0	48.5
208	8.5	56.7	4.83	5.98	0.592	1.99				
209	8.3	56.6	4.15	5.52	0.608	1.96	0.263	65.9	32.4	46.9
210	7.1	57	4.01	5.64	0.629	2.02				
211	9.2	56.3	4.53	5.80	0.650	2.09				
212	13	54.8	3.85	5.79	0.631	2.07				
213	7.6	56.5	4.89	5.61	0.627	2.01				
214	7.2	55.6	5.24	5.77	0.615	2.02				
215	7.1	55.9	4.78	6.04	0.624	2.05				

Jackson County - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	7.7	56.4	4.81	5.81	0.632	2.05				
302	7.2	57	4.15	5.63	0.662	2.07				
303	7.4	55.7	4.94	5.66	0.631	2.05				
304	7.7	56	4.93	5.74	0.626	2.01				
305	7.2	56.3	5.13	5.75	0.643	2.07				
306	7.3	56.4	3.91	5.79	0.622	2.03				
307	8.5	55.5	4.06	5.74	0.606	1.99				
308	7.4	56.9	4.00	5.72	0.631	2.03				
309	8.1	55.33	4.80	5.92	0.611	2.03	0.273	60.9	30.9	49.3
310	7.3	57	4.61	5.87	0.609	1.99				
311	8.1	54.4	3.76	5.94	0.624	2.01				
312	8.1	55.7	4.31	5.83	0.632	2.02	0.272	87.2	32.9	45.6
313	9.1	56.6	3.98	5.66	0.563	1.86				
314	7.3	56.8	3.88	5.92	0.580	1.96	0.252	128.7	31.8	43.5
315	7.5	56.7	4.00	5.89	0.605	1.95	0.267	75.6	29.8	43.3
401	7.6	56.3	5.09	6.00	0.588	1.97	0.256	85.0	29.6	48.7
402	8.3	57	5.34	6.04	0.591	1.97				
403	8.2	56.4	4.13	6.15	0.596	2.01				
404	7.2	52.8	4.76	5.95	0.566	1.89				
405	8.8	56.2	4.84	5.96	0.551	1.95	0.250	60.7	29.0	42.7
406	7.8	55	4.38	6.14	0.575	1.96	0.255	58.5	28.6	45.6
407	11.4	54.2	4.68	6.09	0.621	1.99				
408	7.2	55	5.55	6.26	0.590	1.96	0.257	57.5	30.2	43.9
409	7.2	55.4	5.01	5.88	0.557	1.89				
410	7.5	54.8	5.22	5.78	0.587	1.94				
411	9.7	54.3	5.19	6.00	0.577	1.92				
412	10.3	56.5	4.59	5.98	0.569	1.90				
413	7.5	57.2	5.09	5.95	0.567	1.89				
414	8	56.3	5.18	6.01	0.556	1.88				
415	9.8	56	4.94	6.01	0.613	1.98				

Lyon County - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	11	56.5	0.86	6.67	0.570	2.04	0.333	67.0	30.2	58.3
102	10.2	56.7	0.68	6.74	0.518	2.04				
103	10.3	54.8	0.94	6.93	0.577	1.93				
104	10.3	57.1	0.89	6.89	0.560	1.90				
105	10	53.1	0.74	6.86	0.565	1.97	0.323	65.5	30.5	55.8
106	10	54.5	0.65	6.54	0.503	1.97	0.320	65.7	29.9	59.5
107	9.9	52.9	0.52	6.65	0.540	1.96				
108	9.4	47.5	0.72	6.68	0.560	1.91				
109	10.3	54.4	0.59	6.61	0.508	1.83	0.325	66.8	31.4	55.4
110	10.1	53	0.68	6.85	0.550	2.01				
201	10.4	52.4	0.84	6.70	0.539	1.88	0.315	59.3	29.4	55.0
202	10.4	56.1	0.80	6.86	0.553	1.87	0.303	63.9	29.9	56.4
203	10.4	55.5	0.80	6.81	0.558	1.89				
204	9.7	49.6	0.66	6.82	0.496	1.93	0.305	66.9	26.1	55.7
205	10	54	0.92	6.78	0.530	1.85				
206	1	56.1	0.69	6.56	0.499	1.90				
207	10.2	52	0.68	6.73	0.552	1.84				
208	10.2	55.1	0.84	6.76	0.543	1.93	0.303	69.4	29.7	59.6
209	9.9	55.3	1.00	6.80	0.524	1.96				
210	10.1	55.3	0.72	6.95	0.528	1.97				

Lyon County - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	10.9	54.9	1.06	6.80	0.545	1.94				
302	10.1	56.1	0.88	7.01	0.557	1.92				
303	10.7	54.7	0.99	6.82	0.546	1.92				
304	9.7	51.4	0.81	6.90	0.549	1.94				
305	10.2	52.9	0.81	6.73	0.551	1.91	0.305	66.0	29.9	59.0
306	10	57.8	0.63	6.67	0.501	1.86				
307	10	55	0.63	6.69	0.534	1.89				
308	9.6	56.9	0.94	6.98	0.534	1.91	0.301	67.9	29.2	57.4
309	10.1	53.1	0.86	6.48	0.481	1.87	0.291	61.7	28.8	55.3
310	9.8	51.3	0.78	6.71	0.511	1.98	0.298	67.2	28.9	54.8
401	10.2	54.8	0.63	6.83	0.516	1.96	0.296	62.2	30.0	56.4
402	10.5	54.9	0.83	6.96	0.552	1.85				
403	10.2	54	0.82	6.84	0.540	1.90				
404	10.6	55.1	0.85	6.88	0.517	1.93				
405	10.3	52.8	0.71	6.76	0.524	1.89	0.305	66.8	28.9	55.7
406	10.3	55.4	0.76	6.72	0.523	1.89	0.293	66.7	29.3	57.4
407	10.2	56.2	0.77	6.72	0.517	1.91	0.283	65.7	29.8	56.3
408	10	52.8	0.92	6.75	0.517	1.97				
409	10.2	54.4	0.96	6.81	0.506	1.94				
410	9.9	54.1	1.06	6.82	0.524	1.82				

Riley - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	11.7	54.8	2.24	5.67	0.476	1.90	0.290	66.6	41.7	54.1
102	11.9	55.6	2.07	5.98	0.477	1.87				
103	11.9	54.9	1.91	5.95	0.490	1.91				
104	12.1	55.4	2.09	6.04	0.509	1.94				
105	11.8	55.4	1.90	6.10	0.481	1.91				
106	11.8	54.1	1.87	6.33	0.504	1.91	0.273	61.0	43.3	46.3
107	11.7	54.8	1.64	6.22	0.467	1.85	0.283	67.4	45.1	49.5
108	11.7	55.1	1.73	6.11	0.450	1.81				
109	11.7	54.8	1.95	5.97	0.472	1.84				
110	11.7	55.4	1.81	6.17	0.510	1.93				
111	11.9	55.4	1.04	6.02	0.484	1.93				
112	11.7	54.7	1.68	6.15	0.510	1.92				
113	11.8	55.3	1.52	6.23	0.499	1.91				
114	11.6	54.5	1.67	6.11	0.481	1.83	0.299	67.0	44.9	51.0
115	11.8	55	1.66	6.30	0.512	1.94				
201	11.9	55.1	1.88	5.94	0.481	1.83				
202	12.1	54.9	2.15	6.05	0.494	1.92				
203	11.9	54.6	1.85	5.98	0.472	1.89	0.279	70.5	40.2	47.4
204	12.1	55.1	2.02	6.19	0.489	1.97	0.282	63.3	39.0	44.6
205	11.9	55.2	2.01	.	.	.				
206	11.7	52.5	1.68	5.91	0.473	1.90				
207	11.6	55.1	1.49	6.01	0.459	1.91	0.271	59.9	43.3	42.4
208	11.8	55.3	1.62	5.88	0.455	1.89				
209	11.7	50.4	1.97	6.05	0.503	1.98	0.288	61.2	43.5	49.1
210	11.8	54.5	2.22	6.06	0.504	1.86				
211	11.7	55.5	1.90	5.81	0.480	1.89				
212	11.6	54	1.73	6.06	0.499	1.92				
213	11.7	54.8	1.74	5.96	0.479	1.83				
214	11.6	54.5	1.93	5.96	0.492	1.88				
215	11.7	54.3	1.78	6.12	0.499	1.94				

Riley - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	11.8	52.9	1.88	6.09	0.496	2.01				
302	12	55.1	1.95	6.04	0.501	1.96				
303	11.8	54.2	2.00	6.01	0.517	1.96				
304	12.1	55.2	2.15	6.08	0.516	1.99				
305	12	55.7	2.23	6.20	0.511	1.96				
306	11.8	55.2	2.36	5.81	0.496	1.95				
307	12	54.4	2.33	6.03	0.500	1.92				
308	11.9	54.8	2.08	6.04	0.497	1.91				
309	12	53.9	2.17	6.23	0.510	1.98	0.279	61.1	41.6	53.0
310	11.9	55.4	2.12	5.88	0.474	1.89				
311	11.8	55.3	2.21	6.09	0.515	1.92				
312	11.6	53.8	2.03	6.16	0.507	1.91	0.288	65.3	43.1	45.9
313	11.6	53.4	2.22	6.29	0.515	1.85				
314	11.8	54.5	2.03	6.12	0.480	1.82	0.269	61.1	42.0	46.9
315	11.8	55.1	2.32	6.21	0.487	1.91	0.252	57.6	39.7	46.5
401	11.8	53.8	1.88	6.34	0.494	1.96	0.271	62.6	40.4	44.6
402	12	51.6	2.32	5.96	0.487	1.89				
403	12.1	54.4	1.91	5.97	0.503	1.96				
404	12.1	55.3	2.18	6.12	0.503	1.95				
405	12	54	2.32	6.08	0.491	1.91	0.278	71.0	40.6	43.3
406	12.1	55	2.39	5.84	0.492	1.89	0.283	66.6	43.7	47.8
407	12	55.1	2.59	5.94	0.507	1.96				
408	12	55.3	2.38	6.08	0.506	1.95	0.285	69.8	43.0	44.8
409	12	55.3	2.33	5.91	0.512	2.00				
410	12	55.5	2.25	5.90	0.493	1.91				
411	11.8	55.8	2.24	6.23	0.516	1.96				
412	12	55.4	2.12	5.87	0.483	1.93				
413	11.9	55	2.35	6.06	0.481	1.92				
414	12	55.3	2.25	6.06	0.474	1.89				
415	11.9	55	2.38	5.94	0.505	1.94				

Osage County - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	11.4	56.3	2.85	5.69	0.476	1.94	0.255	71.7	30.5	53.3
102	11.7	56.1	3.00	5.74	0.447	1.91				
103	11.8	56.1	2.59	6.17	0.398	1.98				
104	11.8	56.7	3.13	5.87	0.487	1.98				
105	12	56.3	3.17	6.21	0.505	2.04				
106	11.8	57.1	2.81	5.80	0.467	1.98	0.237	66.3	29.8	56.4
107	11.4	56.7	2.59	5.73	0.409	1.96	0.231	67.5	27.3	48.6
108	11.6	56.4	3.30	5.43	0.452	1.92				
109	11.7	56.8	3.17	5.99	0.480	1.97				
110	11.4	55.7	2.87	5.93	0.474	1.95				
111	11.7	56.9	3.02	6.19	0.511	1.96				
112	11.6	56.6	3.12	6.22	0.555	2.02				
113	11.6	56.3	2.86	6.11	0.443	2.01				
114	11.7	56.5	2.83	6.01	0.538	2.00	0.264	72.0	30.3	52.1
115	11.5	56.8	2.98	6.03	0.518	1.93				
201	11.7	56.5	3.39	6.01	0.493	1.97				
202	11.7	56.5	3.58	5.81	0.523	1.97				
203	11.5	56.2	3.46	5.92	0.535	2.05	0.241	70.5	30.3	47.6
204	11.4	56.6	3.07	5.98	0.498	1.99	0.256	73.1	30.0	50.8
205	11.5	56.8	3.17	5.68	0.536	1.97				
206	11.5	58	3.17	5.96	0.507	1.96				
207	11	56.9	3.01	6.05	0.500	1.92	0.252	71.2	30.4	49.8
208	11.2	55.9	2.84	6.17	0.489	1.92				
209	11.4	56.7	2.91	5.95	0.524	1.94	0.259	72.7	29.6	52.8
210	11.6	56.8	3.55	5.95	0.536	1.95				
211	11.6	56.9	3.44	5.98	0.511	1.93				
212	11.4	56.3	3.13	6.03	0.516	1.97				
213	11.4	56.9	3.02	6.06	0.536	1.89				
214	11.6	56	2.89	6.16	0.510	1.90				
215	11.4	57	2.86	6.09	0.479	1.87				

Osage County - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	10.1	.	3.04	5.81	0.526	2.03				
302	10.5	53.3	3.09	5.80	0.474	1.92				
303	10.7	55.9	3.49	6.14	0.504	1.95				
304	10.5	55	2.93	5.76	0.528	1.93				
305	10.6	56	3.06	6.11	0.535	1.88				
306	10.7	55.9	3.18	6.20	0.533	1.93				
307	10.6	56.2	3.08	6.09	0.541	1.93				
308	10.6	54.8	2.95	6.06	0.511	1.88				
309	10.5	55	3.09	6.00	0.514	1.95	0.265	72.0	33.0	51.8
310	10.5	55.7	3.06	5.89	0.501	1.88				
311	10.4	55.4	3.07	6.00	0.518	1.87				
312	10.4	56.1	3.02	5.90	0.528	1.94	0.254	74.4	30.1	53.2
313	10.4	56.2	3.23	6.13	0.476	1.87				
314	10.4	56.3	2.81	6.17	0.472	1.88	0.248	76.3	29.2	52.0
315	10.4	55.9	3.03	6.10	0.516	1.85	0.253	76.6	29.9	50.4
401	10.4	51.3	3.89	6.05	0.550	1.95	0.259	73.0	36.1	48.9
402	7.2	54.8	3.36	6.09	0.545	1.94				
403	7.1	54.6	2.97	6.28	0.569	2.02				
404	10.3	51.7	3.30	6.08	0.500	1.97				
405	7	54.7	3.23	6.18	0.542	1.96	0.275	74.6	35.5	50.5
406	7.1	54.9	2.99	5.70	0.556	2.01	0.246	77.4	33.9	49.7
407	10.3	54.9	3.06	5.78	0.544	2.01				
408	7.3	54.5	3.15	5.69	0.492	1.88	0.252	77.8	32.1	50.4
409	7.1	55.6	2.88	5.67	0.520	1.95				
410	10.2	53.5	2.93	5.64	0.538	1.96				
411	7.2	56.1	3.38	5.87	0.512	1.86				
412	7	54.6	2.78	5.99	0.506	1.96				
413	10.4	55.8	3.45	5.93	0.547	1.90				
414	6.8	52.1	3.71	6.11	0.547	1.94				
415	7	53.7	3.63	5.84	0.539	1.95				

Woodson County - meadow - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	9.9	56.9	1.47	5.83	0.510	1.76	0.272	63.2	34.8	54.7
102	8.9	56.5	1.80	5.94	0.481	1.75				
103	8.2	56.7	1.76	5.92	0.494	1.77				
104	8.3	55.4	1.41	6.06	0.523	1.75				
105	8	54.7	2.01	5.89	0.518	1.74				
106	9.1	56.5	2.09	5.62	0.479	1.63	0.262	69.9	34.9	47.6
107	8.9	55.2	1.89	5.55	0.445	1.60	0.257	63.5	33.2	53.6
108	8.2	55.6	1.64	5.51	0.535	1.74				
109	8.4	56.2	1.81	5.51	0.536	1.71				
110	8.6	55.3	1.90	5.36	0.526	1.68				
111	8.6	55.7	1.59	5.45	0.523	1.52				
112	9	54.6	2.40	5.46	0.536	1.73				
113	9.6	54.3	2.31	5.49	0.502	1.71				
114	9	55.4	2.12	5.05	0.549	1.74	0.291	85.4	43.0	49.4
115	10.1	55.5	1.12	6.03	0.524	1.66				
201	8.9	56.3	2.09	5.72	0.497	1.67				
202	8.6	56	2.22	5.59	0.493	1.65				
203	9.3	55.5	2.28	5.65	0.484	1.67	0.266	75.8	35.5	42.5
204	9.1	56.5	1.89	5.86	0.504	1.68	0.267	64.9	31.2	46.1
205	9.8	56	2.04	5.69	0.513	1.68				
206	8.8	56.1	1.81	5.55	0.454	1.66				
207	9.3	55.7	1.91	5.71	0.482	1.72	0.265	68.3	34.5	46.2
208	10.6	52.5	2.31	5.92	0.549	1.72				
209	9.6	55.3	1.52	6.07	0.531	1.75	0.270	65.2	35.0	53.2
210	8.9	55	2.17	5.62	0.536	1.71				
211	9.5	54.9	2.22	5.43	0.488	1.57				
212	8.8	54.6	2.67	5.50	0.505	1.71				
213	9.9	54.3	2.68	5.49	0.529	1.70				
214	10.3	55.2	2.64	5.23	0.471	1.66				
215	8.6	55.6	1.85	5.94	0.476	1.65				

Woodson County - meadow - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	8.1	55.5	1.96	5.68	0.457	1.70				
302	10.5	55.3	2.30	5.56	0.479	1.69				
303	8.2	56.1	2.01	5.45	0.505	1.63				
304	10	54.2	1.85	6.06	0.545	1.83				
305	8.7	55.8	2.05	6.12	0.533	1.73				
306	8.7	57.5	1.35	6.29	0.547	1.85				
307	9.7	55.7	1.85	5.98	0.560	1.84				
308	9	54.9	1.77	6.01	0.570	1.84				
309	8.7	55.6	1.75	5.88	0.573	1.92	0.273	74.5	42.3	53.0
310	9.4	54.6	2.26	5.58	0.499	1.76				
311	9	54.1	2.57	5.27	0.518	1.68				
312	10.1	54	2.61	5.46	0.545	1.84	0.279	82.4	38.2	50.6
313	9	54.2	2.63	5.46	0.490	1.80				
314	9.6	54.1	2.72	5.26	0.438	1.73	0.256	74.6	34.6	48.1
315	9	54.9	1.97	5.77	0.508	1.66	0.267	81.4	33.4	44.9
401	9.2	54.4	1.97	5.70	0.463	1.70	0.274	76.4	36.3	50.3
402	9	55.4	2.01	5.55	0.516	1.67				
403	11.2	54.8	2.17	5.82	0.494	1.65				
404	9.8	54.4	1.91	5.80	0.505	1.75				
405	8.5	55	2.18	5.72	0.528	1.80	0.280	71.9	34.8	52.7
406	9.1	56.6	2.04	6.06	0.530	1.82	0.288	69.1	34.7	54.5
407	9	55.8	1.71	5.77	0.541	1.75				
408	8.5	54.3	2.13	5.43	0.537	1.81	0.269	78.6	37.3	50.9
409	9.2	54.7	2.59	5.61	0.515	1.75				
410	9.6	54.5	2.29	5.43	0.535	1.80				
411	9.6	54.8	2.78	5.57	0.544	1.86				
412	9.1	53.7	2.53	5.46	0.509	1.82				
413	10	54.4	2.77	5.61	0.553	1.84				
414	10.5	53.6	2.53	5.57	0.496	1.85				
415	8	54.5	2.21	5.97	0.522	1.72				

Woodson County - pasture - grain analysis										
plot	moisture	test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
101	8.1	56.2	1.82	4.89	0.583	2.00	0.307	81.5	51.5	63.6
102	8.3	56.2	1.93	5.54	0.536	1.91				
103	8.1	54.9	2.64	5.21	0.500	1.90				
104	8.4	53.1	2.73	5.15	0.536	1.86				
105	8	54.5	2.84	5.07	0.493	1.81				
106	8.4	54.2	2.14	5.28	0.504	1.77	0.288	80.4	41.3	50.6
107	8.3	53.2	2.14	5.18	0.424	1.80	0.287	73.7	40.9	50.5
108	9.4	53.7	2.32	5.07	0.481	1.79				
109	7.7	53.5	1.98	5.01	0.521	1.87				
110	7.5	51.6	2.55	5.06	0.466	1.79				
111	8.2	53.3	2.12	5.51	0.503	1.84				
112	8.96	53.2	2.71	4.97	0.460	1.67				
113	8.9	53.2	2.29	5.10	0.400	1.67				
114	9.1	53	2.14	4.85	0.496	1.83	0.307	79.7	44.2	55.3
115	.	.	.	5.58	0.508	1.83				
201	8	56.1	1.98	5.27	0.542	1.89				
202	7.9	56.2	2.42	5.33	0.528	1.88				
203	8.1	55.4	2.79	5.40	0.480	1.80	0.297	76.2	45.7	54.4
204	8.2	55.3	2.61	5.01	0.527	1.85	0.297	90.2	44.0	59.0
205	8.6	54.9	2.69	5.19	0.514	1.81				
206	8.7	53.2	1.88	5.45	0.465	1.75				
207	7.3	53.1	2.43	5.21	0.406	1.71	0.262	68.5	35.0	44.1
208	.	.	.	.	.	.				
209	7.7	55.5	1.56	4.79	0.562	2.03	0.286	76.3	39.0	52.8
210	8.4	53.7	2.26	5.13	0.481	1.81				
211	8.2	53.5	2.59	5.06	0.461	1.74				
212	9.5	53.9	1.81	5.20	0.466	1.80				
213	7.7	54	2.04	5.34	0.500	1.80				
214	9.3	53.9	2.42	5.25	0.436	1.73				
215	8	54.3	1.79	5.45	0.465	1.82				

Woodson County - pasture - grain analysis										
plot	moisture	Test weight	yield at 13 %	N	P	K	S	Fe	Mn	Zn
	%	lbs bu^{-1}	Mg ha^{-1}	%				ppm		
301	8	57	1.85	5.82	0.531	1.93				
302	8.4	56.2	1.88	5.58	0.513	1.88				
303	7.5	54.8	1.93	5.51	0.523	1.88				
304	8.2	53.3	1.55	5.70	0.540	1.93				
305	8	55.7	2.08	5.57	0.545	1.93				
306	7.8	55.8	2.31	5.21	0.487	1.74				
307	8.3	53	1.55	5.59	0.515	1.79				
308	9	54.2	1.64	5.48	0.516	1.87				
309	8.2	54.8	1.68	5.39	0.508	1.91	0.271	71.5	37.1	51.9
310	8.1	54.1	1.84	4.87	0.419	1.70				
311	9.8	53.9	2.13	4.84	0.467	1.76				
312	8.2	54.4	1.67	4.92	0.509	1.89	0.267	72.9	36.0	51.6
313										
314	8.1	54.9	1.74	5.31	0.451	1.80	0.268	66.5	30.1	45.6
315	8.9	54.4	1.56	5.19	0.510	1.82	0.271	76.5	36.5	53.9
401	8.1	56.2	1.62	5.62	0.540	1.84	0.273	68.9	35.4	50.1
402	8.4	56.2	1.52	5.95	0.557	1.87				
403	8.8	54.4	1.93	5.76	0.535	1.85				
404	8	56.4	2.00	5.69	0.519	1.88				
405	7.7	54.7	2.17	5.77	0.536	1.88	0.269	72.2	35.2	49.2
406	8.2	55.7	1.91	5.75	0.555	1.91	0.266	70.4	33.1	50.9
407	9.2	53.2	1.60	5.69	0.538	1.91				
408	8.4	54.1	1.60	5.60	0.510	1.85	0.270	70.5	32.3	52.2
409	8.4	55.8	1.64	5.71	0.504	1.78				
410	8	53.4	1.97	5.57	0.459	1.83				
411										
412	8.7	53.5	2.25	5.01	0.434	1.75				
413	8.9	54.4	2.12							
414	8.1	53.1	2.14	5.21	0.410	1.68				
415	8.1	53.3	1.50	5.60	0.504	1.87				