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Soybean Yield and Plant Response to Phosphorus Fertilization

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SOYBEAN YIELD AND PLANT RESPONSE TO PHOSPHORUS FERTILIZATION

BY

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SOYBEAN YIELD AND PLANT RESPONSE TO PHOSPHORUS FERTILIZATION

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ABSTRACT

SOYBEAN YIELD AND PLANT RESPONSE TO PHOSPHORUS FERTILIZATION

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Phosphorus (P) is a key limiting nutrient for soybean production in South Dakota. Soil tests have been used as a baseline indicator for plant available P and fertilizer recommendations for over a century. Plant nutrient analysis may be used to complement a soil test as a way to validate fertilizer and management practices. Soybean nutrient sufficiency ranges have only been slightly adjusted since they were published in the 1960's. The objectives of this study were to update the soil test P and soybean plant P sufficiency level in South Dakota and to recognize implications of improper plant sampling. We also wanted to differentiate between nutrient concentration and nutrient uptake. A randomized complete block design was used for this experiment in Eastern South Dakota at eleven locations in 2013, and ten locations in 2014. Triple Super Phosphate (TSP)-fertilizer treatments were broadcast applied at the following rates: 0, 22, 45, 67, 90 kg P^2O^5 ha^{-1}. Data collected included pre-plant soil samples, plant tissue samples at V4, R2 and R6.5 growth stages. In addition, grain samples and yield was measured. Tissue samples were analyzed for total P and soil samples were analyzed for Olsen, Bray-P1 and Mehlich 3 P. There were no significant differences in yield across locations in either year of the study. Grain P concentration increased at higher P rates. Failing to remove the petiole diluted trifoliolate P concentration by 15 to 18% . Improper

plant sampling methods result in inaccurate nutrient data to make management decisions with. Fertilizer recommendations should be reevaluated with economic optimum in mind.

CHAPTER 1

INTRODUCTION

South Dakota producers are looking for ways to maximize soybean production. Soil tests have been used as a baseline indicator for plant available P and fertilizer recommendations for over a century. Fertilizers are used to supply soil and plant nutrients, maximize yield and return on investment. Phosphorus (P) is a key nutrient used in fertilizer due to its role in energy transfer, photosynthesis and growth in plants (Li et al., 1998). Phosphorus is a nutritional requirement in soybean for nodule development and functioning (Sa and Israel, 1991). There are a wide variety of influences in the soil that affect P availability. Investigating efficacy of the current P fertilizer management practices in South Dakota is of prime importance. The nutrient requirement of plants depends on many coexisting factors including plant type, yield goal, soil nutrient status, soil type, climatic conditions and land management. A significant amount of P and other nutrients are removed at harvest in the grain. For instance, 3350 kg ha^{-1} soybean yield will remove 46 kg P ha^{-1}, 12600 kg ha^{-1} corn yield will remove 46 kg P ha^{-1}, and 4020 kg ha^{-1} wheat yield will remove 22 P kg P ha^{-1}. When the soil itself does not supply adequate plant essential nutrients, the nutrients may need to be added through fertilizer in order to maintain yields.

Prediction equations based on initial soil nutrient levels, crop being grown and yield goals are used to determine the economic fertilizer rate (Halvin, 1999). Following this rate may or may not replace what is removed during harvest. These equations rely on many assumptions that depend on nutrient cycling (Anthony et al., 2012). It is obvious that yield has a relationship with soil nutrient status; however, there are many other variables that also contribute to yield (Dahnke and Olson, 1990).

There are a few common ways to determine fertilizer recommendations (Dahnke and Olson, 1990; Olson et al, 1987). The sufficiency method is the most common for interpreting soil test results and making a fertilizer recommendation. This method applies P based on current season yield response. With this method, the soil test analysis will correspond with an interpretation of very low, low, medium, high and very high (probabililty of responding to fertilizer application). The other approach to making a fertilizer recommendation is the build-up and maintain method. A significant amount of nutrients are removed every time a crop is harvested from the field. With this approach, the producer will replace what is removed with the grain at harvest, regardless of the soil test analysis. Soil will be built up to sufficiency and maintained by replacing the harvest removal of the nutrients, to avoid mining the soil. With this approach, even with very high soil test levels, fertilization will be required to maintain that level (Olson et al. 1987). Another method of fertilizer recommendation is the cation ratio method. This method proposes and recommends “ideal” proportions of exchangeable cations in soil. This method is not utilized as a majority of research studies refute the idea that such an ideal ratio exists (Dahnke and Olson, 1990).

Grain removal of P in soybeans has been estimated to be up to 81% of total P uptake during the growing season (Adeli et al, 2005). P is removed from the soil primarily through crop removal (Pierzynski et al. 2005). P availability in the soil can vary greatly with multiple and coexisting causes. For instance, the P source and soil properties such as pH or drainage can impact soil P availability to plants. Maximum P availability is generally observed between pH 6.5 and 7 (Halvin, 1999, Anthony et al, 2012).

Phosphorus cycling in soils is a complex phenomenon and depends on environmental factors including soil moisture and temperature. The amount of labile or available P available to plants in solution is low and is influenced by soil, plants and microorganisms. Labile P has to be constantly replenished to replace plant needs over the course of a plant's life so that P in solution is available to the plant at every growth stage. Contribution and bioavailability of organic P in soil solution is not completely understood. Further, mechanisms controlling rate of P exchange and availability are not completely understood (Pierzynski et al. 2005). Phosphorus is taken up as an inorganic anion ($H_2PO_4^-$ and HPO_4^{2-}) and therefore, organic P must be mineralized prior to plant uptake. Because P transport to the root is predominantly through diffusion, uptake can be decreased by soil drying or increased by practices that increase root length (Halvin, 1999). Rate of diffusion is affected by temperature and moisture; therefore it is not the quantity of P applied that affects availability, but the rate at which P in solution can be replenished. Most P in soils is derived from the weathering of apatite (Pierzynski et al. 2005). As apatite is broken down, the P has potential to bind with metals or salts and become unavailable to plants (Pierzynski et al. 2005). Soils with high clay content will adsorb more P because of the large surface area. Eastern SD soils have higher pH; sometimes alkaline conditions exist with very high levels of soluble salts. In conditions as such, the P becomes unavailable when it binds with the Ca and forms insoluble compounds.

Symbiotic relationships between arbuscular mycorrhizal fungi and soybean creates extension of the root system and allows for more growth and soil exploration for plants. As a result, the roots are able to locate more nutrients for the plant. In no-till/undisturbed soil, this healthy symbiotic mycorrhizal relationship can create a more efficient environment for nutrient uptake. This relationship allows plants to overcome nutrient depletion zones and extend into more soil. If roots do not grow into a new zone of nutrients, rate of uptake may be decreased because the depletion zone in the rhizosphere is replenished very slowly (Taiz et al, 2015). Smith and Read found that P uptake was 5 times higher from soybean roots that were colonized by mychorrhizal fungi than non-infected roots. In no-till soils or soils that have embraced a more diverse rotation, healthy symbiotic mycorrhizal relationships may create effective soil environment for P availability (Smith and Read, 1997).

Adding inorganic P fertilizers to soil will likely cause an increase in the concentration of P in soil solution (Pierzynski et al. 2005). Fertilizer recommendations will be higher for soils that have a fine texture, high clay content and high pH (Halvin, 1999). Anthony, et al (2012) reported that soil pH has a large influence on soil test P, and that at high levels it can form calcium phosphates. After fertilization, more than 80% of the P may become immobile due to the soil pH and other soil physiological processes (Doberman et al. 1998).

We have relied on these soil test P values, and harvest removal values for many years. However, spatial and temporal variability cause variation in soil, causing lack in uniformity. Multiple studies have indicated that soil nutrients are spatially variable (Cahn et al, 1994; Cambardella et al., 1994; Robertson et al., 1997, Chang et al., 2004). This is a result of many soil and management factors that interact and also because nutrient cycling is dynamic and always changing. Previous research has indicated that soil nutrients can increase or decrease in uniform plots after fertilization (Barber, 1979, Dodd and Mallarino, 2005, Leikam, 1992, Randall et al. 1997, Webb et al. 1992).

The cost of phosphate fertilizer production is expensive and very energy intensive. In addition, phosphate reserves are finite, and have already reached critical levels (Sanders, 2010). It is important to determine if the current nutrient recommendations are sound and up to date to prevent unnecessary additions and farmer expense. Another issue with P management is the land use practices on the land with surface applied P. Applying high levels of P to land that is tilled, sloped or has poor soil structure, has a tendency to flow off or "run-off." The runoff may flow into streams, ponds, lakes and downstream. Nutrient runoff causes eutrophication and excessive algae growth, reducing oxygen for aquatic animals and destroying ecosystems. A prime example of this environmental destruction from nutrient runoff, specifically P is Lake Erie in Ohio. Since th e1960's, Lake Erie is known to be "dying" due to nutrient contamination. The lake provides drinking water to thousands and has been quarantined in the past due to toxic algal blooms resulting from nutrients, P in particular (Hinchey-Malloy, 2016).

Phosphorus is a relatively immobile, nevertheless, in the anion form it is able to leach downward through the soil profile during times of precipitation or irrigation (Mills and Jones, 1996). Because the available soil P will leach, there is concern that excess P moves through tile drainage systems and move into water sources and pollutes fresh water sources. Excessive fertilization increases cost with no promise in yield, on the other hand, can cause environmental pollution and reduce supply of a finite resource.

Long-term P management results in a different soil nutrient composition than short-term P management. (Ciampitti et al. 2011) The general soil fertility influences P and other fertilizer efficiency (Otinga et al., 2012). Balancing inputs and outputs of nutrients is important to sustain fertility and productivity in the long term. Therefore, it is important for researchers, agronomists, scientists and producers to have references to long-term research in this area to monitor P availability over time and with different land management practices. Because management practices alter soil structure, organic matter (OM), water infiltration, temperature, etc., it is important to recognize that management practices will affect P mobility and uptake of plants. Effectiveness of broadcast fertilization can be affected by land management such as no-till or conventional tillage practices. Differences in placement of P fertilizer have been studied and results are inconsistent. Broadcast fertilizing is a common, easy and inexpensive fertilizing practice. Unfortunately, depending on all of the aforementioned variables, broadcast P fertilization may prove unsuccessful due to the lack of mobility. The root zone supply of P and other nutrients becomes depleted and is slowly replenished through the process of diffusion.

Plant tissue analysis may complement fertilizer recommendations based on soil testing. Historically, chemists determined that a relationship exists between production and plant tissue nutrient concentration in the early 1800's while studying content in plant ash (Reuter and Robinson, 1997). Producers rely on yield as the ultimate indicator of crop response to environmental stimuli but plant nutrient composition is a more precise indicator of nutrient status (Melsted et al, 1969). Utilizing plant tissue to determine status of soil nutrients dates back to early 1900's. Back then, the idea was that the plant itself would be the most accrate reflection of the medium in which it was growing (Kamprath and Watson, 1980).

Currently, plant analysis is used for trouble-shooting nutrient imbalances or deficiencies. It is used to determine probable nutrient problems that may contribute to production problems, and improve crop production by monitoring nutrient status (Reuter and Robinson, 1997). Plants may indirectly reflect the soil nutrient status while showing their own nutrient status (Kamprath and Watson, 1980). Sufficiency ranges for 12 plant essential nutrients in soybean trifoliolates were developed in the 1960's by Sigurd W. Melsted (1969**).** These sufficiency ranges may be questionable due to age as soybean yield potential has increased over time. In addition, a definitive protocol has not been developed. There is importance in familiarization with normal variation in plant composition in a variety of environments for logical interpretation (Melsted et al., 1969). Because of the multiple and coexisting variables affecting soil and plant P, it is important to try to identify trends and replicate any experiment for further study, analysis and validation.

Two stages of growth where nutrients are in high demand are late vegetative (V) and early reproductive (R). During these stages, nutrient demand is high, but there is enough time in the growing season to correct a deficiency (Halvin et al., 1999). Translocation of nutrients during flowering and reproductive stages shifts nutrients from vegetative organs into the seed/grain of the plant. Up to 85% of P is translocated into the grain of plants. Because of these relationships, it is of upmost importance to understand partitioning relationships of plant nutrients and how this relates to plant growth and production. Improving plant tissue analysis interpretation is important for understanding plant nutrient translocation, remobilization and plant growth to increase production and sustainability (Reuter and Robinson, 1997).

Nutrient sufficiency ranges for vegetative growth stages or profiles for petiole nutrition have not been developed. Soybean plant nutrients collect in the leaf tissue, but petioles and other plant tissues can also store nutrient reserves (Reuter and Robinson, 1997). Because it is difficult to predict accurately when a nutrient deficiency will occur, it may be useful to have nutrient sufficiency ranges at multiple growth stages to use as a reference. Multiple sample dates of reference will also allow more convenience for the grower. Melsted et al. (1969) stated that it would take thousands of samples and hundreds of fertility trials to create useful sufficiency range for comparison between plant samples and even then, there would be wide variation in nutrient composition between samples. There may be no visible signs or increase in yield when a nutrient is available in higher levels. Plant tissue analysis is a way to directly evaluate the nutrient status of the plant and may indirectly evaluate soil nutrient status (Kamprath and Watson, 1980).

Sampling consistent plant parts at the correct growth stages is very important. Inaccurate or inconsistent sampling will provide values that may be unable to be compared with other published sufficiency ranges at specific growth stages (Halvin, 1999). Melsted et al. (1969) developed the soybean nutrient sufficiency ranges based on tissue sampling the upper most fully expanded trifoliolate including the petiole at full bloom prior to pod set. No interpretations for other growth stages or plant parts have been identified or standardized. J.B. Jones also developed soybean nutrient sufficiency ranges however he did not include the petiole with the trifoliolate (Jones, 1967). According to Mills and Jones (1996), nutrient uptake depends on the plant genetics and environmental conditions. Kamprath and Watson commented that plant analysis can lead to meaningless interpretation when the concentration is analyzed without considering plant growth/uptake (1980). Consistent protocols for soybean tissue sampling need to be developed to make relevant comparison to previous nutrient values. Previous research in plant tissue analysis has proven that specific part of the plant and location must be consistent to draw any conclusion or comparison to previous plant nutritional data available (Jones, 1967). The protocol needs to be consistent throughout the growing season and nutrient sufficiency ranges need to be developed for multiple growth stages for use as a nutrient monitor.

Understanding the relationships that exist between nutrient composition and production is very valuable. Multiple relationships between nutrient concentration and yield have been developed over the years. In production environments, the most logical relationship is that yield will increase with nutrient concentration to a point, saturation point (plateau), followed by toxic levels of a nutrient (yield will decrease). Depending on the nutrient being analyzed, the linear portion of the relationship may be longer or shorter as with the plateau. (Munson and Nelson, 1990). Many plants may never acquire a luxury or toxic accumulation of the nutrient. It is also notable to recognize that multiple biological and environmental influences nutrient composition of a plant; therefore, a nutrient sufficiency range is more appropriate than an individual concentration number (Reuter and Robinson, 1997).

Despite these historical research studies, a tremendous gap of information continues to exist with regard to soybean nutrient data. Technology, genetics and yields have significantly changed since the 1960's; therefore sufficiency ranges need to be revisited and verified. Yields are significantly higher than they were in the 1960's yet we continue to use the same sufficiency ranges. It is important to evaluate potential changes in critical and optimum sufficiency levels. Sufficiency ranges for soybean trifoliolates may need to be updated. Petioles need to be studied because they contain nutritional reserves for the rest of the plant. The impact of including petioles in the sample should be demonstrated to those taking samples and interpretating data. Time of sampling, location on the plant, drying, grinding and chemical analysis must be consistent for valid comparisons to be made.

Improper tissue sampling (specific tissue and/or growth stage) could result in inaccurate data due to dilution or other variables. Personal judgement in plant part selection plays a role in tissue sampling and may cause noise in nutrient data. "Measuring only plant P concentration without evaluating plant growth can lead to meaningless interpretation when the purpose of the measurement is to establish guidelines to separate plants deficient in P from those sufficient in P (Kamprath and Watson, 1980)." When a plant grows larger, the nutrients spread out through the new plant tissue causing a lower nutrient concentration per sample. This is why it is important to consider the weight of the plant tissue to understand the nutrient content. A large and small plant may have the same total amount of a nutrient. The small plant has a higher concentration, but after uptake is determined, the small and large plant have the same total nutrient.

OBJECTIVES

The objectives of this study were to validate current soil test P interpretations in SD with respect to soybean yield response. Also, we wanted to confirm the accuracy of trifoliolate P sufficiency ranges and relationship between trifoliolate, petiole and grain in response to applied P to improve fertilizer recommendations. We also wanted to distinguish between nutrient concentration and nutrient uptake. Lastly, we wanted to identify specific growth stages and plant tissues that should be sampled to eliminate inaccurate nutrient interpretation.

MATERIALS AND METHODS

Field research was conducted in 2013 and 2014 at 21 locations in Eastern South Dakota (Table 1). All locations were rain-fed, and crop management practices other than P fertilization were determined by the grower (Table 2). A randomized complete block design with 4 replications was used at each site. Triple super phosphate was broadcast at rates of: 0, 22, 45, 67, 90 kg P_2O_5 ha^{-1} (0, 10, 21, 31, 41 kg P ha^{-1}) at each site. Site 11 had 4 rates of triple super phosphate: 0, 34, 67, 135 kg P_2O_5 ha^{-1} (0, 16, 31, 62 kg P ha^{-1}). The size of each experimental unit was 5 m wide by 9 m long.

A soil probe (1.9 cm diameter) was used to collect soil samples within each plot before treatments were applied. A composite soil sample (10 cores) at the 0-15 cm and 15-30 cm depth were collected for each experimental unit at each location. The samples were analyzed for available P (Mehlich-3, Olsen-P, Bray P-1), and total P according to Frank et al (1998). Additional analysis of soil pH (1:1 soil: water), organic matter (OM) by weight loss-on ignition (Combs and Nathan, 1998), cation exchange capacity (CEC) by summation (Warncke and Brown, 1998), Fe, Mn, Zn, and Cu by DPTA (Whitney, 1998), and B by hot water were performed (Watson, 1998).

Tissue samples were collected at V4 and R2 growth stages (Ritchie et al., 1994). Samples from 30 of the uppermost fully-expanded trifoliolates with the petioles were collected within each experimental unit. Samples were separated into trifoliolate (leaflet, rachis, and petiolule) and petiole, oven dried at 65° C (140° F), weighed, and ground to pass a 2 space mm-screen. The tissue samples were digested with HNO_3 and 30% H_2O_2, then analyzed using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) for P, K, Ca, Mg, S, Mn, Fe, B, Cu and Zn. Samples were analyzed for N by Total Kjeldahl Nitrogen (SDSU, 1999). Tissue samples were not washed prior to analysis. Sixty samples were collected at site 2 during V4 sampling as a result of inadequate plant biomass at this growth stage.

At R6.5 (full seed), 1 meter length of row of above ground soybean plants (biomass) per plot were cut from a non-harvest row (Adeli et al, 2005). The biomass samples were weighed, and ground in the chipper/shredder, subsample collected, weighed, dried at 65° C (140°F) and weighed again. The biomass subsamples were ground on a Wiley mill to pass a 2mm screen. The ground sample was then digested with HNO_3 and 30% H_2O_2, then analyzed using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) for P, K, Ca, Mg, S, Mn, Fe, B, Cu, and Zn. Samples were analyzed for N by Total Kjeldahl Nitrogen (SDSU, 1999). These results will not be discussed in this paper as it was not a primary research objective. The data can be found in the appendix (A-1 to A21).

A Massey Ferguson plot combine (8XP) was used for harvest. The middle 1.524 m of each experimental unit was harvested for yield data and expressed at a moisture content of 130 g kg^{-1}. Grain from each plot was run through a Foss Tecator (Infratec 1229 Grain Analyzer) to determine oil and protein. The grain was ground through an industrial coffee grinder, then digested and analyzed using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) for P, K, Ca, Mg, S, Mn, Fe, B, Cu and Zn. Samples were analyzed for N by Total Kjeldahl Nitrogen (SDSU, 1999).

A randomized complete block design (RCBD) with four replications at each test location was used. An analysis of variance (ANOVA) model was fitted to the data for each single location or environment as well as a combined data across all test locations. The ANOVA for the combined data across all test locations was performed in order to obtain treatment-by-location interaction effect. The Fisher Least Significance Difference (LSD) test was used to perform pairwise comparisons among different levels at an alpha level = 0.05.

The linear model for the single location data was a simple RCBD model as shown below:

$$y_{ij} = \mu + T_i + B_j + e_{ij}$$

Where;

Y_{ij} is the observed value

μ is the population mean

T_i is the treatment (Prate) effect

B_j is the block effect nested within location

e_{ij} is the random error

The linear model for the combined data analysis showing location effect and treatment-by-location interaction effect is given below:

$$y_{hij} = \mu + L_h + T_i + LT_{hi} + B_{j(h)} + e_{hij}$$

Where;

y_{hijk} is the observed value

μ is the population mean

L_h is the location/environmental effect

$_{Ti}$ is the treatment (Prate) effect

$_{LThi}$ is the treatment × location interaction effect

$B_{j(h)}$ is the block effect nested within location

e_{hij} is the random error

All data analyses were performed in R. The analysis for the single location data was done by creating a loop function in R that performed the ANOVA for each test location simultaneously. The R codes in the data analyses are shown in Appendix.

RESULTS AND DISCUSSION

Heavy rains in early spring 2013 pushed off planting dates and drought stress during reproductive stages likely hindered seed filling (Todey, 2015). The 2014 season was more conducive for soybean production. Growers were able to plant earlier, and much more rain was scattered early in the growing season. Yields averaged 2916 kg ha^{-1} in 2013, and 4305 kg ha^{-1} in 2014 (Table 7). The highest yielding site in 2013 was site 9 with 3944 kg ha^{-1}. The lowest yielding sites were 3, 6, 7 and 8 with 2247, 2151, 2357 and 2401 kg ha^{-1} respectively. At site 4, the 67 and 90 kg P ha^{-1} treatments yielded significantly lower than all other treatments. At sites 3 and 6, the 90 kg P ha^{-1} treatments yielded lowest as well. Overall there were no significant differences in treatments across sites and no interaction between site and P rate. Table 7 shows that six sites had statistically significant differences in yield; however, only 3 sites had a positive relationship with P application (sites 6, 11 and 20).

The highest yielding site in 2014 was site 17 with 5897 kg ha^{-1}. This site was in continuous no-till with corn as the previous crop and rye cover crop burn down prior to this study. Site 15 had the highest levels of initial soil test P across all sites, yet yielded lower than site 17 with 5432 kg ha^{-1}. The highest yielding treatment at site 15 was the control and the 67 and 90 kg ha^{-1} yielded lowest. Site 15 was conventionally tilled and fallow the previous growing season. The lowest yielding site in 2014 was site 19 with 2961 kg ha^{-1}. This site had weed issues throughout the season, with volunteer soybeans at harvest. Overall there were no significant differences in treatments across sites for either year of this study.

Payne et al, 1992 found that water use efficiency is increased by P fertilization. 2014 had more scattered rainfall early in the season during planting and P application. This may be why 2014 soybean plants visually appeared larger and had more vigor across all locations in comparison to 2013. In fact, in 2013, site 2 was sampled with 60 plants rather than 30, because of inadequate biomass. In 2014, sites 15, 16 and 21 showed an apparent visual response with higher P rates, but yield was not always higher (Table 7). P application often increases seedling vigor without a response in yield (Mills and Jones, 1996).

Soil Test P, P Rates, and Seed Yield Response

Three sites were categorized as “low” and eight sites as “medium” (Tables 4 and 5) in initial Olsen soil P based on current soil test calibration levels (Gelderman et al., 2005). According to SD fertilizer recommendation, 11 of the 21 sites would have needed fertilizer to reach yield goals. However, 10 of the sites in our study were “high” or “very high” in initial soil P. According to SD fertilizer recommendations, producers would be advised not to apply any fertilizer P to these fields because they would not expect an increase in yield or return on investment. Because of the “high” and “very high” soil classifications, it was unlikely to see a yield response with the fertilizer additions at many sites evaluated in this study. However, of the three sites with “low” soil test P (STP)’s, only 1 or 33% of the sites had a positive yield response with applied P. Eight sites were categorized as “medium” soil test P and none of these sites had a positive yield response to applied P. Five sites were categorized as “high” STP, and 40% (sites 6 and 20) had a positive response to P fertilizer additions where one or two treatments yielded higher than the control plots (Table 7). Zero of the “very high” STP sites had a positive yield response to applied P. Despite initial soil classification, most sites did not respond according to current fertilizer recommendations.

Slaton et al. (2009) noted that soil P tests were an indicator of the likelihood of P response; however he had numerous fertility studies when soils categorized as “low” or “very low” in initial soil P were unresponsive when fertilizer additions were applied. This means P was not the limiting factor. Slaton’s studies also had “medium” soil P plots that were responsive to P additions. Further fertility studies will be required to identify trends and consistency over variety of conditions because a soil test only takes into consideration the P in the soil and not the production environment in which it exists. The range of soil P fertility categories are an indicator of the probability of the crop showing a positive response to P fertilizer application. According to Iowa State University Extension, the "very low" soil test level corresponds with an 80% probability of P response. The "low" category corresponds with 65% probability. "Optimum" corresponds with a 25% probability and "high" corresponds with a 5% probability of fertilizer response. When soil is categorized as "very high" in soil P, it is very unlikely for a fertilizer response to occur (Gelderman, 2005, Sawyer, 2014).

Site 10 was classified as "low" in soil P. We would have expected a positive yield response to applied P at these sites, but a yield increase was only measured at site 11 to P fertilization. Site 11 had the lowest initial soil P at 5 ppm (Olsen) and did have a significant positive yield increase from P fertilization (Tables 4 and 8). This was expected based on initial soil P level. However, it is important to note that higher rates of P were applied at this site (up to 135 kg ha^{-1}). This was the only site with soybeans as the previous crop. Site 14 also had "low" initial soil P, but had pH that was higher than ideal range for P availability and uptake. Slaton et al. (2008) found that there was less response to P fertilization when pH is high. High pH from soluble salts in the soil (calcium) causes P to form unavailable, insoluble compounds and to render P unavailable to the plants. This site had slight white mold pressure and experienced an early frost.

Site 4 was categorized as "medium" initial soil P. This site did have a statistically significant yield difference between P rates; however, there was not a positive relationship with increasing P rates and yield. The 90 kg P ha^{-1} rate had lower yield than all other rates at this site. Site 13, also categorized as "medium," did not have a statistically significant yield response which may have been attributed to soil variability within experimental units (Table 7). Also, early season rains caused flooding in fields in this county during the 2014 study. Plants were stunted in wetter spots of the experimental units but no standing water was observed during our study.

Yield increase in response to applied P occurred at three sites across a variety of initial soil test P values. Based on this analysis, sites 6, 11 and 20 had a positive response to applied P. Both sites had "high" initial STP. SDSU fertilizer recommendations (Gelderman, 2005) state that any soil testing 12 or more ppm Olsen soil P would not require any fertilizer for soybeans. Therefore, in this study, our soil test failed to detect the positive yield response achieved at these two sites.

Grain P

Many of the plants at different sites in 2014 (15, 16, 17 and 18) appeared larger and with more vigor early in the season on experimental units where P was applied. However, these visually larger plants did not have higher yields than the smaller plants. Multiple sites had an upward trend in grain P concentration with increased rates of applied P. Sites 4, 6, 9, 11, 15 and 20 had statistically significant differences in grain P concentration with increasing rates of P. Site12 had the same occurrence; however, at the highest P rate the concentration decreased. (Table 7) In 2013, most of the grain P concentration was greater than 4.5 mg kg^{-1}. Grain with less than 4.5 mg kg^{-1} was from site 11 which had the lowest initial soil test P. The range of grain P concentration for the most part was between 4.5 and 5.5 mg kg^{-1}. However the grain concentration for site 11 decreased down to 3.8 g kg^{-1}. Anthony et al. (2011) reported that initial soil P has a positive relationship with grain P concentration and that high or low initial soil P will result in high or low grain P concentration.

Two yield environments were depicted visually when graphing yield versus grain P concentration with the 2014 sites (Figure 1). The lower yield environment measured 4.5-5.8 mg kg^{-1} grain P. The high yield environment measured 5.8-6.0 mg kg^{-1} grain P. This was consistent with research conducted by Anthony et al. (2011). They found that higher grain P concentration corresponded with higher yield (2011). However, Anthony et al. (2011) also found that initial soil test P levels had a relationship with grain P concentration. Our study was not consistent with this finding. For example, sites 15 and 17 had similar grain P concentrations; however site 15 had “very high” initial soil P and 17 had “medium” soil P. While higher yield has been associated with higher seed P, it is not clear if this is a cause and effect relationship.

During this study, we found that our producers would lose money because there was not an increased yield response, yet there was an increase in grain P. The extra P in the grain would be hauled away at harvest, rather than stored in the soil for future crops to utilize. The producer would receive no monetary incentive for selling grain with higher P concentration. Excess P supplied a luxury amount of nutrients to the plants where it did not increase yield. The excess P was stored in the grain and removed with harvest (Table 9). On average in 2013, 15.58 kg P was removed with every 2877 kg ha-1 soybeans harvested (2013 across site average yield). In 2014, an average of 23.23 kg P was removed with every 4289 kg ha-1 soybeans harvested (2014 across site average yield).

V4 Trifoliolate and Petiole P

There are no sufficiency ranges determined for V4 trifoliolates and petioles. Tissue samples from V4 were analyzed for both P concentration and P uptake. V4 petiole concentration in 2013 samples fell between 1.9 and 3.1 mg kg^{-1} (Table 10). Petiole concentration in 2014 was higher and between 2.4 and 3.9 mg kg^{-1}. V4 trifoliolate concentration of samples in 2013 fell between 3.3 and 4.1 mg kg^{-1} (Table 12) 2014 had a much wider range in trifoliolate concentration between 2.3 and 4.7 mg kg^{-1}. V4 petiole uptake in 2013 had a range of 2.3 and 7.3 g P kg^{-1}. 2014 petiole uptake was lower with the range of 0.76 and 5.74 g P kg^{-1}. V4 trifoliolate uptake in 2013 was between 23 and 47.3 g P kg^{-1}. V4 trifoliolate uptake in 2014 was between 12.3 and 37.6 g P kg^{-1} (Table 12).

V4 petioles had an upward trend in P concentration at sites 12, 17 and 20 (Table 10). However, it is important to recognize is that there may or may not be differences in P concentration value provided from the lab, but when the sample weight is taken into account and P uptake is determined, there may be completely different interpretation of the same plants' nutrient status. This data points that out in multiple sites/samples. After determining V4 petiole P uptake, site 15 was the only site that had an upward trend in P uptake in response to P applications (Table 10). This is very important to differentiate between concentration and uptake, when interpreting data from tissue samples. It is a common phenomenon for rapid plant growth to result in a large increase in plant tissue and diluted nutrient concentration. This is because nutrient accumulation within the tissue cannot keep up with growth. Dilution is also important because it prevents toxic nutrient levels to accumulate. Larger sized plants do not necessarily result in greater nutrient concentration. (Kamprath and Watson, 1980).

Tissue samples from V4 trifoliolates had similar outcome when comparing concentration and uptake. Some sites were statistically significant in P concentration but not significant in P uptake (Table 12). Specifically in 2013, the sites that were statistically significant in 2013 for concentration were none of the same sites that were significant in uptake. Sites 4, 6, 12, 15, 17, 18, 20 and 21 were statistically significant in P concentration. However, when P uptake was determined, sites 4, 6, 17 and 21 were not significantly different. Site 1, 9, 10 and 16 were also statistically significant in P uptake but there was no trend in uptake data.

R2 Trifoliolate and Petiole P

Tissue samples from R2 were analyzed for both nutrient concentration and uptake. R2 trifoliolate concentration in 2013 fell between 2.9 and 4.4 g kg^{-1}. The 2014 trifoliolate concentration had a higher range than 2013 and was between 3.2 to 5.4 g kg^{-1}. All trifoliolate concentration values were within sufficiency ranges published in the literature (Table 15). There was a positive yield response at sites 6 and 20 that the soil test failed to detect (Table 7). According to J. Benton Jones, P sufficiency range for the R2 trifoliolate is between 2.6 and 5.0 g kg^{-1} (1967). According to Bell et. al, P sufficiency range is between 3.1 and 5.0 g kg^{-1}. (1995). Because our tissue samples were all within the sufficiency range, our tissue testing would also have failed to detect the fertilizer response. Our study showed a slight upward trend in P concentration with increased P additions with no yield response. Site 20 had the lowest trifoliolate P concentration of all sites; however all treatments were statistically considered the same. Site 11 had lowest initial soil P and did have positive increases with P additions (Tables 17 and 18).

There are no published sufficiency ranges for petioles at any growth stage. 2013 Petiole concentration fell between 2.0 and 3.2 g kg^{-1} (Table14). 2014 petiole concentration had a much wider range than 2013 and was between 1.9 and 4.5 g kg^{-1}. 2013 R2 trifoliolate uptake had a large range between 29.6 to 83.1 g P kg^{-1}. 2014 had a similar range from 31.0 to 80.0 g P kg^{-1} (Table 15). Petiole uptake in 2013 ranged from 4.0 to 23.4 g P kg^{-1}. In 2014, petiole uptake was lower and fell between 4.6 and 11.1 g P kg^{-1}.

R2 samples provided similar results as V4 samples. Different outcomes resulted from concentration and uptake. Petiole P concentration at sites 6, 10, 12, 15 and 20 were statistically significant with a weak upward trend (Table 14). Site 11only had significant increases in P uptake corresponding with increased P application. Many sites were statistically significant; however very few had an upward trend in P. Sites 5 and 20 had significant increases and upward trend in both petiole P concentration and P uptake (Table 14). Site 15 was statistically significant in both P concentration and uptake;

however most treatments in P concentration and uptake were considered the same. In 2013, P concentration in the R2 trifoliolates increased but did not exceed 3.5 mg kg^{-1} on average. The cut-off for R2 trifoliolate P concentration in this study was approximately 3.5 mg kg^{-1} which was within the sufficient range determined in previous research by J Benton Jones (1967) and Bell et al (1995). P concentration in the R2 petioles did not drop below 1.9 mg kg^{-1} at any location and increased to 3.0 mg kg^{-1}. Most P concentration in R2 petiole samples fell between 2.0 and 3.0 mg kg^{-1}.

Specifically in 2014, two yield environments (high and low) were again depicted visually when graphing yield versus R2 petiole and trifoliolate P concentration (Figures 2 and 3). The low yield environment had trifoliate P range between 3.0 and 4.5 mg kg^{-1}. The petiole range of P concentration in the low yield environment was between 2.0 and 3.5 mg kg^{-1}. The high yield environment was represented by much higher P concentration in the tissues. The P concentration of the trifoliolates in the high yield environment ranged between 4.2 and 6.0 mg kg^{-1}. The petiole P range in the high yield environment contained 3.0 and 4.5 mg kg^{-1}.

It is obvious that many of these samples would be interpreted incorrectly if only P concentration or P uptake were taken into account individually. Most available research refers to P concentration and not uptake which may be misleading. Kamprath and Watson made the statement back in the 1980 that only interpreting nutrient concentration could be very misleading information and that plant growth (uptake) also should be considered (1980). As previously stated, bigger plants will weigh more, and if the mass is not taken into consideration, the P concentration may result in a diluted concentration and lower value. When incorrect plant parts are submitted for analysis, the outcome will be inaccurate interpretation. For example, if the petiole is submitted with the trifoliolate and the plant tissues are analyzed together as one sample, it will result in a diluted concentration because of the extra plant tissue from the petiole. In this study, P concentration decreased approximately 15 to 18% on average when the petiole was submitted with trifoliolate (Figures 9 and 10).

Our study showed a distinct point in which the nutrient concentration in grain and R2 petiole increased corresponding with yield, and then plateaued (Figures 2 and 4). Reuter and Robinson (1997) recorded the same phenomenon occurring in their research. This type of relationship was notable across sites and years and all environments of this experiment. Therefore these ranges could be used for plant tissue interpretation when only using P concentration as the measurement. The V4 tissue samplings had a wider range of nutrient concentration which was no surprise (Tables 9 and 10). Earlier growth stages have less plant tissue/size. However, there are no sufficiency ranges to compare V4 samples with; to validate that our samples were within sufficiency at the V4 growth stage. Rapid growth that occurs prior to reproductive stages will result in an increase in plant size and weight. As a result, nutrient concentration at later growth stages were more diluted compared to the earlier growth stages. The only potential benefit to increased P in the plant tissues is that after harvest, if the residue is left on the ground; it will mineralize and release nutrients back into the soil to be utilized by future crops.

There is no benefit for the producer to have excess P in the grain because it there is no incentive for high P grain.

CONCLUSIONS

In this study, despite a range in initial soil P classification from low to very high, yield response to P fertilizer additions were not expected. Eleven of 21 sites had initial soil P levels that would have had a fertilizer recommendation to increase yield. It was unlikely to see a yield response with the fertilizer additions at almost half of the sites evaluated in this study. However, the soil classifications and recommendations did not accurately predict response to applied P in this study. Sites 6, 11 and 20 had a positive response to P application where yield was higher with P fertilizer than the control plots. Both those sites had high initial STP. Therefore, the soil tests failed to detect the fertilizer response.

Grain P concentration increased with corresponding P additions. Because we did not experience consistent yield increases, these fertilizer applications would have an economic loss to producers in this study. There is no benefit for producers to have high P concentration in grain.

Sampling specific and consistent plant parts play an important role in accurately interpreting plant nutrient status. The newest, most mature and fully expanded trifoliolate will provide the most consistent measurement based on our data compared with published literature values. This is especially true if the concentration values will be compared to previous research as part of the interpretation. If the petiole and trifoliolate are analyzed together as 1 sample, the nutrient concentration will be diluted from the petiole, and result in a lower nutrient concentration. In this study, P concentration was approximately 15 to 18% lower on average when petioles were submitted with the trifoliolate. In this study, all sites had sufficient levels of P in the trifoliolates based on previous research by J. Benton Jones (1967) and Bell et al (1995); therefore, plant tissue analysis interpretations failed to predict a yield response to P fertilization at sites 6, 11 and 20.

It is important to recognize the size/weight of the sample to determine nutrient uptake. Determining the actual nutrient uptake rather than nutrient concentration is valuable again because of the dilution factor and genetic differences. Larger plant samples may have diluted uptake measurements simply because the nutrient concentration in the sample has more tissue to saturate. Determining nutrient uptake rather than nutrient concentration may be a more useful tool in the future, for determining current nutrient status of the plant.

Although inconsistencies exist between soil test and prediction to fertilizer additions, soil testing has been reliable for over a century for detecting yield response. Plant tissue analysis may be used in conjunction to an initial soil test and may be a better in season monitor of specific plant nutrients that are easily corrected during the season. However, this study was done in a production environment so we did not have any trifoliolate samples with nutrient content at critical level. Because such a range of nutrient values existed in our study, it is apparent that nutrient concentration and uptake are a function of multiple environmental factors as stated by Mills and Jones (1996).

Cautious interpretation is warranted for producers evaluating plant nutrient concentration without considering plant growth/uptake (Kamprath and Watson, 1980).

When our data was pooled across sites, both years of this study showed no increase in yield gained by using more fertilizer. Therefore, more fertilizer did not promise an increase in yield. Eleven of 21 sites required fertilizer application based on SD fertilizer recommendations. Of these 11 sites, only 1 (site 11) had a positive yield response to applied P. Out of the 10 sites not requiring fertilizer applications, 2 sites responded positively to applied P. All of our tissue samples were sufficient in P; therefore, our tissue test failed to detect the positive response at sites 6 and 20. In this study, both soil test and plant tissue analysis failed to detect P response at sites 6 and 20.

Future research must be conducted with more sites grouped by management, crop history, diversity and disease history. It may be of interest to the grower to start with a soil test, but also focus on biological mechanisms that allow the soybean crop to be productive in low P environments.

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FIGURES

FIGURE 1. Relationship between Yield (kg ha^{-1}) and Grain Phosphorus (g kg^{-1}) in 2013 soybean Phosphorus fertility experiment at 10 sites in Eastern South Dakota.

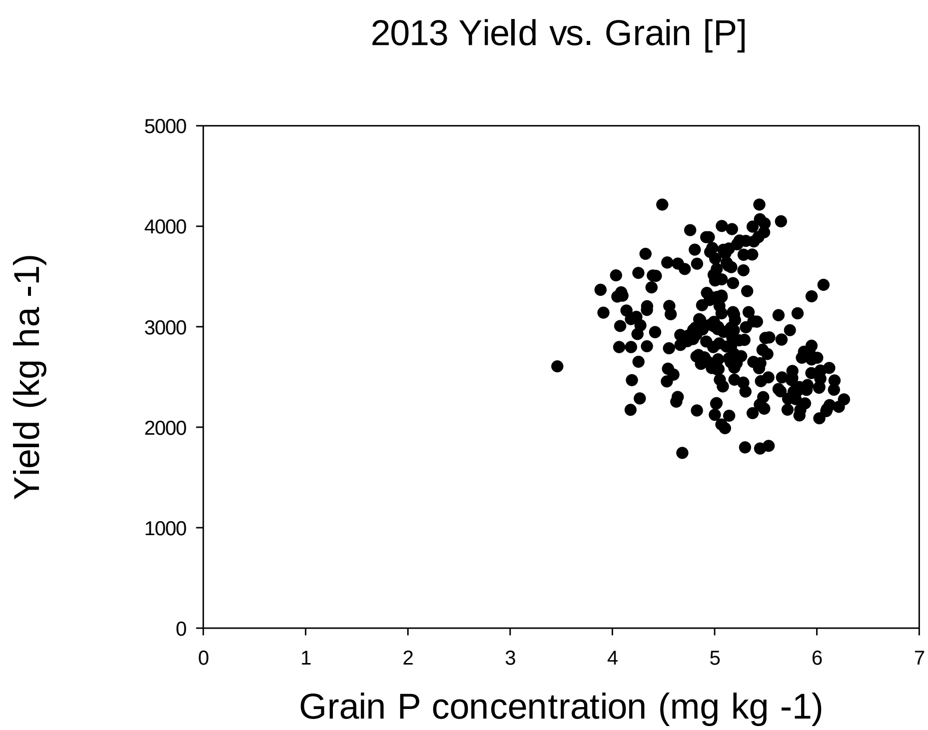


FIGURE 2. Relationship between Yield (kg ha $^{-1}$) and Grain Phosphorus (g kg^{-1}) in 2014 soybean Phosphorus fertility experiment at 10 sites in Eastern South Dakota.

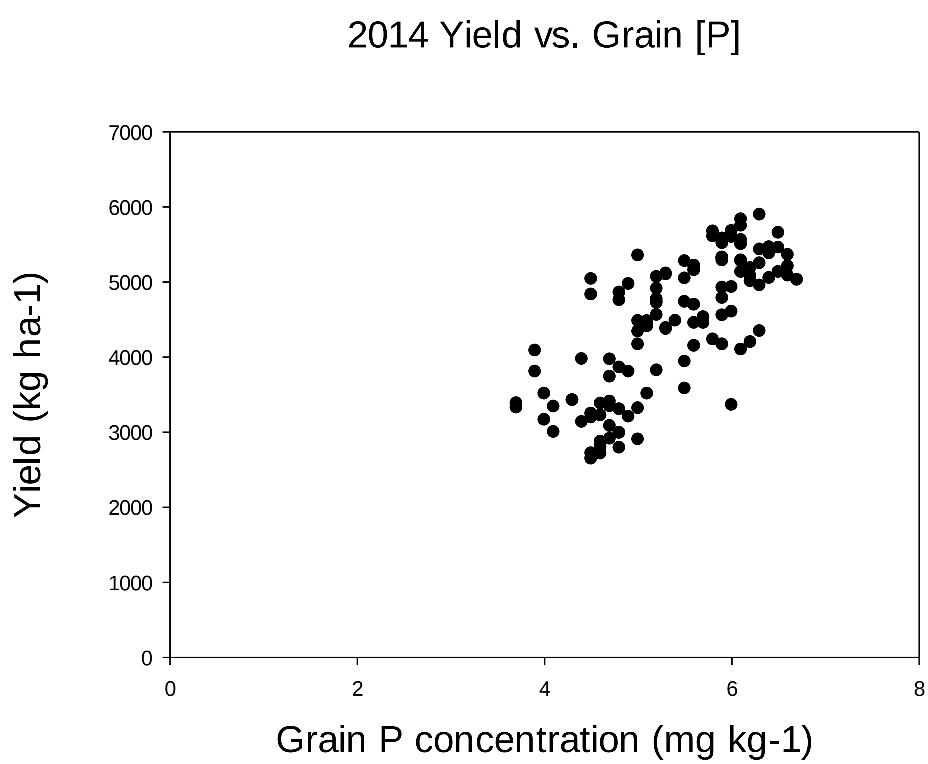


FIGURE 3. Relationship between yield (kg ha $^{-1}$) and R2 Petiole Phosphorus (g kg $^{-1}$) in 2013 soybean Phosphorus fertility experiment in 10 sites in Eastern South Dakota.

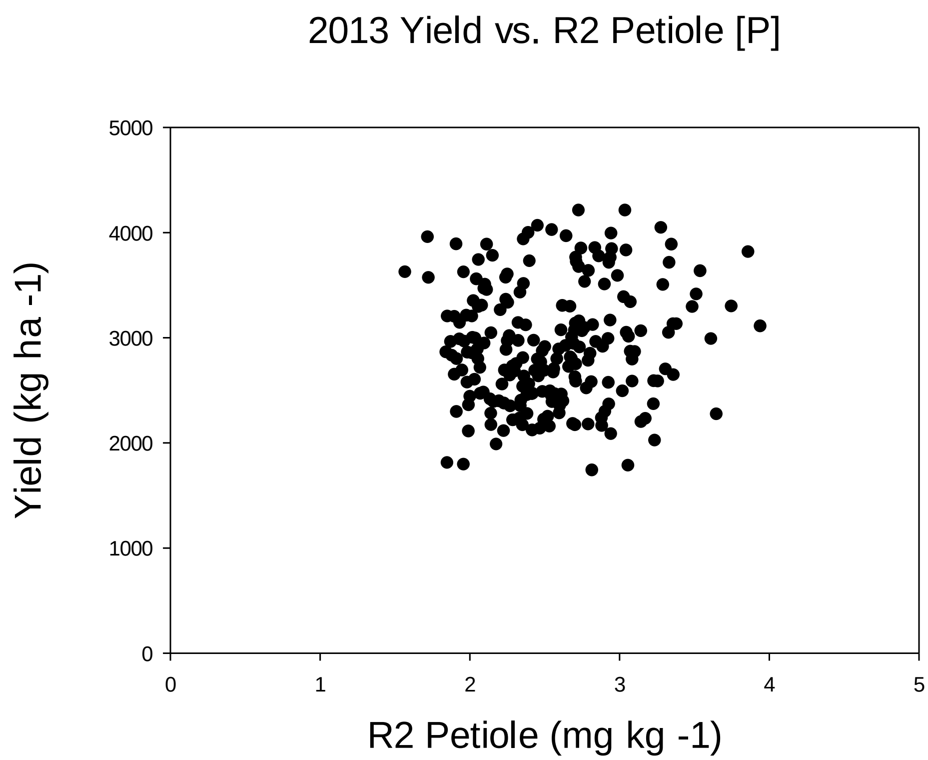


FIGURE 4. Relationship between yield (kg ha $^{-1}$) and R2 Petiole Phosphorus (g kg $^{-1}$) in 2014 soybean Phosphorus fertility experiment at 10 sites in Eastern South Dakota. Two yield environments were depicted. Low yield environment ranged 2-3.5 g kg $^{-1}$ P and high yield environment ranged 3.0 to 4.5 g kg $^{-1}$ P.

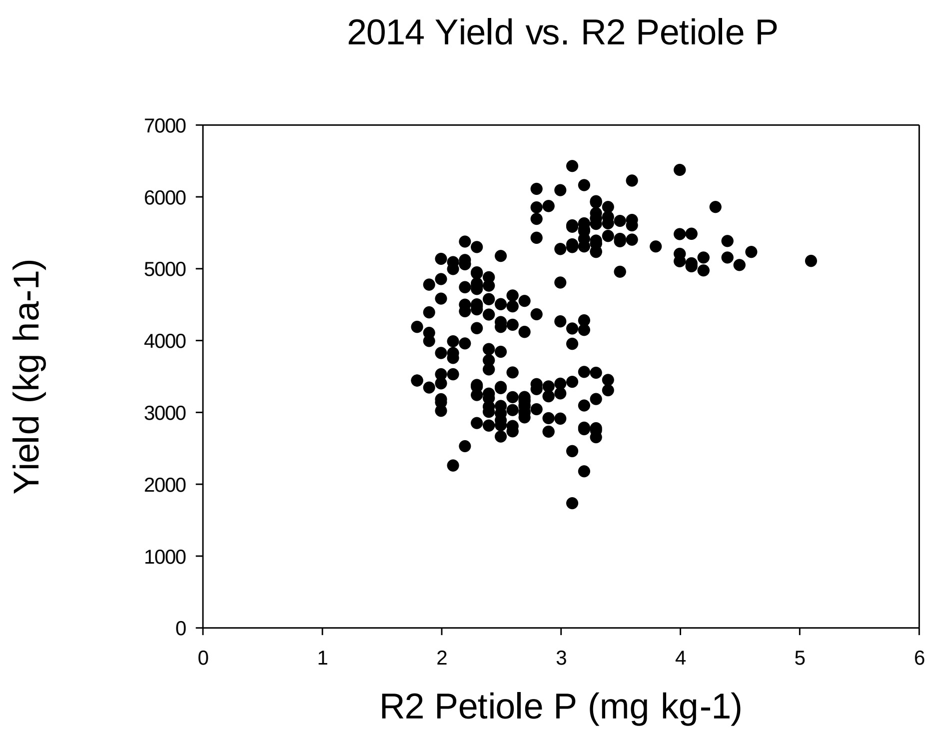


FIGURE 5. Relationship between yield (kg ha $^{-1}$) and R2 Trifoliolate Phosphorus (g kg $^{-1}$) in 2013 soybean Phosphorus fertility experiment at 10 sites in Eastern South Dakota.

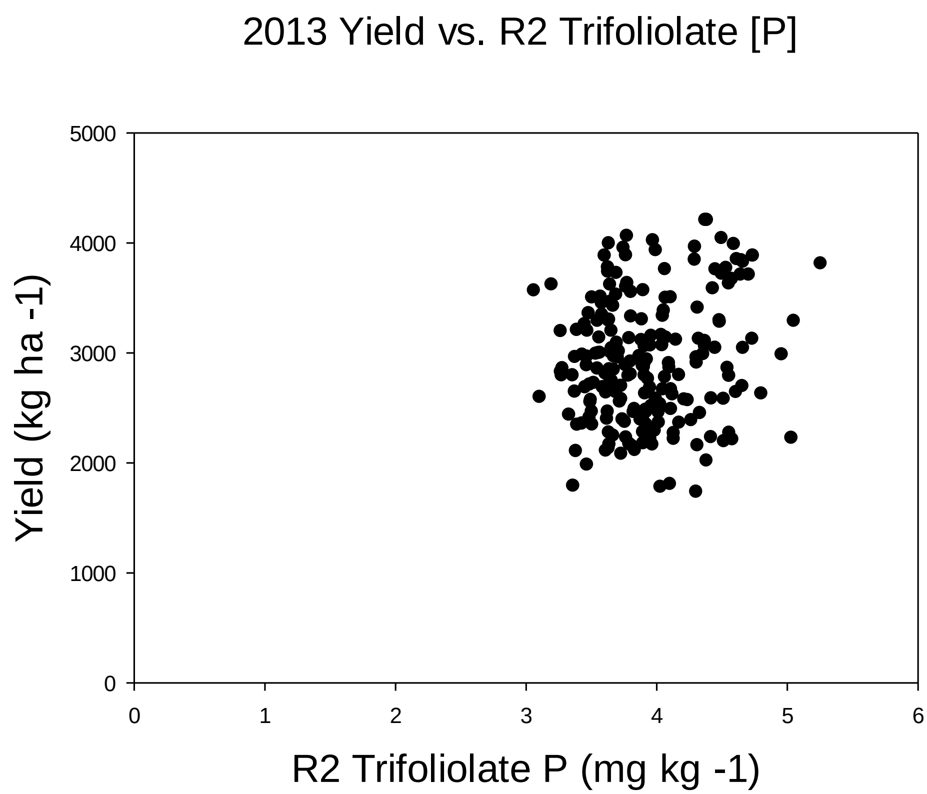


FIGURE 6. Relationship between yield (kg ha $^{-1}$) and R2 Trifoliolate Phosphorus (g kg $^{-1}$) in2014 soybean Phosphorus fertility experiment at 10 sites in Eastern South Dakota. Two yield environments were depicted. Low yield environment ranged 3-4.5 g kg $^{-1}$ P and high yield environment ranged 4.2 to 6.0 g kg $^{-1}$ P.

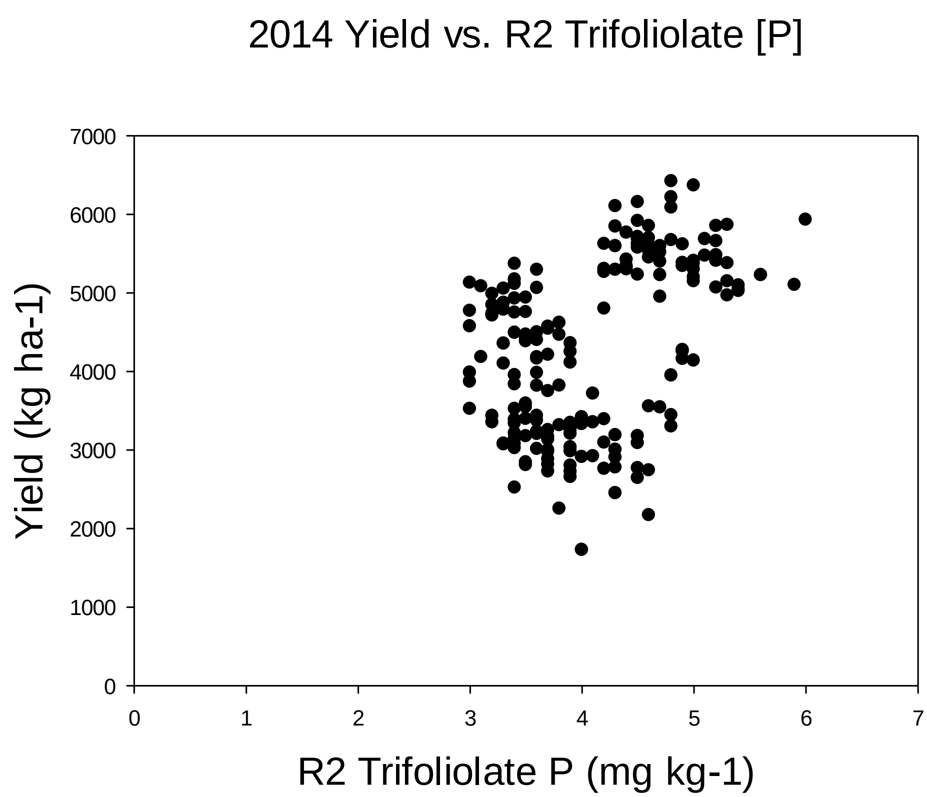


FIGURE 7. 2013 V4 soybean trifoliolate, petiole and trifoliolate plus petiole phosphorus (P) concentration (g kg^{-1}). Means across all 10 sites for phosphorus rates 0, 22, 45, 67, and 90 kg ha^{-1}.

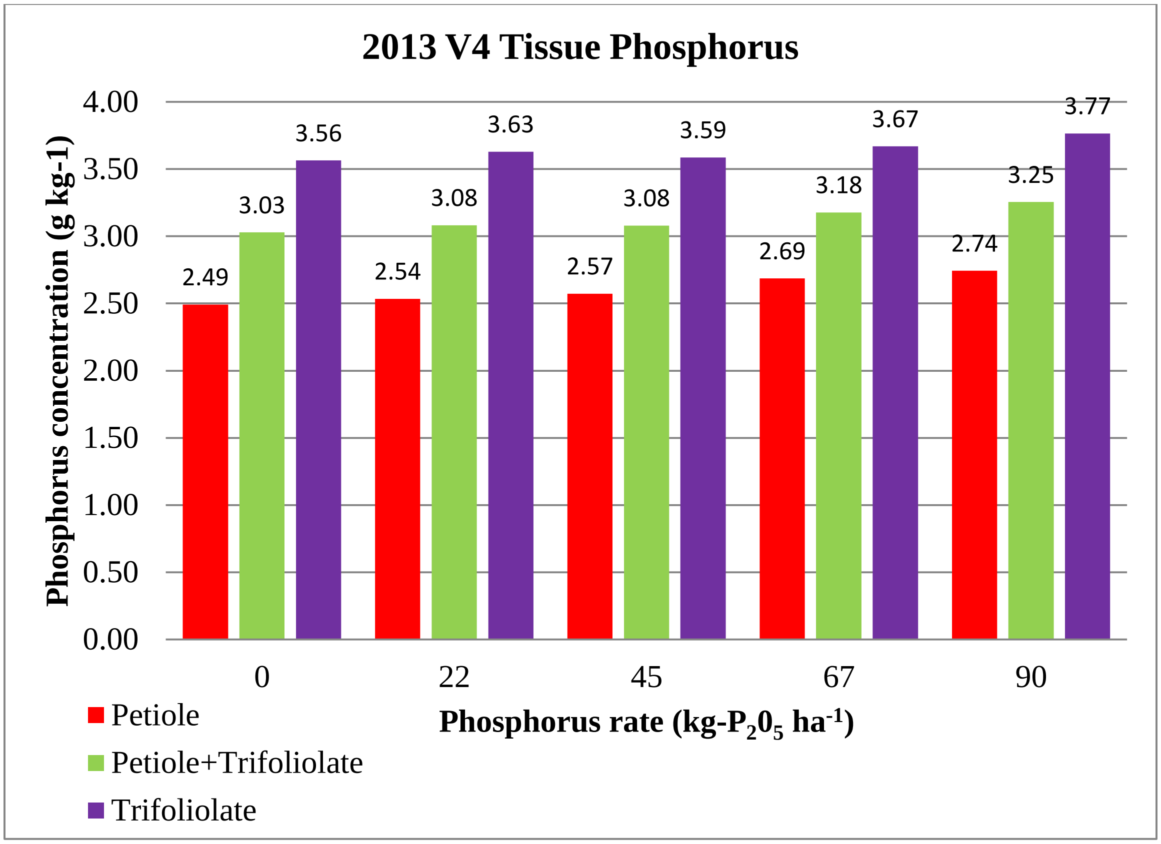


FIGURE 8. 2014 V4 soybean trifoliolate, petiole and trifoliolate plus petiole phosphorus (P) concentration (g kg^{-1}). Means across all 10 sites for phosphorus rates 0, 22, 45, 67, and 90 kg ha^{-1}.

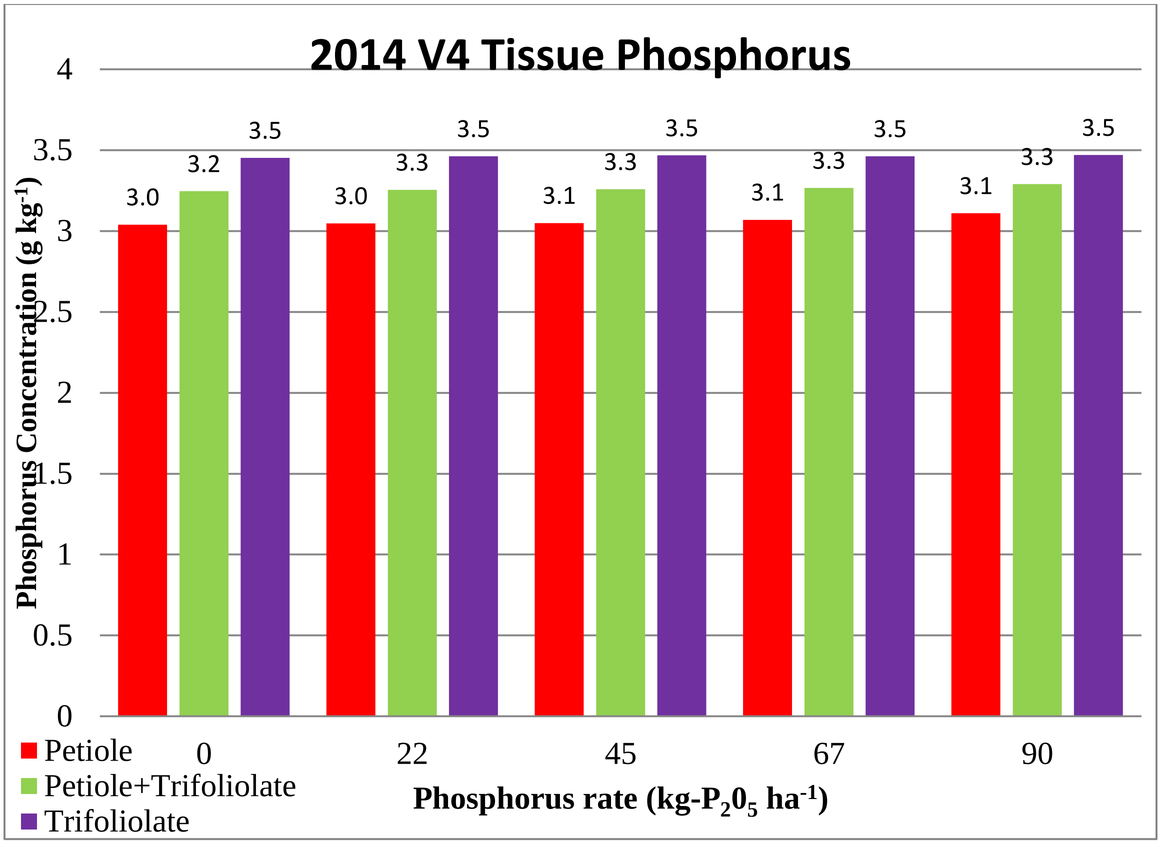


FIGURE 9. 2013 R2 soybean trifoliolate, petiole and trifoliolate plus petiole phosphorus (P) concentration (g kg^{-1}). Means across all 10 sites for phosphorus rates 0, 22, 45, 67, and 90 kg ha^{-1}.

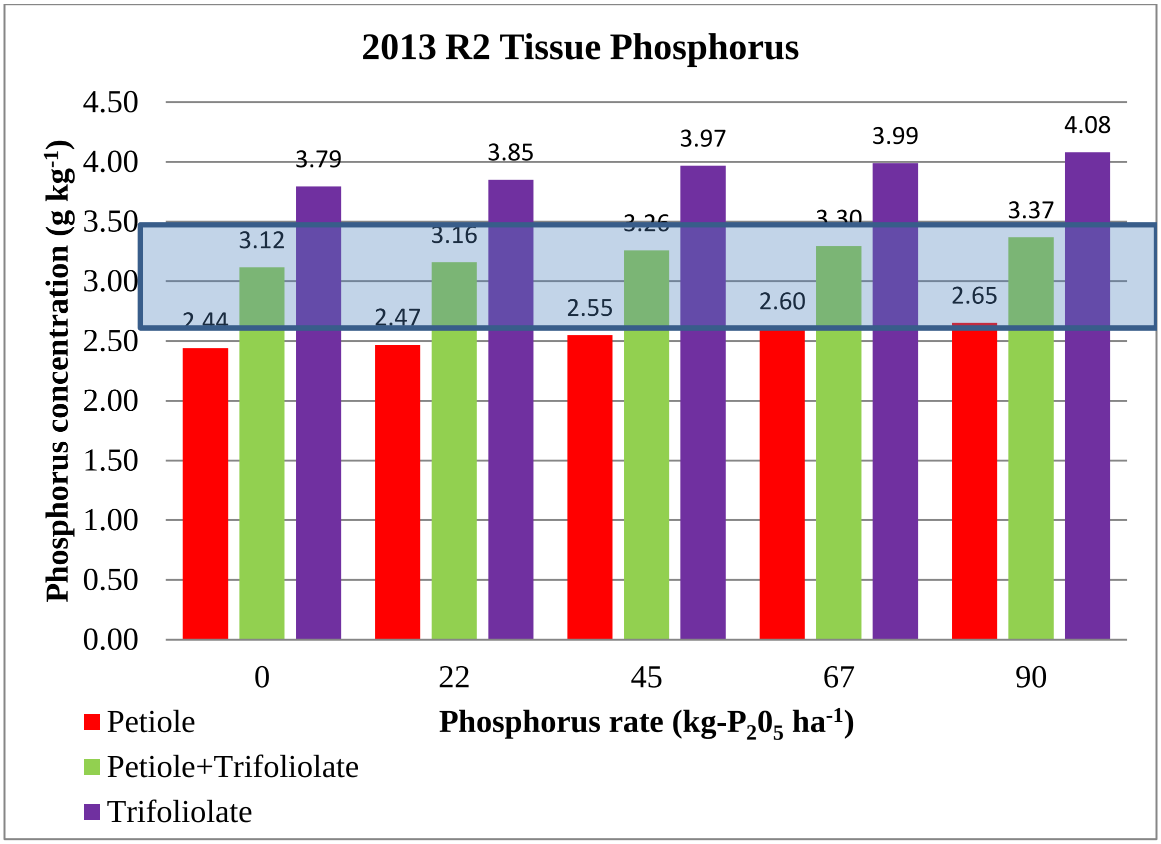
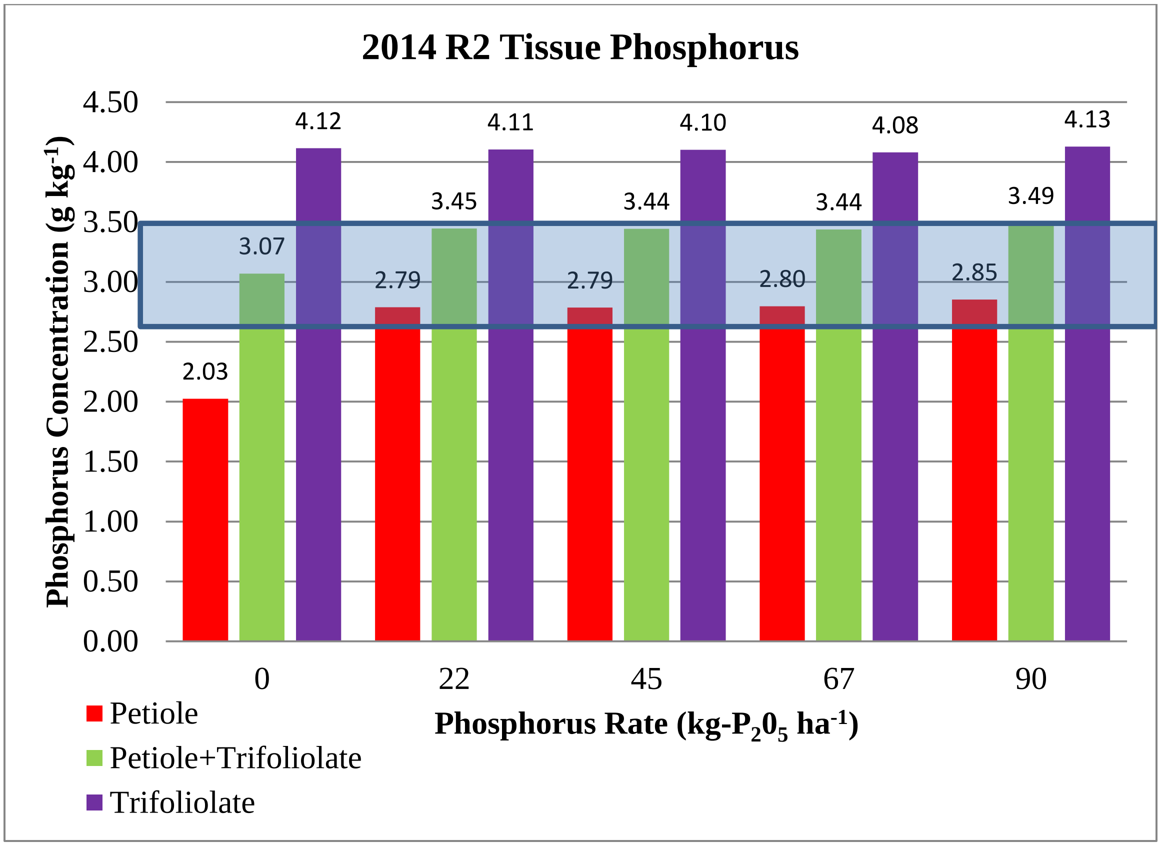


FIGURE 10. 2014 R2 soybean trifoliolate, petiole and trifoliolate plus petiole phosphorus (P) concentration (g kg^{-1}). Means across all 10 sites for phosphorus rates 0, 22, 45, 67, and 90 kg ha^{-1}.



TABLES

TABLE 1. Soybean phosphorus fertility experiments labeled by site, city, and county in Eastern South Dakota for 2013 and 2014. Experimental locations will be referred to as 'Site' based on this table.

Site	City	County
1	Aurora	Brookings
2	Bancroft	Kingsbury
3	Freeman	Hutchinson
4	Geddes	Charles Mix
5	Mitchell	Davidson
6	South Shore	Codington
7	Tripp	Hutchinson
8	Wagner	Charles Mix
9	W. Springs-1	Jerauld
10	W. Springs-2	Jerauld
11	Beresford	Clay
12	Aurora	Brookings
13	Doland	Spink
14	Flandreau	Moody
15	South Shore	Codington
16	Ward	Moody
17	Beresford	Clay
18	St. Lawrence-1	Hand
19	St. Lawrence-2	Hand
20	Wessington-1	Beadle
21	Wessington-2	Beadle

TABLE 2. Soybean variety, previous crop, planting and harvest dates for soybean phosphorus experiment in 2013 and 2014 in Eastern South Dakota.

Site	Year	Previous Crop	Variety	Planting Date	Harvest Date
1	2013	Corn	AG1431	6/2	10/8
2	2013	Corn	Stine 16RA02	6/5	10/10
3	2013	Corn	Pioneer92Y51	6/3	9/30
4	2013	winter wheat	Pioneer92Y70	6/4	10/2
5	2013	Corn	Curry1289	5/13	9/30
6	2013	Corn	AG1431	6/4	10/25
7	2013	Corn	Pioneer93M11	5/20	10/23
8	2013	Corn	Wensman3230	6/3	9/25
9	2013	Corn	Pioneer90M80	5/9	9/13
10	2013	Corn	CroplanR2C2200	6/4	10/2
11	2013	soybean	AG2433	5/16	9/23
12	2014	Corn	SD2101R2Y	5/15	10/1
13	2014	CRP	Wensman3178	5/23	10/2
14	2014	Corn	Pioneer25T51	5/20	10/16
15	2014	Fallow	AG0634	5/25	10/10
16	2014	Corn	AG0832	5/6	9/22
17	2014	corn, rye	AG2733	5/20	10/14
18	2014	Corn	Croplan1572	5/20	NR
19	2014	Corn	Croplan1750	5/20	10/2
20	2014	Corn	Wensman3230	5/17	10/7
21	2014	Corn	Wensman3230	5/17	10/15

CRP: Conservation Reserve Program.
NR: Not recorded.

TABLE 3. Soil series name for site research plots for soybean phosphorus fertility experiment in 2013 and 2014, in Eastern South Dakota.

Site	Research Year	Soil Type
1	2013	Brandt silty clay loam, coteau
2	2013	Houdek-Stickney complex
3	2013	Alcester silty clay loam
4	2013	Highmore silt loam
5	2013	Houdek-Prosper loams
6	2013	Vienna-Brookings complex, coteau
7	2013	Dudley-Stickney complex
8	2013	Eakin silt loam
9	2013	Eakin-Ethan-Onita complex
10	2013	Houdek-Prosper loams
11	2013	Egan-Trent silty clay loams
12	2014	Brandt silty clay loam, coteau
13	2014	Kranzburg-Cresbard silt loams
14	2014	Wakonda-Chancellor silty clay loams
15	2014	Kranzburg-Brookings silty clay loams
16	2014	Lamo silty clay loam
17	2014	Egan-Clarno-Trent complex
18	2014	Houdek-Prosper loams
19	2014	Durrstein silty clay loam
20	2014	Hand-Bonilla loams
21	2014	Prosper-Stickney loams

Source: Web Soil Survey.

TABLE 4. Average initial soil phosphorus (mg kg $^{-1}$) for soybean phosphorus experiment sites in Eastern South Dakota in 2013 and 2014. Bray, Olsen, and Mehlich results are presented. Average is based on four replications.

Site	Year	Bray	Olsen	Mehlich
			mg kg $^{-1}$	
1	2013	20.25	10.75	21.50
2	2013	27.30	18.66	27.35
3	2013	34.50	15.52	29.25
4	2013	18.65	9.75	18.30
5	2013	22.75	11.44	22.20
6	2013	9.64	12.25	16.13
7	2013	18.75	7.75	19.00
8	2013	24.17	16.17	30.50
9	2013	13.80	8.50	19.80
10	2013	13.00	7.32	15.35
11	2013	12.25	4.50	9.50
12	2014	19.00	10.05	19.43
13	2014	11.00	7.98	16.31
14	2014	7.35	5.00	7.14
15	2014	63.90	46.62	66.03
16	2014	33.45	22.73	40.64
17	2014	15.65	10.21	15.30
18	2014	17.29	12.51	21.08
19	2014	19.30	12.98	24.81
20	2014	18.25	11.73	21.49
21	2014	17.15	11.74	18.41

TABLE 5. Average initial organic matter (g kg^{-1}); soil mineral test results (mg kg^{-1}); and cation ion exchange capacity (CEC) Meq $100g^{-1}$ for soybean phosphorus experiment in Eastern South Dakota in 2013 and 2014. Bray, Olsen, and Mehlich phosphorus results presented are the same as Table 4. Average is based on four replications.

Site	OM	pH	Bray P	Olsen P	Mehlich P	K	Zn	Fe	Mn	Cu	Ca	Mg	Na	CEC
	g kg^{-1}		mg kg^{-1}											Meq $100g^{-1}$
1	3.5	5.7	20.3	10.8	21.5	368.0	2.5	73.6	52.7	1.1	2054.0	388.3	14.4	20.2
2	4.1	6.1	27.3	18.7	27.4	401.8	1.8	62.1	101.2	1.3	2015.7	539.0	17.3	17.5
3	4.7	5.7	34.5	15.5	29.3	172.0	3.0	79.2	41.6	2.2	2679.8	720.3	24.4	25.4
4	3.8	6.3	18.7	9.8	18.3	443.9	1.4	47.3	53.3	1.1	2307.3	524.2	43.6	18.1
5	4.1	5.7	22.8	11.4	22.2	223.3	1.2	83.6	78.1	1.7	1814.3	672.5	26.3	19.9
6	3.7	6.2	9.6	12.3	16.1	139.8	1.0	76.4	32.8	1.0	NR	NR	NR	NR
7	2.7	6.0	18.8	7.8	19.0	191.8	0.6	51.2	53.4	1.4	1608.0	766.8	16.9	16.2
8	4.4	6.6	24.2	16.2	30.5	479.2	1.5	26.8	67.0	1.2	2709.7	527.7	17.1	19.2
9	5.6	6.3	13.8	8.5	19.8	512.4	2.2	63.1	87.2	1.0	2376.4	471.2	8.8	19.4
10	3.2	6.1	13.0	7.3	15.4	284.2	1.0	43.2	112.0	1.2	2004.8	502.3	16.9	16.9
11	4.2	6.0	12.3	4.5	9.5	216.8	1.3	64.7	66.6	1.6	2214.3	666.5	18.6	20.0
12	4.1	5.7	19.0	10.1	19.4	155.0	2.1	65.1	39.3	1.1	2271.7	493.9	24.0	19.9
13	3.0	8.0	11.0	8.0	16.3	388.0	0.9	9.4	23.2	1.2	3732.7	591.0	139.7	25.2
14	5.0	7.5	7.4	5.0	7.1	170.0	1.2	27.4	15.3	1.2	3895.1	1116.1	62.8	29.6
15	4.7	5.1	63.9	46.6	66.0	201.0	0.9	119.2	87.2	1.5	2110.6	571.1	31.8	23.1
16	5.9	7.0	33.5	22.7	40.6	156.0	1.4	28.5	30.7	1.4	4099.1	893.2	35.5	28.4
17	4.7	5.7	15.7	10.2	15.3	232.0	4.9	110.9	60.1	1.6	2353.7	565.9	58.5	22.7
18	3.4	5.9	17.3	12.5	21.1	283.0	0.6	55.9	45.0	1.0	1788.9	589.5	28.4	16.7
19	4.7	5.5	19.3	13.0	24.8	420.0	1.5	100.9	74.5	0.9	1710.4	421.1	28.8	17.4
20	4.2	5.4	18.3	11.7	21.5	305.0	0.9	74.0	64.7	0.9	1689.4	389.6	21.8	17.3
21	2.9	5.6	17.2	11.7	18.4	316.0	1.3	100.3	69.9	1.0	1634.7	415.6	19.0	15.8

NR: data not recorded.

TABLE 6. Olsen soil test phosphorus categories for South Dakota (Gelderman, 2005) with kg ha^{-1} Phosphorus application rates required for 4020 kg ha^{-1} yield goal. Numer of sites in phosphorus fertility experiment in 2013 and 2014 that would require fertilization based on soil test phosphorus interpretation.

Soil Test Phosphorus-Olsen			
	ppm	kg P ha^{-1}	sites
Very Low	0-3	5360	0
Low	4-7	3149	3
Medium	8-11	871	8
High	12-15	0	5
Very High	16+	0	5

TABLE 7. Grain yield and seed phosphorus concentration for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Grain yield and seed were collected at maturity (R8) at each site in 2013 and 2014. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
1	Yield	kg ha^{-1}	3059	2973	2984	2951	3205	3034	599	NS
	P con.	g P kg^{-1}	4.7	5	4.7	5.2	5.2	4.9	93	NS
2	Yield	kg ha^{-1}	2573	2573	3071	2600	2537	2681	1008	NS
	P con.	g P kg^{-1}	4.9	4.7	5.2	5.1	5.2	5	32.9	0.3
3	Yield	kg ha^{-1}	2401	2302	2247	2352	2496	2360	360	196
	P con.	g P kg^{-1}	5.7	5.4	5.7	5.6	5.6	5.6	36.4	NS
4	Yield	kg ha^{-1}	3266	3266	3559	3582	3010	3337	727	558
	P con.	g P kg^{-1}	5.1	5.1	5.1	5.2	5.2	5.2	18.3	0.1
5	Yield	kg ha^{-1}	3055	3072	3025	3037	3118	3062	298	NS
	P con.	g P kg^{-1}	4.8	5	5	5.1	5.2	5	39.3	0.3
6	Yield	kg ha^{-1}	2392	2499	2261	2657	2151	2407	467	218
	P con.	g P kg^{-1}	4.3	4.4	4.7	4.8	5	4.7	33.1	0.2
7	Yield	kg ha^{-1}	2409	2384	2357	2392	2618	2432	1040	NS
	P con.	g P kg^{-1}	5.5	5.5	5.6	5.6	5.2	5.5	54.9	NS
8	Yield	kg ha^{-1}	2401	2498	2464	2490	2427	2456	358	NS
	P con.	g P kg^{-1}	6	6	6	6	6.1	6	17.4	NS
9	Yield	kg ha^{-1}	3944	3424	3840	3921	3922	3810	307	269
	P con.	g P kg^{-1}	4.9	5.1	5.3	5.3	5.3	5.2	44.6	0.4
10	Yield	kg ha^{-1}	3364	3064	2971	3146	3063	3122	1006	NS
	P con.	g P kg^{-1}	4.6	4.9	4.9	5	5.2	4.9	25.2	0.2
11	Yield	kg ha^{-1}	†							
	P con.	g P kg^{-1}	†							
12	Yield	kg ha^{-1}	3018	2904	3278	3025	3119	3069	590	NS
	P con.	g P kg^{-1}	5.4	5.7	5.7	5.9	5.8	5.695	24	0.2
13	Yield	kg ha^{-1}	3131	3231	3156	3309	3067	3179	1085	NS
	P con.	g P kg^{-1}	6	5.8	6.2	6.2	6.1	6	44.5	NS
14	Yield	kg ha^{-1}	3769	3643	3672	3491	3682	3651	726	NS

	P con.	g P kg^{-1}	4.3	4.2	4.6	4.6	4.8	4.5	81.7	NS
15	Yield	kg ha^{-1}	5432	5345	5385	5061	5180	5281	304	369
	P con.	g P kg^{-1}	6.1	6.3	6.3	6.3	6.6	6.3	33.4	0.3
16	Yield	kg ha^{-1}	5325	5457	5322	5465	5484	5410	261	NS
	P con.	g P kg^{-1}	5.8	5.9	5.9	6.3	6.1	6	22.5	0.2
17	Yield	kg ha^{-1}	5897	5806	5797	5802	5625	5785	463	NS
	P con.	g P kg^{-1}	5.8	6	6	6.1	6.2	6	42.8	0.4
18	Yield	kg ha^{-1}	‡							
	P con.	g P kg^{-1}	‡							
19	Yield	kg ha^{-1}	3105	2961	2974	3108	3079	3045	634	NS
	P con.	g P kg^{-1}	4.5	4.6	4.6	4.8	4.9	4.7	25.2	0.2
20	Yield	kg ha^{-1}	4456	4683	4923	4867	5008	4788	381	419
	P con.	g P kg^{-1}	4.7	5	5.2	5.5	5.4	5.1	45	0.4
21	Yield	kg ha^{-1}	4465	4268	4334	4332	4579	4396	738	NS
	P con.	g P kg^{-1}	5.4	5.5	5.7	5.9	5.8	5.6	41	0.4

† Site listed in Table 8.
‡ Yield and grain measurements not recorded.
NS: not significant at $\alpha = 0.05$.

TABLE 8. Grain yield and seed phosphorus concentration for phosphorus (P) fertilizer rates of 0, 34, 67, and 135 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain yield and seed were collected at maturity (R8) at each site in 2013 and 2014. Site 11 is presented separately due to different P fertilizer rates. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate						
			0	34	67	135	Mean	CV(%)	LSD (0.05)
			kg P ha^{-1}						
11	Yield	kg ha^{-1}	1223	1310	1329	1440	1332	211	169
	P con.	g kg^{-1}	3.8	4	4.2	4.4	4.1	4.8	0.3

TABLE 9. Across site analysis of grain yield and seed phosphorus concentration for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring Grain yield and seed were collected at maturity (R8) at each site in 2013 and 2014. Mean, CV (%), and LSD at alpha (α) = 0.05.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			——— kg P ha^{-1} ———							
2013	Yield	kg ha^{-1}	2899	2855	2861	2906	2863	2877	10.16	NS
	P con.	g kg^{-1}	5.1	5.1	5.2	5.3	5.3	5.2	4.29	0.1
2014	Yield	kg ha^{-1}	4289	4255	4316	4273	4314	4289	8.27	NS
	P con.	g kg^{-1}	5.3	5.4	5.6	5.7	5.7	5.6	4.14	0.1

NS: not significant at α = 0.05.

TABLE 10. Petiole phosphorus (P) concentration and uptake for 30 petioles at V4 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Site 2 had 60 samples taken due to insufficient plant tissue. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
1	P con.	g kg^{-1}	3	3	2.9	3.1	3	3	13	NS
	Uptake	g P kg^{-1}	2.8	3	2.5	2.5	3.2	2.8	38	NS
2	P con.	g kg^{-1}	2.6	2.6	2.6	2.7	2.8	2.7	9.3	NS
	Uptake	g P kg^{-1}	7.1	6.6	6.3	8.4	7.9	7.3	17.8	2
3	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
4	P con.	g kg^{-1}	2.4	2.5	1.9	2.4	2.7	2.4	17.49	0.6
	Uptake	g P kg^{-1}	6.4	7.3	6.6	7.5	7.4	7	10.3	NS
5	P con.	g kg^{-1}	2.3	2.3	2	2.3	2.4	2.3	12.6	NS
	Uptake	g P kg^{-1}	4.6	5.2	4.7	5.1	4.9	4.9	12.6	NS
6	P con.	g kg^{-1}	3.2	3.2	3.2	3.1	3.1	3.1	4.16	NS
	Uptake	g P kg^{-1}	6.8	4	3.7	4.2	4	4.5	50.5	NS
7	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
8	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
9	P con.	g kg^{-1}	2.4	2.4	2.4	2.4	2.4	2.4	17.49	NS
	Uptake	g P kg^{-1}	3.2	2.3	3.7	2.4	3.5	3	26.2	1.2
10	P con.	g kg^{-1}	2.4	2.3	2.4	2.2	2.4	2.2	25.16	NS
	Uptake	g P kg^{-1}	3.9	4.5	4.7	5.2	6.3	4.9	15.9	1.2
11	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
12	P con.	g kg^{-1}	2.4	2.4	2.5	2.7	2.8	2.5	10.18	0.4
	Uptake	g P kg^{-1}	1.2	1.4	1.4	1.3	1.5	1.4	21.7	NS
13	P con.	g kg^{-1}	3.6	3.6	3.5	3.6	3.7	3.6	5.16	NS

	Uptake	$g\ P\ kg^{-1}$	2.1	2	2.1	2.1	2	2	19.7	NS
14	P con.	$g\ kg^{-1}$	2.5	2.7	2.6	2.8	2.8	2.7	11.58	NS
	Uptake	$g\ P\ kg^{-1}$	1.9	1.6	1.8	1.7	1.8	1.8	22.9	NS
15	P con.	$g\ kg^{-1}$	3	3.4	3.3	3.5	3.6	3.3	9.56	0.49
	Uptake	$g\ P\ kg^{-1}$	4.5	5.6	5.3	5.7	5.8	5.4	4.7	0.4
16	P con.	$g\ kg^{-1}$	3.4	3.5	3.4	3.5	3.7	3.5	2.76	0.15
	Uptake	$g\ P\ kg^{-1}$	1.9	1.9	2.1	2.3	1.9	2	16.7	NS
17	P con.	$g\ kg^{-1}$	3.6	3.6	3.9	3.8	4	3.8	5.81	0.34
	Uptake	$g\ P\ kg^{-1}$	2.6	2.9	3.1	3.1	3.1	3	19	NS
18	P con.	$g\ kg^{-1}$	3.7	3.4	3.4	3.5	3.8	3.5	10.97	NS
	Uptake	$g\ P\ kg^{-1}$	1.1	0.8	0.7	1	0.9	0.9	39.7	NS
19	P con.	$g\ kg^{-1}$	2.4	3	3.8	2.9	2.3	2.9	43.87	NS
	Uptake	$g\ P\ kg^{-1}$	1.6	2.3	2.9	2.5	1.6	2.2	35.9	1.2
20	P con.	$g\ kg^{-1}$	3.6	3.9	3.9	4.3	4.2	4	7.83	0.48
	Uptake	$g\ P\ kg^{-1}$	1.2	1.5	1.3	1.7	1.4	1.4	47.7	NS
21	P con.	$g\ kg^{-1}$	2.4	2.7	2.4	2.8	2.9	4	7.83	0.64
	Uptake	$g\ P\ kg^{-1}$	1.8	1.8	1.6	2.5	2	1.9	19.9	0.6

†Site not sampled.
NS: not significant at $\alpha = 0.05$.

TABLE 11. Across site analysis of Trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at V4 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%), and LSD at alpha (α) = 0.05.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
2013	P con.	g kg^{-1}	3.7	3.7	3.5	3.7	3.7	3.6	6.14	0.1
	Uptake	g P kg^{-1}	34	33.9	34.3	35.4	36.7	34.8	11.6	2.1
2014	P con.	g kg^{-1}	3.5	3.5	3.6	3.6	3.7	3.6	11.63	0.2
	Uptake	g P kg^{-1}	18	18.3	19.2	19.7	19.2	18.8	16.44	1.4

TABLE 12. Trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at V4 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Site 2 had 60 samples taken due to insufficient plant tissue. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
1	P con.	g kg^{-1}	3	3	2.9	3.1	3	3	13	NS
	Uptake	g P kg^{-1}	2.8	3	2.5	2.5	3.2	2.8	38	NS
2	P con.	g kg^{-1}	2.6	2.6	2.6	2.7	2.8	2.7	9.3	NS
	Uptake	g P kg^{-1}	7.1	6.6	6.3	8.4	7.9	7.3	17.8	2
3	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
4	P con.	g kg^{-1}	2.4	2.5	1.9	2.4	2.7	2.4	17.49	0.6
	Uptake	g P kg^{-1}	6.4	7.3	6.6	7.5	7.4	7	10.3	NS
5	P con.	g kg^{-1}	2.3	2.3	2	2.3	2.4	2.3	12.6	NS
	Uptake	g P kg^{-1}	4.6	5.2	4.7	5.1	4.9	4.9	12.6	NS
6	P con.	g kg^{-1}	3.2	3.2	3.2	3.1	3.1	3.1	4.16	NS
	Uptake	g P kg^{-1}	6.8	4	3.7	4.2	4	4.5	50.5	NS
7	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
8	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
9	P con.	g kg^{-1}	2.4	2.4	2.4	2.4	2.4	2.4	17.49	NS
	Uptake	g P kg^{-1}	3.2	2.3	3.7	2.4	3.5	3	26.2	1.2
10	P con.	g kg^{-1}	2.4	2.3	2.4	2.2	2.4	2.2	25.16	NS
	Uptake	g P kg^{-1}	3.9	4.5	4.7	5.2	6.3	4.9	15.9	1.2

11	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
12	P con.	g kg^{-1}	2.4	2.4	2.5	2.7	2.8	2.5	10.18	0.4
	Uptake	g P kg^{-1}	1.2	1.4	1.4	1.3	1.5	1.4	21.7	NS
13	P con.	g kg^{-1}	3.6	3.6	3.5	3.6	3.7	3.6	5.16	NS
	Uptake	g P kg^{-1}	2.1	2	2.1	2.1	2	2	19.7	NS
14	P con.	g kg^{-1}	2.5	2.7	2.6	2.8	2.8	2.7	11.58	NS
	Uptake	g P kg^{-1}	1.9	1.6	1.8	1.7	1.8	1.8	22.9	NS
15	P con.	g kg^{-1}	3	3.4	3.3	3.5	3.6	3.3	9.56	0.49
	Uptake	g P kg^{-1}	4.5	5.6	5.3	5.7	5.8	5.4	4.7	0.4
16	P con.	g kg^{-1}	3.4	3.5	3.4	3.5	3.7	3.5	2.76	0.15
	Uptake	g P kg^{-1}	1.9	1.9	2.1	2.3	1.9	2	16.7	NS
17	P con.	g kg^{-1}	3.6	3.6	3.9	3.8	4	3.8	5.81	0.34
	Uptake	g P kg^{-1}	2.6	2.9	3.1	3.1	3.1	3	19	NS
18	P con.	g kg^{-1}	3.7	3.4	3.4	3.5	3.8	3.5	10.97	NS
	Uptake	g P kg^{-1}	1.1	0.8	0.7	1	0.9	0.9	39.7	NS
19	P con.	g kg^{-1}	2.4	3	3.8	2.9	2.3	2.9	43.87	NS
	Uptake	g P kg^{-1}	1.6	2.3	2.9	2.5	1.6	2.2	35.9	1.2
20	P con.	g kg^{-1}	3.6	3.9	3.9	4.3	4.2	4	7.83	0.48
	Uptake	g P kg^{-1}	1.2	1.5	1.3	1.7	1.4	1.4	47.7	NS
21	P con.	g kg^{-1}	2.4	2.7	2.4	2.8	2.9	4	7.83	0.64
	Uptake	g P kg^{-1}	1.8	1.8	1.6	2.5	2	1.9	19.9	0.6

† Site not sampled.
NS: not significant at α = 0.05.

Table 13. Across site analysis of Trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at V4 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%), and LSD at alpha (α) = 0.05.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
2013	P con.	g kg^{-1}	3.7	3.7	3.5	3.7	3.7	3.6	6.14	0.1
	Uptake	g P kg^{-1}	33.6	33.9	34.3	35.4	36.7	34.8	11.6	2.1
2014	P con.	g kg^{-1}	3.5	3.5	3.6	3.6	3.7	3.6	11.63	0.2
	Uptake	g P kg^{-1}	17.8	18.3	19.2	19.7	19.2	18.8	16.44	1.4

Table 14. Petiole phosphorus (P) concentration and uptake for 30 petioles at R2 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
1	P con.	g kg^{-1}	2.9	3	2.8	3	3.2	3	9.3	NS
	Uptake	g P kg^{-1}	9.7	11	10	10.6	11	10.5	14.2	NS
2	P con.	g kg^{-1}	2.1	2	2.3	2.2	2.3	2.2	6.49	0.22
	Uptake	g P kg^{-1}	12	10	10	12.3	12.2	11.3	11.5	2
3	P con.	g kg^{-1}	2.3	2.2	2.3	2.2	2.2	2.2	9.39	NS
	Uptake	g P kg^{-1}	7.2	6.3	6.4	6.1	5.8	6.4	10.9	1.1
4	P con.	g kg^{-1}	2.7	2.9	3	3.1	3	2.9	15.7	NS
	Uptake	g P kg^{-1}	19	21	21.2	23.4	19.5	20.8	12.6	4
5	P con.	g kg^{-1}	1.9	2	2.2	2.2	2.3	2.1	8.82	0.29
	Uptake	g P kg^{-1}	8.5	11	11.1	11	12.8	10.8	18.9	3.1
6	P con.	g kg^{-1}	2.6	2.6	2.7	2.9	3	2.8	6.46	0.28
	Uptake	g P kg^{-1}	12	12	12.2	12.4	12.9	12.2	9.2	NS
7	P con.	g kg^{-1}	2.5	2.5	2.4	2.2	2.4	2.4	14.65	NS
	Uptake	g P kg^{-1}	4.9	4.9	4.3	4	4.6	4.5	16.6	NS
8	P con.	g kg^{-1}	2.7	2.6	2.8	2.6	2.8	2.7	12.37	NS
	Uptake	g P kg^{-1}	18	15	17.6	15.8	18.3	16.8	11.8	3.1
9	P con.	g kg^{-1}	2.5	2.4	2.5	2.8	2.7	2.6	12.89	NS
	Uptake	g P kg^{-1}	10	7	10.6	10.3	10.6	9.7	27.5	NS
10	P con.	g kg^{-1}	2	2.4	2.6	2.6	2.6	2.4	11.03	0.42
	Uptake	g P kg^{-1}	15	17	16.5	17.8	16.9	16.6	8.9	2.3
11	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
12	P con.	g kg^{-1}	2.3	2.5	2.6	2.6	2.6	2.5	4.89	0.19
	Uptake	g P kg^{-1}	4.9	4.6	5.3	5.7	5.5	5.2	9.3	0.7
13	P con.	g kg^{-1}	3.2	3.2	3.2	3.3	3.2	3.2	2.78	NS
	Uptake	g P kg^{-1}	5	4.7	5	5.3	5.1	5	11.9	NS

14	P con.	g kg^{-1}	2.1	2.2	2.2	2.2	1.9	2.1	7.16	0.23
	Uptake	g P kg^{-1}	6.3	6.1	6.2	6.2	5.9	6.1	14.2	NS
15	P con.	g kg^{-1}	3.4	4	4	4.4	4.5	4.1	6.01	0.38
	Uptake	g P kg^{-1}	5.2	6.7	6.6	7.2	7.3	6.6	5.6	0.6
16	P con.	g kg^{-1}	3.3	3.2	3.2	3.2	3.2	3.2	3.74	NS
	Uptake	g P kg^{-1}	7	7.3	7.5	8	6.8	7.3	9.1	1
17	P con.	g kg^{-1}	3.1	3.2	3.3	3.3	3.4	3.2	9.16	NS
	Uptake	g P kg^{-1}	8.4	8.5	8.6	8.4	9	8.6	6.9	NS
18	P con.	g kg^{-1}	3.2	3.2	3.1	3.2	3.5	3.2	9.3	NS
	Uptake	g P kg^{-1}	10	8.3	8.2	8.7	9.1	8.9	14.9	NS
19	P con.	g kg^{-1}	2.8	2.8	2.7	2.6	2.8	2.7	8.43	NS
	Uptake	g P kg^{-1}	9.9	11	9.8	10.5	10.8	10.4	11.8	NS
20	P con.	g kg^{-1}	2	2.1	2.2	2.3	2.3	2.2	6.63	0.22
	Uptake	g P kg^{-1}	6.6	7.1	7.3	7.9	8.3	7.4	13.3	1.5
21	P con.	g kg^{-1}	2.4	2.5	2.5	2.5	2.5	2.4	6	NS
	Uptake	g P kg^{-1}	6.5	7	6.7	6.5	6.9	6.7	16.9	NS

† Site listed in Table 15.
NS: not significant at $\alpha = 0.05$.

TABLE 15. Petiole phosphorus (P) concentration and uptake for 30 trifoliolates at R2 for soybean phosphorus experiment. Fertilizer rates of 0, 34, 67, and 135 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring at site 11. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate						
			0	30	60	135	mean	cv	LSD
			—— kg P ha^{-1} ——						
11	P con.	g kg $^{-1}$	2.55	2.55	2.9	2.95	2.74	9.57	0.42
	Uptake	g P kg^{-1}	9.3	10	10.7	11.4	10.3	9.3	1.5

NS: not significant at α = 0.05.

TABLE 16. Across site analysis for R2 Petiole P Concentration and P uptake for 30 petioles in 2013 and 2014 for the soybean Phosphous fertility study in Eastern South Dakota. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%) and LSD at 0.05 alpha.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			——— kg P ha^{-1} ———							
2013	P con.	g kg^{-1}	2.4	2.5	2.6	2.6	2.7	2.5	11.41	0.1
	Uptake	g P kg^{-1}	11.6	11.3	12	12.4	12	12	14.72	0.8
2014	P con.	g kg^{-1}	2.8	2.9	2.9	2.9	3	2.9	6.85	0.1
	Uptake	g P kg^{-1}	7	7.1	7.1	7.4	7.5	7.2	12.25	0.4

TABLE 17. Trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at R2 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
1	P con.	g kg^{-1}	4	4.1	3.9	4.1	4.1	4.1	5.44	NS
	Uptake	g P kg^{-1}	43.5	47.6	44.4	45.1	45	45.2	7.1	NS
2	P con.	g kg^{-1}	3.5	3.5	3.7	3.6	3.7	3.6	3.54	NS
	Uptake	g P kg^{-1}	56.6	40	53.5	57.8	56	52.9	20.1	16.4
3	P con.	g kg^{-1}	3.7	3.6	3.6	3.6	3.6	3.6	5.64	0.31
	Uptake	g P kg^{-1}	34.1	31	29.6	30	29	30.8	9.5	4.5
4	P con.	g kg^{-1}	4.1	4.2	4.4	4.3	4.4	4.3	10.49	NS
	Uptake	g P kg^{-1}	79.2	82.4	82.9	83.1	80	81.5	8.1	NS
5	P con.	g kg^{-1}	3.3	3.4	3.5	3.5	3.7	3.5	3.88	0.21
	Uptake	g P kg^{-1}	33.7	38.8	43	40.5	45	40.2	9.4	5.8
6	P con.	g kg^{-1}	4	3.9	3.9	4.3	4.5	4.1	5.61	0.36
	Uptake	g P kg^{-1}	59.4	57.6	59.2	62	64	60.5	7.4	NS
7	P con.	g kg^{-1}	3.9	3.8	4.4	4.1	4.2	4.1	7.1	0.45
	Uptake	g P kg^{-1}	31.1	32.1	33.1	33.5	33	32.7	7	NS
8	P con.	g kg^{-1}	3.8	3.9	3.9	2.9	4.1	3.7	23.83	NS
	Uptake	g P kg^{-1}	60	53.9	61.7	59.2	63	59.5	6.2	5.8
9	P con.	g kg^{-1}	4.3	4.1	4.2	4.4	4.3	4.3	5.24	NS
	Uptake	g P kg^{-1}	59	53.7	60.8	57.5	61	58.4	9.1	NS
10	P con.	g kg^{-1}	3.6	3.9	4.1	4.1	4.2	4	6	0.37
	Uptake	g P kg^{-1}	65.8	67.5	66.7	75.5	71	69.3	9.9	NS
11	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
12	P con.	g kg^{-1}	3.8	3.7	3.6	3.5	3.7	3.7	7.78	NS
	Uptake	g P kg^{-1}	42.6	38	41.1	39.9	41	40.5	8.6	NS
13	P con.	g kg^{-1}	4.6	4.6	4.6	4.8	4.5	4.6	3.58	NS
	Uptake	g P kg^{-1}	37.2	37	37.5	40.2	37	37.8	9.4	NS

14	P con.	g kg^{-1}	3.6	3.4	3.5	3.4	3.3	3.4	5.82	NS
	Uptake	g P kg^{-1}	35.4	31	35.1	32	33	33.4	9.6	4.9
15	P con.	g kg^{-1}	4.6	5.1	5.2	5.4	5.4	5.1	4.56	0.36
	Uptake	g P kg^{-1}	64.2	75.7	75.8	77.6	80	74.7	5.3	6.1
16	P con.	g kg^{-1}	4.6	4.5	4.4	4.4	4.5	4.5	4.29	NS
	Uptake	g P kg^{-1}	45.2	47.6	49	50	45	47.3	8.4	6.1
17	P con.	g kg^{-1}	4.9	4.9	4.7	5.1	4.9	4.9	7.29	NS
	Uptake	g P kg^{-1}	51.4	52.6	54.7	51.9	56	53.3	7.1	NS
18	P con.	g kg^{-1}	4.7	4.6	4.8	4.8	5	4.8	7.86	NS
	Uptake	g P kg^{-1}	64.2	57.7	58.2	59.6	63	60.5	10.7	NS
19	P con.	g kg^{-1}	3.8	4	3.9	3.9	3.8	3.9	6.07	NS
	Uptake	g P kg^{-1}	48.4	53.3	50.2	53.2	50	51	11.5	NS
20	P con.	g kg^{-1}	3.2	3.2	3.3	3.3	3.4	3.3	4.56	NS
	Uptake	g P kg^{-1}	38.6	42	41	43	45	42	9	5.8
21	P con.	g kg^{-1}	3.6	3.6	3.7	3.7	3.7	3.6	4.56	NS
	Uptake	g P kg^{-1}	39.2	40.6	41.9	42	42	41.1	14.2	NS

† Site listed in Table 18.
NS: not significant at $\alpha = 0.05$.

TABLE 18. Trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at R2 for soybean phosphorus experiment. Fertilizer rates of 0, 34, 67, and 135 kg P ha^{-1}. were applied pre-plant broadcast in the spring at site 11. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate						
			0	34	67	135	mean	CV(%)	LSD (0.05)
			——— kg P ha^{-1} ———						
11	P con.	g kg^{-1}	3.6	3.6	3.8	4.1	3.8	7.52	0.45
	Uptake	g P kg^{-1}	32.8	33.8	35.3	36.7	34.6	9.9	NS

NS: not significant at α = 0.05.

TABLE 19. Across site analysis of trifoliolate phosphorus (P) concentration and uptake for 30 trifoliolates at R2 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%), and LSD at alpha (α) = 0.05.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			——— kg P ha^{-1} ———							
2013	P con.	g kg $^{-1}$	3.8	3.9	4	3.9	4.1	3.9	9.42	0.2
	Uptake	g P kg^{-1}	52.8	50.5	53.5	54.3	54.8	53.2	10.47	2.5
2014	P con.	g kg $^{-1}$	4.1	4.1	4.2	4.2	4.2	4.2	5.93	0.1
	Uptake	g P kg^{-1}	46.6	47.5	48.5	48.9	49.2	48.2	9.4	2

TABLE 20. Petiole plus trifoliolate phosphorus (P) concentration and uptake for 30 petiole plus trifoliolates at R2 for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%) and LSD at 0.05 alpha.

Site			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			———— kg P ha^{-1} ————							
1	P con.	g kg^{-1}	3.5	3.6	3.3	3.6	3.7	3.5	6.6	NS
	Uptake	g P kg^{-1}	5.3	5.9	5.4	5.6	5.6	5.6	8.28	0.71
2	P con.	g kg^{-1}	2.8	2.8	3	2.9	3	2.9	4.43	0.2
	Uptake	g P kg^{-1}	6.8	6.3	6.4	7	6.9	6.7	6.56	NS
3	P con.	g kg^{-1}	3	2.9	2.9	2.9	2.9	2.9	6.3	NS
	Uptake	g P kg^{-1}	4.1	3.7	3.6	3.6	3.5	3.7	9.29	0.53
4	P con.	g kg^{-1}	3.4	3.5	3.7	3.7	3.7	3.6	12.17	NS
	Uptake	g P kg^{-1}	9.9	10.3	10.4	11	10	10	8.76	NS
5	P con.	g kg^{-1}	2.6	2.7	2.9	2.9	3	2.8	5.42	0.23
	Uptake	g P kg^{-1}	4.2	4.9	5.4	5.1	5.8	5.1	11.02	0.87
6	P con.	g kg^{-1}	3.3	3.2	3.3	3.6	3.8	3.4	5.55	0.29
	Uptake	g P kg^{-1}	7.1	6.9	7.1	7.4	7.7	7.3	7.47	NS
7	P con.	g kg^{-1}	3.2	3.2	3.4	3.2	3.3	3.2	6.55	NS
	Uptake	g P kg^{-1}	3.6	3.7	3.7	3.7	3.8	3.7	6.11	NS
8	P con.	g kg^{-1}	3.3	3.3	3.4	3.3	3.5	3.3	7.44	NS
	Uptake	g P kg^{-1}	7.8	6.8	7.9	7.5	8.1	7.6	5.94	NS
9	P con.	g kg^{-1}	3.4	3.2	3.4	3.6	3.5	3.4	7.82	NS
	Uptake	g P kg^{-1}	6.9	6.7	7.1	6.8	7.2	6.9	8.75	NS
10	P con.	g kg^{-1}	2.8	3.1	3.4	3.3	3.4	3.2	7.79	0.39
	Uptake	g P kg^{-1}	8.1	8.4	8.3	9.3	8.8	8.6	9.48	NS
11	P con.	g kg^{-1}	†							
	Uptake	g P kg^{-1}	†							
12	P con.	g kg^{-1}	3.1	3.1	3.1	3	3.1	3.1	5.34	NS
	Uptake	g P kg^{-1}	4.7	4.6	4.6	4.6	4.3	4.6	8.27	NS
13	P con.	g kg^{-1}	3.9	3.9	3.9	4	3.9	3.9	2.91	NS

	Uptake	g P kg^{-1}	4.6	4.2	4.2	4.2	4.2	4.3	9.42	NS
14	P con.	g kg^{-1}	2.8	2.8	2.8	2.8	2.6	2.8	3.65	0.16
	Uptake	g P kg^{-1}	4.2	4.1	3.9	3.8	3.7	4	9.47	NS
15	P con.	g kg^{-1}	4	4.5	4.6	4.9	4.9	4.6	5	0.35
	Uptake	g P kg^{-1}	8.7	8.5	8.2	8.2	6.9	8.1	5.19	0.65
16	P con.	g kg^{-1}	4	3.9	3.8	3.8	3.9	3.8	3.59	NS
	Uptake	g P kg^{-1}	5.3	5.5	5.6	5.8	5.2	5.5	8.59	NS
17	P con.	g kg^{-1}	4	4	4	4.2	4.1	4.1	6.71	NS
	Uptake	g P kg^{-1}	6.5	6.3	6.1	6	6	6.2	6.82	NS
18	P con.	g kg^{-1}	4	3.9	3.9	4	4.2	4	7.86	NS
	Uptake	g P kg^{-1}	7.4	7.2	6.8	6.6	6.6	6.9	11	NS
19	P con.	g kg^{-1}	3.3	3.4	3.3	3.3	3.3	3.3	5.78	NS
	Uptake	g P kg^{-1}	6.4	6.4	6.1	6	5.8	6.1	10.83	NS
20	P con.	g kg^{-1}	2.6	2.7	2.8	2.8	2.8	2.7	4.94	0.21
	Uptake	g P kg^{-1}	5.4	5.1	4.9	4.8	4.5	4.9	9.51	0.72
21	P con.	g kg^{-1}	3	3	3.1	3.1	3.1	3	4.89	NS
	Uptake	g P kg^{-1}	4.9	4.9	4.8	4.8	4.6	4.8	14.48	NS

† Site listed in Table 21.
NS: not significant at $\alpha = 0.05$.

TABLE 19. Petiole plus trifoliolate phosphorus (P) concentration and uptake of 30 petiole plus trifoliolates at R2 for soybean phosphorus experiment. Fertilizer rates of 0, 34, 67, and 135 kg P ha^{-1} were applied pre-plant broadcast in the spring at site 11 in 2013. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site			P Rate						
			0	34	67	135	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}						
11	P con.	g kg^{-1}	3.2	3.1	3.4	3.5	3.3	7.52	0.4
	Uptake	g P kg^{-1}	4.4	4.5	4.7	4.8	4.6	8.93	NS

NS: not significant at α = 0.05.

TABLE 22. Across site analysis of petiole plus trifoliolate P Concentration and uptake of 30 petiole plus trifoliolates for soybean phosphorus experiment. Phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} applied pre-plant broadcast in the spring. Mean, CV (%) and LSD at 0.05 alpha.

Year			P Rate							
			0	22	45	67	90	mean	CV(%)	LSD (0.05)
			kg P ha^{-1}							
2013	P con.	g kg^{-1}	3.1	3.2	3.3	3.3	3.4	3.2	7.52	3.98
	Uptake	g P kg^{-1}	6.5	6.4	6.6	6.7	6.7	6.6	8.93	NS
2014	P con.	g kg^{-1}	3.4	3.5	3.5	3.6	3.6	3.5	9.47	0.09
	Uptake	g P kg^{-1}	5.4	5.5	5.6	5.6	5.7	5.5	9.47	0.23

NS: not significant at $\alpha = 0.05$.

APPENDIX

A-1. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 1. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
1	1	0	42.70	18.75	3.80	2.60	3.83	10.31	38.20	12.84	109.41	34.07	91.39
1	1	22	43.20	20.42	3.93	2.44	3.49	10.31	36.56	11.38	114.46	31.24	82.01
1	1	45	40.50	20.39	3.67	2.35	3.32	10.78	37.18	13.59	108.67	35.89	86.71
1	1	67	39.80	20.28	4.10	2.48	3.57	10.77	36.50	14.03	321.59	42.69	89.26
1	1	90	43.40	18.29	3.61	2.39	3.77	10.07	39.32	12.33	113.00	30.73	95.97
1	2	0	39.80	24.95	4.32	2.38	3.19	11.34	33.67	42.75	112.33	47.24	61.68
1	2	22	43.80	23.93	4.48	2.42	3.13	11.21	33.97	11.12	111.12	31.91	68.75
1	2	45	42.10	20.61	3.95	2.69	3.86	11.21	37.37	13.12	124.84	35.09	87.93
1	2	67	42.10	22.98	4.32	2.42	3.36	11.63	34.60	12.19	111.71	31.66	70.90
1	2	90	46.60	21.63	4.37	2.70	3.34	10.10	32.01	11.94	121.37	31.41	68.80
1	3	0	42.10	21.78	4.04	2.55	3.84	11.47	38.92	15.81	122.67	37.52	90.58
1	3	22	43.10	22.46	4.37	2.61	3.61	11.51	34.74	12.75	116.57	36.17	82.24
1	3	45	39.50	19.56	3.91	2.52	4.23	11.39	40.26	14.74	118.46	35.59	86.72
1	3	67	41.00	18.65	3.91	2.59	4.66	11.74	44.51	12.71	118.52	34.92	93.55
1	3	90	40.30	21.70	4.50	2.73	3.56	10.99	36.63	12.88	120.73	35.51	80.53
1	4	0	44.30	17.25	3.91	2.68	5.14	11.48	46.67	13.06	114.27	39.71	101.82
1	4	22	43.50	14.92	3.69	2.63	5.75	12.37	48.92	13.24	134.87	38.14	101.81
1	4	45	41.50	17.57	3.96	2.71	4.72	11.19	45.04	12.12	111.77	33.37	97.85
1	4	67	46.10	16.32	4.17	2.85	5.68	12.06	48.36	14.73	121.08	37.40	98.39
1	4	90	43.20	16.07	4.09	2.90	5.66	11.92	48.86	23.73	136.06	42.04	103.39

A-2. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 2. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	——— g kg^{-1} ———						——— mg kg^{-1} ———				
2	1	0	52.40	18.72	3.83	3.01	4.76	11.01	56.73	8.81	134.99	35.72	188.25
2	1	67	52.30	20.57	3.62	3.01	5.02	10.82	55.64	8.78	121.71	30.00	150.81
2	1	22	51.70	21.72	3.64	2.89	4.70	11.27	56.66	8.91	121.21	29.20	190.79
2	1	45	53.60	21.75	3.91	3.02	4.32	10.82	55.68	9.09	115.89	29.89	193.95
2	1	90	53.80	21.19	3.94	3.17	3.94	10.43	58.85	9.42	107.73	29.73	171.27
2	2	0	52.50	18.05	3.45	3.03	4.07	10.47	61.54	9.17	108.94	30.67	174.24
2	2	45	47.20	19.69	3.55	3.00	4.51	11.40	56.87	8.91	129.42	29.04	186.35
2	2	67	48.10	18.46	3.66	3.02	4.27	10.80	60.45	8.53	113.63	28.44	179.41
2	2	90	53.30	19.52	3.71	2.98	3.55	11.41	57.43	8.05	111.98	33.37	162.93
2	2	22	49.60	22.08	3.55	3.11	3.83	11.79	55.27	9.16	101.32	29.85	164.75
2	3	45	52.20	21.07	3.87	3.07	4.13	11.88	57.18	9.32	108.63	32.09	150.18
2	3	0	51.70	20.11	3.50	3.06	4.21	11.30	61.51	8.51	114.87	31.71	167.64
2	3	67	49.90	18.17	3.61	3.12	3.90	10.20	65.29	8.25	116.68	30.91	178.43
2	3	22	50.20	19.11	3.43	2.89	3.83	11.35	56.79	8.27	124.27	30.56	162.96
2	3	90	56.80	19.71	3.67	2.93	4.17	10.73	65.55	8.27	106.41	28.73	178.84
2	4	45	50.40	20.41	3.47	2.93	4.40	12.34	62.55	7.85	105.95	32.78	181.95
2	4	90	49.10	18.07	3.36	2.90	4.89	11.56	72.64	8.27	114.01	30.53	193.03
2	4	67	47.70	19.93	3.38	2.88	4.06	10.67	71.32	8.85	107.98	30.48	183.64
2	4	22	49.00	21.07	3.51	2.61	3.73	11.36	57.00	9.27	104.40	31.76	193.82
2	4	0	51.00	20.58	3.38	2.73	3.37	10.85	55.61	8.82	101.48	29.38	175.32

A-3. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 3. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	——— g kg^{-1} ———						——— mg kg^{-1} ———				
3	1	0	53.00	21.33	3.74	2.80	3.92	9.98	54.26	9.12	113.34	34.76	62.16
3	1	67	50.90	18.41	3.49	2.81	4.39	10.06	56.95	8.83	115.53	33.74	63.77
3	1	22	52.70	18.26	3.76	2.97	4.71	10.28	54.27	10.09	132.83	37.53	66.52
3	1	45	49.20	19.73	3.39	2.58	4.36	10.57	55.12	8.64	92.18	31.93	53.69
3	1	90	51.70	18.26	3.43	2.75	4.49	10.35	56.85	9.53	121.07	34.60	61.27
3	2	0	52.70	20.53	3.77	2.81	4.07	9.86	51.73	8.42	103.61	33.04	75.55
3	2	45	53.90	18.99	3.64	2.72	4.38	9.99	50.97	8.34	108.58	32.80	62.96
3	2	67	53.40	19.78	3.61	2.84	4.43	10.08	55.22	8.42	115.66	34.38	65.52
3	2	90	46.90	19.03	3.92	2.92	4.22	9.67	52.36	8.60	106.81	34.22	64.35
3	2	22	48.30	20.02	3.63	2.57	4.00	9.24	49.07	8.37	94.67	33.36	56.44
3	3	45	51.40	18.68	3.51	2.67	4.23	9.55	51.58	8.38	96.24	32.08	61.52
3	3	0	56.90	19.70	3.63	2.83	4.45	9.93	53.49	9.21	114.56	34.09	63.97
3	3	67	53.30	17.23	3.33	2.67	4.53	10.14	55.01	9.84	116.18	35.97	66.76
3	3	22	52.00	18.13	3.50	2.65	4.07	9.49	52.51	9.23	110.69	34.78	57.66
3	3	90	50.80	19.09	3.28	2.66	4.07	9.77	53.33	8.93	101.73	33.81	57.72
3	4	45	49.90	18.91	3.80	2.67	4.13	9.75	56.15	9.31	104.46	35.32	67.82
3	4	90	52.10	20.10	3.92	2.66	4.42	9.56	51.88	9.45	89.33	34.39	58.85
3	4	67	54.60	19.09	4.11	2.72	4.21	9.34	49.66	9.22	99.60	35.59	64.62
3	4	22	53.20	19.50	3.63	2.73	4.13	9.73	52.88	9.53	108.56	34.33	63.38
3	4	0	53.80	19.92	3.49	2.63	4.09	10.09	57.45	9.59	105.94	33.99	58.98

A-4. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 4. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
4	1	0	55.40	22.46	4.96	3.12	3.32	7.71	39.53	8.44	107.93	35.64	103.74
4	1	67	45.40	21.21	4.45	3.21	3.21	8.21	41.35	7.84	112.38	33.28	129.01
4	1	22	57.10	22.22	5.05	3.29	3.21	7.63	39.64	8.46	110.24	35.15	110.30
4	1	45	46.20	21.14	4.66	3.32	3.03	7.52	38.03	8.35	107.85	33.48	112.38
4	1	90	50.40	23.10	4.61	3.36	3.25	8.18	41.47	7.60	105.23	34.04	113.10
4	2	0	53.90	22.39	4.31	3.08	3.03	8.00	43.78	7.97	97.18	32.33	104.54
4	2	45	55.80	22.02	4.43	3.22	2.97	8.09	40.07	7.99	105.40	31.53	113.03
4	2	67	45.40	23.74	4.71	3.34	2.96	8.14	41.22	8.20	102.10	35.17	110.20
4	2	90	53.70	22.52	4.36	3.48	3.03	8.10	40.44	7.90	106.84	33.41	112.40
4	2	22	49.00	22.63	4.42	3.87	3.86	7.89	46.03	7.11	97.92	32.14	105.76
4	3	45	46.90	22.39	3.63	3.13	2.81	9.09	42.93	8.16	103.41	32.97	114.71
4	3	0	48.50	22.97	3.60	3.13	2.91	9.26	42.94	8.38	103.93	35.06	117.96
4	3	67	51.50	20.52	3.64	3.33	2.88	8.86	43.46	8.88	109.85	35.11	126.24
4	3	22	49.40	22.59	3.57	3.15	2.87	8.97	43.26	8.26	101.05	34.80	107.72
4	3	90	48.60	21.47	3.37	3.35	3.48	8.72	47.24	7.01	102.26	31.52	117.10
4	4	45	47.40	23.09	4.74	2.96	3.01	8.09	39.96	8.63	97.77	33.58	92.85
4	4	90	52.40	23.99	5.26	3.01	3.14	8.09	41.23	8.15	94.70	34.12	105.89
4	4	67	55.70	21.14	4.55	3.11	2.90	7.29	39.94	8.23	100.77	35.23	108.40
4	4	22	53.10	20.75	3.69	3.09	2.82	8.98	42.96	8.55	104.14	34.04	103.43
4	4	0	48.50	21.97	3.55	3.08	3.09	8.29	45.18	8.95	98.58	34.10	94.19

A-5. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 5. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
5	1	0	58.30	17.68	3.49	3.00	5.09	8.27	76.34	14.28	108.64	30.04	81.85
5	1	67	61.50	17.27	3.64	3.14	5.06	8.43	77.73	19.33	105.54	32.14	78.23
5	1	22	56.70	17.86	3.36	3.00	5.05	8.38	69.71	15.16	99.63	29.59	86.18
5	1	45	57.30	17.67	3.52	2.86	5.08	8.39	61.52	13.82	97.76	30.15	76.58
5	1	90	56.00	17.11	3.59	2.87	5.13	8.08	67.80	14.05	108.04	27.27	82.83
5	2	0	56.90	17.67	3.27	2.72	4.56	9.06	61.48	28.25	96.89	36.16	74.86
5	2	45	59.40	16.39	3.47	2.90	4.69	8.36	65.63	15.11	98.91	31.07	68.67
5	2	67	59.60	17.11	3.47	2.90	5.29	8.48	65.11	13.13	109.57	28.64	75.32
5	2	90	59.30	16.97	3.76	2.91	5.28	7.41	71.10	12.23	98.01	26.82	77.12
5	2	22	56.80	18.27	3.27	2.92	5.23	7.97	62.72	16.80	119.22	31.46	80.57
5	3	45	56.70	17.58	3.54	2.86	4.87	8.84	59.72	13.11	104.74	30.28	72.66
5	3	0	54.90	18.18	3.27	2.86	5.09	9.15	59.80	12.04	100.25	31.77	69.92
5	3	67	55.80	16.34	3.39	2.82	4.98	8.75	59.05	15.67	101.67	30.12	70.31
5	3	22	61.30	15.03	3.45	2.93	4.61	8.60	57.98	10.87	108.74	29.41	67.29
5	3	90	59.40	17.44	3.77	3.01	4.47	9.03	56.42	14.81	108.55	32.73	71.92
5	4	45	57.00	19.56	3.65	2.95	4.59	9.42	55.66	14.16	91.86	32.82	71.91
5	4	90	58.20	17.54	3.58	2.93	4.35	9.15	54.48	13.65	107.95	32.13	73.72
5	4	67	59.30	18.39	3.67	2.91	4.31	9.32	54.95	30.52	107.19	40.29	68.24
5	4	22	59.40	17.63	3.58	2.96	4.23	9.14	52.90	13.26	109.66	32.58	72.75
5	4	0	54.90	17.93	3.06	2.80	4.08	9.03	52.29	17.66	113.02	35.88	72.71

A-6. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 6. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
6	1	0	54.10	12.46	3.84	2.65	5.29	10.42	43.82	9.62	112.35	25.79	81.24
6	1	22	52.70	12.91	3.90	2.51	5.15	10.04	43.44	9.79	108.12	26.17	82.24
6	1	45	52.40	12.55	4.06	2.64	5.88	10.99	45.56	9.74	113.92	26.14	86.23
6	1	67	54.10	13.22	4.12	2.69	5.51	10.15	44.28	9.77	110.14	25.62	86.04
6	1	90	55.00	14.24	5.03	2.81	5.38	10.68	43.07	10.22	103.21	26.95	82.22
6	2	0	53.80	13.37	3.97	2.58	5.04	10.11	42.45	11.85	105.10	27.18	80.28
6	2	22	52.80	12.98	3.79	2.58	5.54	10.56	44.99	11.41	110.12	26.63	85.08
6	2	45	51.60	13.52	4.04	2.63	5.45	10.74	44.04	11.50	650.37	36.86	89.50
6	2	67	52.40	14.82	4.66	2.71	5.19	9.97	41.35	11.14	100.47	28.08	76.20
6	2	90	52.80	13.83	4.42	2.78	5.37	10.40	43.68	10.04	107.14	26.45	79.40
6	3	0	54.70	13.33	4.21	2.55	5.19	10.02	44.08	10.82	106.91	27.21	79.03
6	3	22	51.60	13.60	3.90	2.44	5.09	10.01	42.84	9.90	105.46	26.38	83.55
6	3	45	53.00	13.57	3.94	2.44	5.02	9.98	42.25	9.94	106.73	25.34	82.92
6	3	67	53.80	13.42	4.24	2.47	5.07	10.11	42.49	10.16	106.81	26.75	79.40
6	3	90	54.00	14.71	4.38	2.47	4.97	10.75	41.76	10.08	100.15	28.03	82.83
6	4	0	51.90	13.19	3.83	2.46	5.27	10.43	42.13	9.63	103.96	26.16	82.60
6	4	22	52.50	14.06	3.96	2.48	5.11	10.19	41.68	10.14	102.39	26.31	79.39
6	4	45	48.60	12.40	3.67	2.39	5.42	10.98	44.59	10.13	105.92	25.05	81.01
6	4	67	49.20	13.14	4.06	2.46	5.02	10.07	41.87	10.14	106.34	26.63	82.92
6	4	90	51.30	14.00	4.31	2.58	5.16	10.35	43.38	11.50	109.93	27.52	82.33

A-7. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 7. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
7	1	0	54.30	21.12	3.70	2.99	5.60	8.69	49.29	12.72	154.01	36.77	91.01
7	1	67	50.30	24.77	3.99	3.00	4.76	7.77	45.43	10.56	112.41	32.71	79.30
7	1	22	49.70	24.31	3.83	2.68	5.06	8.71	50.33	10.49	100.70	32.45	84.03
7	1	45	59.00	24.14	4.80	3.30	5.82	8.29	55.75	11.61	118.84	35.47	96.81
7	1	90	51.70	21.60	3.92	2.85	4.88	7.61	54.20	11.64	136.81	32.39	88.49
7	2	0	54.30	21.81	4.03	2.85	5.20	7.81	47.61	10.84	134.90	32.10	83.51
7	2	45	52.50	23.87	4.27	2.93	5.08	7.81	48.40	11.39	117.93	34.19	77.16
7	2	67	55.20	23.42	4.58	2.95	5.02	7.94	44.47	11.60	102.18	34.33	74.64
7	2	90	48.80	23.13	4.31	2.71	4.75	7.59	43.93	10.75	95.86	33.52	75.07
7	2	22	54.20	21.50	3.73	2.87	5.12	8.13	50.08	10.83	135.94	33.78	81.64
7	3	45	49.80	23.08	3.90	2.87	4.98	8.23	44.52	12.47	120.83	35.82	77.47
7	3	0	49.40	21.74	3.95	2.85	5.09	8.38	48.93	11.22	123.97	33.80	83.62
7	3	67	51.80	21.12	3.89	2.87	4.97	7.85	47.87	11.64	122.98	34.42	77.88
7	3	22	50.40	22.48	4.10	2.80	4.73	7.60	45.77	11.08	110.54	32.26	81.99
7	3	90	49.50	21.68	4.05	2.93	5.53	7.99	59.45	11.45	116.60	31.64	101.95
7	4	45	53.00	21.13	4.56	3.10	5.88	8.11	63.73	10.80	131.90	33.89	109.22
7	4	90	50.60	22.96	4.33	2.98	5.30	8.13	52.99	10.43	145.65	32.86	92.28
7	4	67	51.20	22.41	4.13	2.82	5.14	8.29	47.48	11.33	133.46	34.34	81.29
7	4	22	50.40	22.66	3.73	2.99	5.30	8.34	52.98	11.79	141.90	36.80	86.60
7	4	0	NR										

NR: not recorded.

A-8. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 8. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1} were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
8	1	0	50.90	23.26	3.81	2.78	3.55	9.28	47.22	9.65	133.72	33.90	133.33
8	1	67	52.50	23.89	4.02	2.99	3.87	10.81	43.94	8.91	132.65	33.78	153.61
8	1	22	52.80	25.55	3.90	2.98	3.68	9.92	44.58	9.11	120.25	34.70	138.63
8	1	45	51.80	24.34	3.88	2.93	3.74	9.96	46.63	9.12	110.69	34.26	140.14
8	1	90	55.20	24.49	4.52	3.11	3.76	9.49	47.81	8.44	123.55	34.65	140.21
8	2	0	50.70	24.68	3.73	2.89	3.53	10.35	39.66	9.96	115.88	35.40	139.42
8	2	45	54.30	24.77	4.17	3.04	3.41	9.10	41.50	9.45	102.54	35.51	118.64
8	2	67	51.10	23.43	3.79	3.01	3.75	10.20	43.60	9.67	109.41	34.12	137.74
8	2	90	50.90	24.62	4.13	2.97	3.62	10.04	43.89	8.49	104.65	32.73	136.74
8	2	22	52.50	23.54	4.02	3.06	3.66	9.90	40.97	9.12	115.29	34.67	135.68
8	3	45	53.00	25.11	3.99	3.05	3.59	10.41	38.69	9.61	115.19	34.93	136.88
8	3	0	53.30	24.61	3.66	2.93	3.41	10.44	39.13	10.88	115.49	37.73	142.07
8	3	67	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
8	3	22	54.10	23.76	4.03	3.06	3.44	10.54	38.45	9.52	118.81	38.54	132.57
8	3	90	50.70	25.41	3.80	2.88	3.15	10.52	37.29	8.90	102.04	34.04	116.73
8	4	45	54.80	22.67	3.72	3.09	3.46	11.60	38.03	10.29	117.05	36.62	139.05
8	4	90	52.10	25.04	3.91	3.02	3.37	11.89	37.90	9.09	109.43	36.42	132.05
8	4	67	52.90	23.58	3.95	2.91	3.11	10.48	38.15	9.03	104.03	34.80	118.78
8	4	22	52.10	23.69	3.65	2.80	3.08	10.13	36.01	9.44	102.74	35.49	117.39
8	4	0	52.90	25.36	4.11	3.03	3.22	11.32	39.66	9.93	104.78	38.22	130.02

NR: not recorded.

A-9. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 9. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
9	1	0	60.90	24.37	4.64	3.20	4.13	9.64	43.10	13.48	115.42	41.05	118.71
9	1	67	56.80	26.28	4.65	3.10	4.20	10.30	46.40	12.64	123.82	36.74	127.95
9	1	22	58.50	25.91	4.48	3.00	4.25	10.47	41.94	15.21	107.89	37.05	132.31
9	1	45	58.20	25.53	4.53	3.04	4.26	10.87	45.53	14.34	102.29	38.57	133.22
9	1	90	53.70	26.82	4.29	3.01	4.22	11.25	45.89	10.43	123.41	37.27	147.86
9	2	0	56.80	26.27	4.29	3.03	4.03	10.55	45.48	11.08	104.89	39.48	124.99
9	2	45	57.30	26.24	4.66	3.01	3.90	9.99	45.04	10.54	106.68	38.86	125.86
9	2	67	57.50	27.20	4.58	3.19	4.34	11.06	44.45	10.83	109.44	36.20	140.13
9	2	90	58.80	27.39	4.61	3.04	4.16	10.83	46.11	13.88	102.92	35.95	131.60
9	2	22	57.40	26.84	4.45	2.99	3.86	10.01	41.84	13.26	114.17	37.12	127.64
9	3	45	58.50	23.32	3.99	3.05	4.18	11.76	46.06	9.99	103.56	35.38	140.08
9	3	0	55.30	23.87	3.75	2.92	4.18	11.81	50.40	9.98	101.07	36.40	139.95
9	3	67	52.00	24.50	3.97	2.92	3.94	11.27	50.23	10.93	103.40	36.39	151.72
9	3	22	51.80	22.88	3.56	2.78	4.05	12.72	48.78	10.31	99.71	32.46	174.54
9	3	80	54.30	24.34	3.77	2.93	4.35	13.02	40.75	11.72	106.85	34.22	160.72
9	4	40	57.90	23.07	3.77	3.00	4.08	11.82	49.42	9.73	102.30	35.30	135.20
9	4	90	60.40	25.03	4.59	2.99	3.87	10.91	49.27	9.11	104.32	38.64	121.49
9	4	67	54.90	24.89	4.37	2.90	3.77	10.36	47.86	10.83	100.36	36.87	137.10
9	4	22	54.40	24.63	3.90	2.79	3.89	10.70	48.65	10.83	100.50	39.26	156.12
9	4	0	57.20	25.82	4.39	2.85	3.81	9.79	43.50	10.93	106.69	38.25	129.21

A-10. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 10. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
10	1	0	54.80	18.80	4.04	2.96	3.31	9.15	33.64	9.70	123.69	31.55	188.10
10	1	67	53.30	18.67	4.07	3.05	3.53	9.09	34.12	9.45	122.69	30.22	195.40
10	1	22	54.50	18.30	4.15	2.87	3.66	9.34	33.58	9.90	128.55	31.63	201.92
10	1	45	56.40	18.34	4.30	3.01	3.54	9.11	35.59	9.89	122.04	32.42	187.88
10	1	90	55.60	19.13	4.51	2.84	3.59	9.38	33.18	9.08	112.53	31.11	200.07
10	2	0	49.60	18.31	3.47	2.90	3.62	9.94	35.76	10.20	131.03	33.33	246.70
10	2	45	54.60	18.18	4.73	2.92	3.75	9.09	31.64	8.82	113.67	31.07	186.18
10	2	67	52.80	19.36	4.56	2.91	3.62	9.64	33.44	9.85	111.40	31.34	186.77
10	2	90	53.40	19.93	4.54	2.87	3.80	9.85	35.95	9.41	113.70	32.16	205.51
10	2	22	45.70	16.92	3.90	2.76	3.34	8.67	33.38	9.24	114.78	29.72	217.55
10	3	45	49.80	18.18	3.63	2.85	3.59	10.30	36.29	10.06	124.60	30.43	233.54
10	3	0	53.60	18.64	3.65	3.13	4.04	10.41	39.01	10.26	128.27	32.34	235.27
10	3	67	54.10	20.25	4.07	3.10	3.83	10.28	39.08	10.07	125.74	32.34	218.30
10	3	22	47.90	20.60	3.88	2.91	3.77	10.53	38.65	11.52	121.82	33.99	216.28
10	3	90	50.50	20.12	3.89	2.97	3.89	11.01	39.26	10.49	126.76	32.52	272.89
10	4	45	48.20	19.93	3.81	3.04	3.79	10.85	39.25	10.02	125.47	34.77	250.85
10	4	90	52.00	17.64	3.80	3.16	4.13	10.80	39.45	9.37	137.68	31.04	273.55
10	4	67	51.20	18.26	3.87	3.23	4.25	11.02	39.98	9.91	134.35	33.97	248.16
10	4	22	50.60	18.33	3.65	2.99	4.09	11.26	40.12	10.93	132.58	37.67	261.89
10	4	0	49.70	19.13	3.20	2.82	3.64	10.43	37.85	10.59	120.56	33.57	246.57

A-11. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 11. Fertilizer rates of 0, 34, 67, and 135 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2013. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
11	1	0	55.30	19.51	3.56	3.44	4.35	9.49	55.43	12.07	92.84	38.24	68.12
11	1	67	55.90	20.65	3.65	4.35	4.58	8.88	55.95	10.72	92.77	37.76	65.66
11	1	135	57.30	19.70	4.50	3.48	4.25	8.82	54.27	15.84	93.72	38.91	63.53
11	1	34	52.20	21.04	3.57	4.69	4.33	8.85	53.18	14.44	89.23	40.31	67.36
11	2	0	56.30	21.48	4.05	3.51	4.31	9.15	50.49	11.27	85.95	37.62	63.05
11	2	67	55.70	20.12	3.69	3.06	4.44	8.75	55.52	10.61	88.55	35.31	63.93
11	2	135	54.60	20.39	4.07	3.26	4.09	8.41	50.64	13.94	87.23	38.30	60.63
11	2	34	54.60	19.76	3.64	2.99	4.36	8.75	56.84	15.72	89.75	39.38	65.89
11	3	0	56.00	22.54	3.79	3.16	4.31	8.76	51.83	13.50	90.08	40.17	63.13
11	3	67	56.40	19.94	3.70	2.86	4.39	9.70	51.44	14.66	85.69	39.27	64.67
11	3	135	58.00	19.72	4.05	3.06	4.45	8.78	52.61	10.45	87.81	36.68	61.87
11	3	34	53.80	20.06	3.63	2.96	4.33	9.17	55.39	11.22	89.04	38.22	67.21
11	4	0	58.50	19.14	3.11	2.82	4.30	10.24	49.44	11.65	88.14	39.31	71.73
11	4	67	59.40	19.81	4.11	3.07	4.44	9.05	52.76	11.36	95.60	42.01	68.92
11	4	135	57.30	20.06	3.78	2.91	4.44	9.91	51.65	10.92	86.37	36.50	66.24
11	4	34	57.00	19.96	3.48	2.84	4.38	10.11	54.03	12.07	93.42	40.27	69.88

A-12. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 12. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
12	1	67	44.60	17.80	3.40	2.40	4.40	12.30	39.01	11.51	181.25	59.97	100.54
12	1	22	44.30	20.40	3.90	2.70	4.90	12.90	46.52	14.11	223.81	57.64	103.87
12	1	90	43.90	20.10	3.90	2.80	5.10	13.60	46.71	14.53	271.99	57.17	108.83
12	1	0	44.50	18.90	3.50	2.60	5.20	13.90	44.75	15.52	201.23	55.77	113.49
12	1	45	46.60	18.30	3.40	2.60	4.20	11.30	39.42	11.46	212.18	49.34	96.19
12	2	67	44.00	17.60	3.40	2.50	4.70	12.40	39.14	11.59	196.73	58.15	105.93
12	2	45	43.00	17.60	3.30	2.30	4.60	12.30	40.49	11.21	250.21	49.85	101.91
12	2	90	45.00	20.10	3.70	2.70	4.70	13.20	40.17	11.79	173.61	69.03	106.39
12	2	0	45.10	21.90	4.30	2.90	5.40	14.00	46.29	13.86	263.30	60.80	113.00
12	2	22	46.00	19.30	3.90	2.70	4.80	13.00	43.46	14.30	242.32	56.22	112.47
12	3	22	43.80	20.40	3.70	2.70	5.30	14.30	47.29	13.99	198.70	52.58	116.22
12	3	67	42.60	19.60	3.60	2.50	4.80	13.00	42.95	14.22	247.36	54.65	106.67
12	3	90	43.80	20.30	3.70	2.70	5.00	13.20	41.98	14.04	200.88	56.06	111.94
12	3	0	43.50	19.80	3.70	2.70	5.10	12.90	50.11	13.51	222.03	55.98	108.01
12	3	45	42.50	23.00	4.10	2.80	5.30	14.00	47.63	14.33	252.51	63.76	110.98
12	4	0	46.00	19.60	3.80	2.60	5.30	13.80	42.04	12.94	143.92	56.50	105.31
12	4	45	40.20	20.10	3.70	2.60	4.80	13.30	45.30	13.72	193.33	64.60	103.40
12	4	22	41.70	17.90	3.40	2.40	4.30	12.10	41.20	11.94	198.77	63.75	106.32
12	4	90	41.20	18.30	3.30	2.30	4.40	12.20	39.95	11.30	155.68	49.64	106.34
12	4	65	45.10	19.40	3.50	2.50	4.60	12.70	40.64	12.43	230.68	54.11	108.08

A-13. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 13. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
13	1	65	57.80	34.70	4.90	3.80	3.70	9.90	35.13	13.99	107.85	31.11	272.01
13	1	22	61.30	33.30	4.90	3.80	3.70	9.80	35.93	12.08	119.55	31.02	294.62
13	1	90	58.40	34.40	5.00	3.90	3.60	10.50	36.31	11.53	109.62	31.78	280.44
13	1	0	62.40	32.80	4.90	4.00	3.60	10.00	36.93	12.60	115.24	36.27	291.83
13	1	45	59.80	33.20	4.80	3.90	3.80	10.50	37.28	10.25	103.49	33.80	295.53
13	2	67	57.60	30.50	4.80	3.50	3.70	9.80	38.09	12.72	116.96	32.65	291.78
13	2	45	58.60	31.10	4.80	3.60	3.90	10.80	41.15	15.58	93.13	32.12	346.98
13	2	90	54.20	30.40	4.30	3.80	4.10	11.30	39.88	15.04	95.62	73.27	320.48
13	2	0	59.20	31.30	4.60	3.50	4.00	10.90	37.10	13.96	97.66	42.12	326.77
13	2	22	57.80	31.50	4.50	3.60	4.00	10.50	38.82	14.13	78.09	40.81	287.33
13	3	22	58.00	30.20	4.50	3.50	4.00	10.90	39.35	16.63	94.30	48.78	333.67
13	3	65	58.00	33.00	4.60	3.30	4.00	11.80	38.51	15.14	97.30	41.41	353.73
13	3	90	58.20	30.40	4.50	3.60	3.90	10.70	36.69	13.22	82.87	44.01	379.30
13	3	0	56.00	32.10	4.50	3.20	3.90	11.50	33.73	13.82	78.56	43.96	364.78
13	3	45	59.80	32.10	4.60	3.60	4.20	11.20	41.43	14.94	90.83	42.59	312.98
13	4	0	54.90	31.80	4.30	3.20	3.80	11.30	37.40	15.80	96.18	51.40	341.60
13	4	45	54.60	31.20	4.00	3.20	3.60	10.40	35.48	13.02	69.41	44.13	338.69
13	4	22	56.20	29.90	4.30	3.40	3.70	10.30	34.29	14.46	92.13	63.94	343.45
13	4	90	55.60	30.80	4.20	3.20	3.60	10.40	36.78	14.06	86.43	44.98	267.21
13	4	65	59.30	31.90	4.70	3.60	3.80	10.20	39.64	17.31	80.79	62.63	257.62

A-14. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 14. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	——— g kg^{-1} ———						——— mg kg^{-1} ———				
14	1	65	59.80	21.60	3.60	3.30	5.20	9.40	48.11	13.89	125.19	44.70	84.31
14	1	22	61.00	22.70	3.50	3.30	4.60	8.60	42.65	11.33	153.84	40.81	90.57
14	1	90	58.70	22.00	3.20	3.20	4.80	8.70	43.65	11.86	153.05	36.00	85.06
14	1	0	59.30	21.60	3.80	3.20	4.50	8.90	45.83	10.41	128.20	38.35	69.79
14	1	45	54.50	22.90	3.60	3.50	5.70	9.30	47.49	16.12	169.26	37.31	96.27
14	2	67	61.30	22.70	3.50	3.30	5.00	8.90	43.19	12.12	155.71	38.79	106.03
14	2	45	58.80	22.00	3.40	3.30	5.40	9.10	46.77	12.13	150.91	38.24	100.08
14	2	90	60.10	22.90	3.60	3.50	5.50	9.50	48.78	13.01	165.33	41.05	95.48
14	2	0	59.20	21.80	3.30	3.30	5.50	9.30	47.55	17.12	152.59	39.83	97.17
14	2	22	57.90	21.50	3.20	3.20	5.20	8.10	44.26	10.02	127.32	36.34	90.86
14	3	22	59.20	21.90	3.40	3.40	5.40	8.50	47.03	12.26	147.17	34.97	93.24
14	3	65	60.50	59.00	3.00	2.70	7.50	19.70	28.92	5.98	381.67	43.69	39.96
14	3	90	59.20	64.10	3.00	2.30	6.70	18.50	27.23	5.02	314.90	38.35	50.08
14	3	0	57.30	23.80	3.60	3.20	4.60	10.10	46.94	15.51	132.84	42.76	79.75
14	3	45	56.00	21.10	3.40	3.00	4.10	8.10	40.06	10.29	128.07	37.67	69.97
14	4	0	58.70	21.40	3.60	3.20	4.50	9.00	46.30	13.08	132.40	39.38	68.93
14	4	45	57.90	22.40	3.70	3.30	4.50	9.20	46.80	12.63	136.26	42.45	74.46
14	4	22	58.20	21.00	3.30	3.30	4.90	8.90	45.82	10.79	126.33	35.31	85.33
14	4	90	60.20	20.40	3.50	3.10	4.30	8.30	44.06	8.70	132.39	35.59	70.52
14	4	65	59.60	18.30	3.40	3.00	4.20	7.90	40.88	9.20	128.46	34.88	69.24

A-15. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 15. Fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
15	1	65	65.00	23.80	5.90	3.90	4.80	12.50	43.56	5.11	154.87	29.28	222.66
15	1	22	63.50	24.90	5.00	3.90	4.90	13.20	45.63	7.83	177.10	33.12	244.98
15	1	90	64.90	22.80	5.30	3.90	5.30	12.80	43.78	7.08	163.10	35.03	278.29
15	1	0	62.70	23.00	4.40	3.60	5.30	13.90	45.86	6.50	185.65	31.05	291.88
15	1	45	66.90	23.90	5.20	3.90	5.10	12.30	43.15	6.89	175.21	32.51	296.91
15	2	67	66.10	21.40	5.00	3.70	5.10	12.00	41.64	4.81	144.80	29.96	259.30
15	2	45	65.30	23.10	5.20	3.90	5.30	12.20	43.83	3.19	148.68	31.45	222.75
15	2	90	63.70	22.60	5.60	4.00	5.30	12.70	43.53	4.15	166.88	29.21	234.37
15	2	0	62.80	23.50	4.70	3.90	5.70	14.10	43.82	3.91	155.27	31.44	233.08
15	2	22	65.30	23.00	5.10	3.90	5.50	12.40	44.39	6.67	140.74	33.06	225.03
15	3	22	64.60	24.50	5.00	4.00	5.30	12.70	43.96	4.46	180.47	29.10	204.82
15	3	65	64.90	24.40	5.40	4.20	5.90	14.00	47.72	4.58	177.15	28.66	227.24
15	3	90	62.00	23.00	5.30	3.70	5.60	13.70	42.29	3.52	149.93	26.22	227.66
15	3	0	62.80	24.00	4.50	3.80	5.50	14.20	44.16	4.64	188.14	31.40	223.79
15	3	45	62.50	24.50	4.80	3.90	5.70	14.00	44.97	4.13	165.40	31.76	216.16
15	4	0	63.10	23.00	4.70	3.90	5.50	13.60	44.41	4.76	172.63	32.29	225.03
15	4	45	61.80	23.30	5.40	4.00	6.20	13.90	46.43	4.74	199.90	25.43	217.28
15	4	22	62.60	24.60	5.20	3.80	5.80	13.50	44.75	4.06	153.10	27.62	226.79
15	4	90	65.70	25.00	5.40	3.90	5.40	12.90	42.41	4.08	149.50	29.53	213.83
15	4	67	66.00	26.20	5.30	3.80	5.10	12.40	41.37	4.58	132.25	30.07	198.93

A-16. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 16. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
16	1	67	52.00	23.60	4.20	2.90	4.80	11.80	48.42	9.54	126.41	40.02	115.45
16	1	22	54.50	26.30	4.60	3.10	4.60	11.40	48.88	10.79	136.14	35.18	113.72
16	1	90	52.80	29.10	4.50	3.10	4.80	12.30	45.74	8.86	108.84	32.30	110.31
16	1	0	52.10	27.30	4.40	2.80	4.30	11.30	48.83	10.27	129.39	37.64	107.24
16	1	45	51.40	24.90	4.20	3.00	4.30	10.90	45.61	12.37	136.12	39.70	113.37
16	2	67	54.40	26.10	4.60	3.20	4.50	11.20	45.79	9.58	113.99	31.38	107.97
16	2	45	54.30	30.40	4.90	3.20	4.60	11.90	50.14	10.94	127.20	35.09	113.69
16	2	90	54.00	24.10	4.50	3.10	4.60	11.20	46.13	9.43	105.50	35.71	106.74
16	2	0	56.40	25.10	4.60	3.10	5.00	11.10	49.48	10.45	148.74	37.12	113.56
16	2	22	53.00	28.30	4.40	3.00	4.20	11.50	45.49	8.83	118.63	34.70	115.46
16	3	22	53.60	27.70	4.60	3.00	4.40	11.50	44.60	9.69	125.80	33.77	121.84
16	3	67	52.10	25.70	4.50	3.10	4.60	11.40	47.32	11.05	140.48	34.57	115.85
16	3	90	58.70	28.60	4.70	3.60	4.70	11.90	51.83	60.55	157.35	64.99	125.03
16	3	0	52.00	27.20	4.50	3.00	4.20	10.70	44.64	10.00	130.52	38.48	108.76
16	3	45	50.90	28.50	4.30	2.90	4.30	11.50	47.43	10.32	126.46	41.90	116.32
16	4	0	52.70	28.60	4.70	2.90	4.90	11.90	46.68	12.26	100.88	38.78	115.04
16	4	45	52.80	27.90	4.20	2.90	4.10	10.90	43.30	9.58	123.20	35.55	115.91
16	4	22	53.30	27.40	4.40	3.10	4.60	11.20	48.19	9.56	112.98	38.25	110.54
16	4	90	50.70	27.50	4.30	3.00	4.50	11.90	47.46	9.19	121.83	31.94	124.35
16	4	67	50.00	27.80	4.20	2.80	4.30	11.70	46.34	10.09	125.93	35.66	120.01

A-17. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 17. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
17	1	67	53.40	36.50	5.20	4.00	4.50	12.40	49.32	13.02	156.32	91.91	183.88
17	1	22	54.60	30.50	4.80	3.40	4.10	10.30	44.21	18.50	125.22	90.80	208.20
17	1	90	53.10	30.60	5.20	3.40	4.00	10.70	45.63	23.42	114.59	92.68	220.90
17	1	0	54.20	34.40	5.10	4.00	4.50	11.60	49.38	17.75	127.06	92.60	229.21
17	1	45	52.50	29.30	4.80	3.20	3.80	9.70	42.59	12.37	96.29	76.29	167.91
17	2	67	53.10	29.60	4.70	3.10	3.70	9.60	42.07	11.28	111.91	74.10	165.85
17	2	45	52.30	30.50	4.50	3.40	3.90	9.60	42.43	14.55	110.29	89.62	155.91
17	2	90	52.60	30.00	5.00	3.20	3.80	10.10	44.40	13.37	113.06	70.97	168.99
17	2	0	49.80	31.40	4.50	3.00	4.00	10.70	43.99	13.88	149.26	104.80	187.10
17	2	22	54.50	33.50	5.00	3.50	4.00	10.40	43.95	13.74	95.08	82.74	175.58
17	3	22	52.50	36.30	5.30	3.50	4.20	10.80	48.27	16.91	116.71	94.95	200.36
17	3	67	49.80	39.80	6.00	3.90	4.60	12.60	54.39	15.50	141.33	122.78	212.00
17	3	90	51.50	31.20	4.90	3.20	4.00	10.20	45.10	13.86	120.56	101.00	181.90
17	3	0	49.50	33.10	4.80	3.20	4.30	11.20	47.52	15.99	114.15	100.46	181.47
17	3	45	50.70	33.60	4.90	3.20	4.10	10.70	46.57	15.50	122.04	111.15	162.66
17	4	0	51.70	36.90	5.00	3.40	4.30	11.20	50.72	17.33	131.18	107.29	172.88
17	4	45	51.30	31.70	4.60	2.90	3.80	9.80	45.27	13.73	108.23	88.53	146.67
17	4	22	52.10	31.50	4.30	2.90	3.70	9.50	45.01	17.01	113.83	82.64	148.44
17	4	90	53.70	31.20	4.40	3.00	3.80	10.10	44.35	16.63	113.62	83.86	138.38
17	4	67	54.40	28.10	4.30	3.00	4.00	9.60	45.59	17.38	118.50	76.65	130.94

A-18. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 18. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
18	1	67	53.70	29.40	5.30	3.90	6.20	12.20	52.84	16.84	128.79	68.00	184.10
18	1	22	50.20	28.40	4.80	3.40	5.70	12.50	50.07	17.02	105.36	65.43	167.10
18	1	90	52.60	27.90	5.30	3.80	6.00	12.80	47.18	25.60	148.34	67.57	179.73
18	1	0	56.60	27.30	5.30	3.90	5.70	11.90	44.53	18.06	144.98	83.06	141.15
18	1	45	56.40	29.10	5.50	3.70	5.70	13.00	47.01	17.64	157.60	100.89	109.88
18	2	67	48.60	29.90	5.30	3.70	5.80	14.30	47.44	18.56	115.00	62.89	151.75
18	2	45	54.30	28.00	5.10	3.70	5.60	12.30	47.19	17.25	104.02	74.69	135.51
18	2	90	50.60	29.00	5.50	3.90	6.40	14.60	49.40	18.25	122.89	55.94	231.46
18	2	0	51.90	25.30	4.20	3.40	5.50	12.00	43.09	17.13	129.46	105.16	157.39
18	2	22	51.90	25.50	4.50	3.40	5.50	12.20	44.72	16.69	173.44	63.65	143.39
18	3	22	50.40	25.90	4.20	3.30	5.30	11.20	45.41	26.51	120.95	57.32	154.97
18	3	67	51.10	27.10	4.40	3.40	5.80	12.50	48.79	17.59	119.76	48.85	179.28
18	3	90	47.30	25.20	4.70	3.30	6.00	11.90	47.23	15.45	120.37	52.40	233.83
18	3	0	53.20	26.50	4.90	3.70	6.00	11.30	48.25	18.90	141.04	64.06	195.98
18	3	45	54.30	24.80	4.40	3.40	5.80	10.90	49.73	14.75	156.82	48.82	203.09
18	4	0	53.80	25.70	4.30	3.40	5.20	11.50	44.62	41.49	118.37	64.00	122.06
18	4	45	53.30	25.70	4.30	3.40	5.30	11.60	42.35	14.73	112.81	53.49	162.39
18	4	22	51.50	26.60	4.80	3.50	5.70	11.00	47.38	16.42	116.38	61.36	215.11
18	4	90	53.10	24.10	4.30	3.60	6.70	9.20	65.63	15.87	154.22	49.46	196.89
18	4	67	51.40	24.30	4.20	3.40	6.10	9.60	51.34	13.12	136.22	40.99	165.91

A-19. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 19. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
19	1	67	51.40	30.30	4.10	3.30	4.10	10.30	46.33	14.55	126.73	71.99	146.66
19	1	22	54.20	28.70	3.90	3.60	4.30	10.50	49.92	12.65	150.97	49.33	168.10
19	1	90	56.20	27.80	4.10	3.60	4.10	10.00	49.71	12.41	124.55	82.40	144.79
19	1	0	54.20	29.10	4.20	3.30	4.70	10.80	52.87	12.94	137.98	50.00	152.18
19	1	45	54.00	26.30	4.30	3.70	4.80	10.50	50.52	11.68	157.95	54.90	159.14
19	2	67	54.60	28.40	3.70	3.30	3.80	9.90	44.98	12.60	121.00	39.70	148.63
19	2	45	52.90	28.30	3.70	3.20	4.00	9.80	51.71	11.56	124.34	41.79	144.23
19	2	90	55.10	28.60	4.00	3.30	4.10	10.20	49.82	14.62	136.98	44.45	137.89
19	2	0	51.90	30.00	3.90	3.10	4.10	11.40	52.23	14.34	130.35	44.77	131.12
19	2	22	52.70	25.80	4.00	3.10	4.30	11.10	43.33	25.38	144.53	54.17	132.37
19	3	22	52.20	32.40	4.20	3.50	4.60	11.70	55.15	13.71	138.86	41.95	160.50
19	3	67	56.20	27.10	3.90	3.50	4.20	9.30	50.40	13.48	135.46	38.40	152.27
19	3	90	53.60	29.50	3.80	3.50	4.30	10.50	59.07	11.32	150.78	34.73	120.26
19	3	0	56.10	23.90	3.40	2.90	3.80	8.90	48.26	11.23	133.78	33.57	112.33
19	3	45	52.90	26.80	3.90	3.20	4.40	10.80	48.78	8.16	152.87	38.32	165.20
19	4	0	54.50	27.00	3.70	3.30	4.00	9.80	48.16	13.09	135.35	35.11	135.15
19	4	45	53.70	27.40	3.50	3.50	4.00	10.00	44.79	13.06	124.34	43.63	142.87
19	4	22	55.60	28.00	3.90	3.80	4.40	10.40	48.86	12.57	148.21	41.31	160.28
19	4	90	53.20	23.50	3.40	3.00	4.10	8.70	47.85	9.62	123.21	36.17	161.94
19	4	67	58.20	25.60	4.00	3.50	4.80	9.80	49.30	10.64	147.55	36.06	192.47

A-20. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 20. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
20	1	67	48.40	27.10	3.50	2.80	4.40	11.90	37.24	8.48	89.29	34.02	135.35
20	1	22	48.90	26.80	3.60	3.00	4.40	12.70	37.93	8.43	89.42	68.27	147.05
20	1	90	47.20	27.30	3.60	2.70	4.50	13.20	36.56	7.96	84.92	34.53	154.60
20	1	0	45.90	23.80	3.10	2.70	4.60	12.50	37.49	9.96	92.51	67.94	129.94
20	1	45	49.40	23.50	3.40	2.90	5.40	13.20	39.24	9.24	88.13	49.80	172.83
20	2	67	44.80	24.60	3.20	2.60	4.60	13.50	38.02	8.72	89.51	40.04	156.26
20	2	45	48.90	25.20	3.40	2.90	4.70	13.20	38.96	8.61	97.82	60.16	147.04
20	2	90	46.40	24.70	3.40	2.80	4.40	13.00	37.33	7.91	93.80	61.64	164.44
20	2	0	48.10	23.60	3.30	2.60	4.50	12.60	36.29	9.20	88.34	60.31	147.97
20	2	22	49.80	21.90	3.30	2.90	4.90	13.10	38.08	9.14	103.45	50.59	151.67
20	3	22	44.10	22.70	3.00	2.60	4.70	13.00	37.76	7.78	99.82	70.93	146.86
20	3	67	49.60	24.90	3.50	2.90	4.80	13.50	41.49	8.21	88.10	43.34	167.28
20	3	90	47.10	23.70	3.30	2.90	4.60	13.50	38.48	9.29	89.20	43.62	162.67
20	3	0	46.40	24.60	3.20	2.60	4.70	13.30	37.57	8.57	96.13	48.08	149.67
20	3	45	45.70	22.10	3.20	2.70	5.00	14.20	36.23	9.69	88.31	36.43	147.35
20	4	0	46.90	23.20	3.00	2.80	5.00	14.10	41.16	8.34	90.11	42.18	151.77
20	4	45	45.80	23.40	3.20	2.70	4.80	13.00	39.01	7.97	83.05	35.74	150.93
20	4	22	43.70	21.20	3.00	2.70	5.30	13.20	42.48	8.18	85.02	76.22	152.42
20	4	90	43.80	21.10	3.10	2.70	5.20	12.70	39.88	9.12	99.12	40.10	141.72
20	4	67	42.90	22.90	3.00	2.60	5.00	14.20	37.45	6.98	99.90	32.69	166.61

A-21. R2 Trifoliolate nutrient concentration for 30 trifoliolates within in each experimental unit at site 21. Fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ were applied pre-plant broadcast in the spring in 2014. Trifoliolates were not washed prior to analysis.

Site	Block	Prate	N	K	P	S	Mg	Ca	B	Cu	Fe	Zn	Mn
		kg P ha^{-1}	g kg^{-1}						mg kg^{-1}				
21	1	67	54.60	25.10	3.70	3.20	4.80	13.30	40.54	8.97	96.26	41.37	139.30
21	1	22	55.80	26.40	3.80	3.20	4.80	13.10	38.88	10.29	105.55	49.31	118.29
21	1	90	54.10	26.20	3.90	3.40	4.90	13.00	39.82	10.43	99.25	51.20	126.22
21	1	0	52.50	24.60	3.50	3.20	5.10	13.70	42.30	11.26	105.93	39.39	97.72
21	1	45	52.90	25.20	3.90	3.40	4.80	13.00	41.14	10.51	97.31	38.30	104.64
21	2	67	54.20	24.70	3.60	3.10	4.90	12.80	40.24	9.01	96.90	34.21	143.73
21	2	45	53.40	26.30	3.70	3.10	4.70	12.90	38.63	15.49	90.92	45.73	107.81
21	2	90	54.00	24.10	3.70	3.30	5.20	13.10	41.39	9.72	84.47	45.49	128.83
21	2	0	53.90	25.40	3.80	3.30	5.50	13.40	43.31	11.19	90.63	41.09	129.74
21	2	22	52.30	25.00	3.50	3.30	5.00	13.30	41.38	10.12	100.66	48.13	104.01
21	3	22	56.60	25.10	3.60	3.40	5.00	13.10	40.36	13.29	105.78	40.02	120.91
21	3	65	54.00	24.60	3.40	3.20	5.00	12.60	39.64	11.20	88.82	38.52	124.79
21	3	90	55.40	25.10	3.60	3.30	5.20	12.40	42.78	8.95	99.20	36.40	120.66
21	3	0	54.50	22.90	3.60	3.30	5.30	12.70	39.57	10.47	99.65	53.91	111.49
21	3	45	51.50	24.40	3.60	3.30	4.90	11.70	40.15	11.51	99.25	44.35	97.65
21	4	0	57.30	22.30	3.40	3.30	5.10	12.00	39.98	10.02	102.66	35.50	113.27
21	4	45	57.90	23.00	3.40	3.40	5.40	13.10	47.00	10.81	113.59	41.04	113.47
21	4	22	54.50	24.50	3.50	3.90	5.10	13.60	46.98	9.34	77.99	43.24	141.40
21	4	90	57.70	22.90	3.60	3.30	5.20	12.70	42.54	9.02	101.70	33.69	108.54
21	4	67	58.80	22.20	3.90	3.50	5.40	12.50	43.57	11.41	109.47	40.55	113.77

A-22. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 2 in 2013.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}		%	
2	1	0	34.9	21.1	11.9
2	1	67	35.4	20.6	12.1
2	1	22	35.1	20.7	11.9
2	1	45	35.3	20.5	11.7
2	1	90	34.9	20.8	11.6
2	2	0	35.1	20.5	12.2
2	2	45	34.5	21.0	12.1
2	2	67	35.5	20.5	11.8
2	2	90	35.1	21.0	11.6
2	2	22	33.7	21.7	11.6
2	3	45	33.6	21.7	12.2
2	3	0	33.3	22.0	12.2
2	3	67	34.1	21.2	11.9
2	3	22	33.4	21.8	11.4
2	3	90	32.7	22.1	11.8
2	4	45	33.7	21.6	12.0
2	4	90	33.8	21.6	11.8
2	4	67	35.1	20.7	11.7
2	4	22	34.5	21.1	11.9
2	4	0	33.7	21.6	11.6

A-23. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 4 in 2013.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	———	%	———
4	1	0	38.20	18.3	8.4
4	1	67	37.30	18.6	8.4
4	1	22	35.50	19.9	8.3
4	1	45	35.20	19.9	8.2
4	1	90	38.40	17.8	8.2
4	2	0	38.00	18.1	8.1
4	2	45	34.80	20.1	8.3
4	2	67	34.30	20.3	8.2
4	2	90	36.30	19.4	8.1
4	2	22	36.30	18.9	8.1
4	3	45	34.60	20.1	8.6
4	3	0	34.30	20.3	8.4
4	3	67	33.80	20.6	8.1
4	3	22	36.70	19.1	8.1
4	3	90	37.70	18.0	8.1
4	4	45	34.50	20.3	8.4
4	4	90	34.60	20.2	8.3
4	4	67	34.70	20.1	8.1
4	4	22	34.60	20.2	8.2
4	4	0	36.90	19.1	8.1

A-24. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 5 in 2013.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	%		
5	1	0	41.3	16.7	8.2
5	1	67	41.5	16.7	7.8
5	1	22	41.3	16.8	7.9
5	1	45	42.6	16.4	8.2
5	1	90	42.8	16.1	8.0
5	2	0	42.5	16.5	8.2
5	2	45	41.0	17.4	8.3
5	2	67	41.8	16.8	8.2
5	2	90	41.7	16.3	7.4
5	2	22	41.5	17.0	7.4
5	3	45	42.1	16.9	7.5
5	3	0	38.8	19.4	8.4
5	3	67	40.6	18.0	8.1
5	3	22	40.3	18.4	8.3
5	3	90	40.4	18.2	8.3
5	4	45	39.0	19.0	8.5
5	4	90	39.8	18.7	8.2
5	4	67	40.6	17.9	7.7
5	4	22	40.6	17.6	8.0
5	4	0	38.6	19.4	8.2

A-25. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 9 in 2013.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}		%	
9	1	0	31.9	20.80	8.5
9	1	67	32.6	20.30	8.8
9	1	22	33.0	20.50	8.7
9	1	45	32.5	20.00	8.6
9	1	90	32.3	20.40	8.4
9	2	0	32.7	20.30	8.5
9	2	45	33.1	19.80	8.5
9	2	67	33.2	20.10	8.7
9	2	90	33.1	19.40	8.6
9	2	22	32.4	20.40	8.4
9	3	45	32.5	20.00	8.5
9	3	0	32.6	20.20	8.5
9	3	67	32.7	20.00	8.5
9	3	22	33.4	19.70	8.7
9	3	90	32.5	20.20	8.6
9	4	45	32.4	20.50	8.5
9	4	90	32.5	20.50	8.6
9	4	67	32.3	20.60	8.5
9	4	22	32.4	20.50	8.7
9	4	0	32.1	20.80	8.4

A-26. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 10 in 2013.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}		%	
10	1	0	37.7	18.4	8.6
10	1	67	36.2	18.9	8.3
10	1	22	38.0	18.2	8
10	1	45	38.4	17.9	8.1
10	1	90	38.5	17.6	8.5
10	2	0	36.6	19.1	8.5
10	2	45	37.0	18.7	8.2
10	2	67	38.6	17.4	8.1
10	2	90	37.7	18.0	8.2
10	2	22	38.6	17.7	8.2
10	3	45	35.9	19.4	8.8
10	3	0	36.5	19.3	8.6
10	3	67	37.3	18.6	8.3
10	3	22	38.0	18.0	7.9
10	3	90	37.2	18.8	8.4
10	4	45	33.9	20.0	8.9
10	4	90	36.7	19.2	8.7
10	4	67	37.7	18.1	9.0
10	4	22	37.2	18.6	8.3
10	4	0	35.9	19.6	8.9

A-27. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 12 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	———	%	———
12	1	67	32.3	17.7	5.7
12	1	22	33.2	17.1	4.7
12	1	90	33.2	17.4	5.5
12	1	0	34.3	17.4	5.9
12	1	45	34	17.1	5.8
12	2	67	33.4	17.7	5.6
12	2	45	33.7	17.2	5.2
12	2	90	33.5	17.8	5.9
12	2	0	34.4	18.0	6.6
12	2	22	34.7	17.7	6.6
12	3	22	33.5	17.6	5.7
12	3	67	33.8	17.3	5.7
12	3	90	33.5	17.6	5.6
12	3	0	34.5	17.6	5.7
12	3	45	34.7	17.4	6.1
12	4	0	33.1	17.3	5.0
12	4	45	32.5	17.7	5.0
12	4	22	32.1	17.9	5.7
12	4	90	32.9	17.8	5.9
12	4	67	33.6	17.4	5.7

A-28. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 13 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	%		
13	1	67	33.2	18.6	5.2
13	1	22	32.6	18.7	5.6
13	1	90	32.6	18.9	5.6
13	1	0	32.8	18.9	5.4
13	1	45	32.3	18.8	5.0
13	2	67	32.7	18.8	5.1
13	2	45	33.3	18.6	5.0
13	2	90	32.8	18.9	5.0
13	2	0	34.1	18.7	5.5
13	2	22	32.9	19.2	5.9
13	3	22	33.2	18.9	5.1
13	3	67	34.1	18.7	5.2
13	3	90	34.2	18.8	5.3
13	3	0	33.5	18.8	4.6
13	3	45	32.9	19.1	5.4
13	4	0	32.1	18.9	5.5
13	4	45	31.9	19.8	5.0
13	4	22	32.1	18.9	5.0
13	4	90	31.2	19.4	5.2
13	4	67	32.5	18.9	5.2

A-29. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 14 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	%		
14	1	67	34.2	17.5	5.1
14	1	22	33.1	18.4	5.2
14	1	90	34.7	17.5	5.4
14	1	0	33.0	18.6	5.3
14	1	45	35.3	17.7	5.8
14	2	67	34.1	17.9	5.6
14	2	45	33.3	18.2	5.2
14	2	90	34.3	17.9	5.3
14	2	0	33.7	18.6	5.8
14	2	22	33.7	18.1	5.3
14	3	22	34.8	17.6	5.5
14	3	67	35.5	17.4	5.5
14	3	90	36.1	16.9	5.5
14	3	0	35.3	17.6	6.0
14	3	45	36.5	17.0	5.8
14	4	0	36.0	17.4	6.3
14	4	45	35.7	17.4	5.2
14	4	22	35.9	17.8	5.9
14	4	90	35.9	17.5	6.0
14	4	67	36.1	17.3	5.9

A-30. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 15 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	%		
15	1	65	37.0	18.2	6.5
15	1	22	37.1	18.1	6.9
15	1	90	37.2	17.9	6.5
15	1	0	36.7	18.5	7.2
15	1	45	37.5	17.9	6.9
15	2	67	38.5	17.7	7.0
15	2	45	37.6	17.9	6.3
15	2	90	37.3	17.2	7.0
15	2	0	37.3	18.1	6.9
15	2	22	37.6	17.9	6.6
15	3	22	36.9	18.7	7.6
15	3	65	36.5	18.5	6.9
15	3	90	36.8	18.1	6.4
15	3	0	37.2	17.9	6.4
15	3	45	37.1	18.2	7.1
15	4	0	38.0	18.1	6.3
15	4	45	37.4	18.1	6.7
15	4	22	37.3	18.3	6.9
15	4	90	37.4	18.2	6.5
15	4	67	37.4	18.1	6.5

A-31. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 16 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	———	%	———
16	1	67	35.0	19.6	6.0
16	1	22	34.7	19.7	5.9
16	1	90	35.4	19.4	6.0
16	1	0	35.0	19.5	6.4
16	1	45	35.3	19.6	6.2
16	2	67	34.9	19.6	5.9
16	2	45	34.7	19.7	6.2
16	2	90	35.2	19.5	6.8
16	2	0	35.0	19.7	6.3
16	2	22	34.3	20.1	6.2
16	3	22	34.7	19.5	6.4
16	3	67	34.8	19.5	6.4
16	3	90	34.5	19.9	6.2
16	3	0	34.1	20.0	6.1
16	3	45	34.5	19.8	6.5
16	4	0	34.8	19.6	6.7
16	4	45	34.5	19.9	6.6
16	4	22	34.6	19.8	6.4
16	4	90	34.5	19.7	6.5
16	4	67	34.7	19.6	6.0

A-32. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 17 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	%		
17	1	67	35.1	18.9	5.9
17	1	22	35.7	18.6	5.8
17	1	90	35.2	18.6	5.7
17	1	0	35.6	18.5	5.4
17	1	45	35.9	18.5	5.9
17	2	67	35.9	18.4	5.7
17	2	45	35.0	18.7	5.9
17	2	90	35.5	18.5	5.6
17	2	0	35.9	18.3	5.4
17	2	22	35.6	18.5	6.0
17	3	22	36.1	18.3	5.5
17	3	67	35.8	18.3	5.4
17	3	90	35.6	18.6	6.3
17	3	0	36.0	18.2	5.7
17	3	45	36.4	18.1	5.7
17	4	0	35.6	18.4	5.6
17	4	45	35.8	18.4	5.8
17	4	22	36.0	18.3	5.8
17	4	90	35.6	18.4	5.5
17	4	67	36.1	18.4	6.1

A-33. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P $ha^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 19 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}		%	
19	1	67	32.0	19.9	5.3
19	1	22	32.4	19.6	4.9
19	1	90	32.6	19.7	5.6
19	1	0	33.3	19.5	5.8
19	1	45	33.5	19.3	5.4
19	2	67	31.7	19.9	4.9
19	2	45	31.8	19.5	5.5
19	2	90	32.6	19.6	5.2
19	2	0	32.1	19.7	5.3
19	2	22	32.5	19.6	5.2
19	3	22	31.9	19.6	4.9
19	3	67	33.4	19.2	5.6
19	3	90	32.5	19.5	5.0
19	3	0	31.8	19.7	5.3
19	3	45	32.0	19.5	5.0
19	4	0	32.5	19.5	5.2
19	4	45	32.9	19.3	4.9
19	4	22	31.7	19.7	4.9
19	4	90	31.9	19.7	4.8
19	4	67	31.8	19.7	4.9

A-34. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha^{-1}. Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 20 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}		%	
20	1	67	32.4	18.8	5.4
20	1	22	32.6	18.5	4.8
20	1	90	32.4	18.4	4.7
20	1	0	33.4	18.7	5.1
20	1	45	32.9	18.3	5.1
20	2	67	31.9	18.2	5.1
20	2	45	33.1	18.3	5.1
20	2	90	32.2	18.4	4.8
20	2	0	33.0	17.9	5.0
20	2	22	31.8	18.5	4.9
20	3	22	32.7	18.4	5.4
20	3	67	32.1	18.3	5.1
20	3	90	32.3	18.4	5.1
20	3	0	34.0	17.7	4.8
20	3	45	32.3	18.6	5.5
20	4	0	31.4	18.3	5.1
20	4	45	31.2	18.5	5.3
20	4	22	33.8	18.0	5.2
20	4	90	32.4	18.4	5.1
20	4	67	31.9	18.3	5.2

A-35. Grain protein, oil and moisture for phosphorus (P) fertilizer rates of 0, 22, 45, 67, and 90 kg P ha$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Grain was collected at maturity (R8) for site 21 in 2014.

Site	Block	Prate	Protein	Oil	Moisture
		kg P ha^{-1}	———	%	———
21	1	67	32.3	18.2	5.1
21	1	22	31.8	18.1	4.6
21	1	90	31.4	18.5	4.9
21	1	0	31.6	18.2	5.1
21	1	45	30.4	18.7	5.1
21	2	67	31.5	18.2	4.8
21	2	45	32.3	18.0	5.0
21	2	90	32.2	18.1	5.2
21	2	0	32.4	18.7	5.2
21	2	22	30.1	18.6	4.7
21	3	22	33.0	17.5	4.6
21	3	67	32.8	17.3	4.2
21	3	90	32.2	18.2	5.0
21	3	0	33.6	18.1	6.1
21	3	45	30.8	18.6	4.8
21	4	0	32.9	17.7	5.0
21	4	45	34.0	17.6	5.4
21	4	22	33.2	17.6	4.8
21	4	90	33.0	17.7	5.4
21	4	67	32.0	18.1	5.2

A-36. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 1 in 2013.

Site	P Rate	Dry Weight	Moisture	P
	lb P a^{-1}	lbs	%	
1	0	1.326	0.699	0.189
1	20	1.648	0.712	0.223
1	40	1.220	0.704	0.258
1	60	1.693	0.696	0.232
1	80	1.244	0.692	0.209
1	0	1.484	0.708	0.322
1	20	1.750	0.711	0.259
1	40	1.702	0.696	0.216
1	60	1.538	0.713	0.324
1	80	1.588	0.709	0.306
1	0	1.734	0.700	0.201
1	20	1.329	0.714	0.232
1	40	1.477	0.703	0.204
1	60	1.564	0.709	0.189
1	80	1.782	0.699	0.264
1	0	1.518	0.700	0.187
1	20	1.164	0.699	0.152
1	40	1.735	0.704	0.228
1	60	1.299	0.701	0.230
1	80	1.460	0.715	0.230

A-37. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 2 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
2	0	0.671	0.049	0.214
2	60	0.379	0.046	0.246
2	20	0.718	0.042	0.193
2	40	0.782	0.041	0.169
2	80	0.998	0.037	0.250
2	0	1.125	0.037	0.187
2	40	0.763	0.039	0.234
2	60	0.932	0.039	0.224
2	80	0.848	0.039	0.195
2	20	1.002	0.012	0.178
2	40	0.850	0.012	0.208
2	0	1.063	0.036	0.183
2	60	1.025	0.011	0.143
2	20	0.891	0.038	0.222
2	80	1.024	0.012	0.218
2	40	0.891	0.037	0.271
2	80	0.807	0.011	0.209
2	60	0.656	0.040	0.240
2	20	0.914	0.036	0.163
2	0	0.913	0.037	0.177

A-38. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 3 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	—— % ——	
3	0	0.449	0.632	0.225
3	60	0.445	0.658	0.243
3	20	0.000	0.646	0.216
3	40	0.681	0.634	0.234
3	80	0.326	0.660	0.240
3	0	0.443	0.739	0.231
3	40	0.428	0.637	0.221
3	60	0.000	0.646	0.216
3	80	0.314	0.652	0.241
3	20	0.000	0.636	0.213
3	40	0.519	0.649	0.227
3	0	0.824	0.648	0.216
3	60	0.295	0.672	0.228
3	20	0.490	0.678	0.219
3	80	0.477	0.664	0.221
3	40	0.363	0.658	0.218
3	80	0.322	0.664	0.231
3	60	0.246	0.658	0.221
3	20	0.551	0.668	0.227
3	0	0.593	0.663	0.227

A-39. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 4 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
4	0	1.371	0.013	0.130
4	60	1.004	0.010	0.209
4	20	1.218	0.013	0.324
4	40	1.300	0.017	0.161
4	80	1.395	0.011	0.225
4	0	1.544	0.013	0.230
4	40	1.363	0.018	0.200
4	60	1.325	0.014	0.170
4	80	1.371	0.013	0.161
4	20	1.347	0.015	0.251
4	40	1.058	0.020	0.200
4	0	1.567	0.013	0.199
4	60	1.283	0.013	0.195
4	20	1.412	0.015	0.221
4	80	1.068	0.011	0.199
4	40	1.372	0.012	0.236
4	80	1.746	0.056	0.216
4	60	1.241	0.012	0.235
4	20	1.521	0.014	0.230
4	0	1.528	0.010	0.303

A-40. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 5 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
5	0	0.610	0.013	0.146
5	60	0.894	0.011	0.187
5	20	0.871	0.012	0.157
5	40	0.893	0.012	0.146
5	80	1.156	0.011	0.207
5	0	1.331	0.010	0.128
5	40	1.134	0.011	0.146
5	60	1.463	0.010	0.153
5	80	1.243	0.011	0.166
5	20	0.983	0.009	0.172
5	40	1.441	0.010	0.178
5	0	1.307	0.012	0.165
5	60	1.418	0.011	0.148
5	20	1.328	0.013	0.154
5	80	1.592	0.011	0.153
5	40	0.958	0.012	0.171
5	80	0.698	0.011	0.165
5	60	0.958	0.013	0.170
5	20	1.044	0.013	0.248
5	0	1.090	0.011	0.154

A-41. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 6 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
6	0	0.759	0.715	0.181
6	20	0.634	0.692	0.190
6	40	0.854	0.704	0.219
6	60	0.749	0.662	0.179
6	80	0.741	0.660	0.190
6	0	0.616	0.686	0.175
6	20	0.591	0.692	0.166
6	40	0.757	0.706	0.214
6	60	0.732	0.695	0.257
6	80	0.622	0.651	0.193
6	0	0.685	0.640	0.173
6	20	0.709	0.705	0.191
6	40	0.795	0.642	0.242
6	60	0.730	0.631	0.197
6	80	0.560	0.569	0.229
6	0	0.588	0.637	0.216
6	20	0.752	0.655	0.163
6	40	0.600	0.647	0.190
6	60	0.857	0.685	0.191
6	80	0.657	0.556	0.178

A-42. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 7 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	%	
7	0	3.000	0.730	0.288
7	60	2.880	0.735	0.287
7	20	2.940	0.729	0.315
7	40	3.360	0.731	0.279
7	80	1.480	0.725	0.265
7	0	2.620	0.736	0.270
7	40	2.860	0.740	0.294
7	60	3.280	0.747	0.298
7	80	2.320	0.744	0.291
7	20	3.300	0.751	0.272
7	40	2.740	0.740	0.284
7	0	3.500	0.748	0.225
7	60	3.180	0.749	0.346
7	20	3.010	0.744	0.239
7	80	2.640	0.738	0.309
7	40	NR	NR	NR
7	80	2.480	0.753	0.338
7	60	2.940	0.752	0.275
7	20	3.080	0.752	0.314
7	0	3.040	0.746	0.330

NR: not recorded.

A-43. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 8 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
8	0	0.840	0.216	0.202
8	60	1.280	0.279	0.289
8	20	1.060	0.282	0.225
8	40	1.300	0.483	0.251
8	80	1.120	0.305	0.266
8	0	1.820	0.442	0.176
8	40	NR	NR	NR
8	60	0.840	0.228	0.282
8	80	0.700	0.918	0.310
8	20	0.580	0.240	0.292
8	40	1.520	0.576	0.189
8	0	1.120	0.427	0.253
8	60	0.960	0.282	0.239
8	20	3.000	0.540	0.259
8	80	0.740	0.213	0.279
8	40	0.620	NR	0.247
8	80	0.500	0.194	0.209
8	60	0.460	0.208	0.217
8	20	1.960	0.579	0.230
8	0	1.500	0.536	0.324

NR; not recorded.

A-44. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 9 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	%	
9	0	1.130	0.033	0.193
9	60	NR	NR	NR
9	20	0.703	0.033	0.180
9	40	1.041	0.036	0.164
9	80	1.232	0.036	0.167
9	0	1.173	0.033	0.127
9	40	1.344	0.032	0.202
9	60	1.172	0.034	0.174
9	80	1.299	0.034	0.187
9	20	1.149	0.035	0.237
9	40	1.131	0.032	0.167
9	0	1.008	0.027	0.209
9	60	0.000	0.034	0.219
9	20	NR	NR	NR
9	80	1.300	0.034	0.195
9	40	1.066	0.033	0.166
9	80	1.214	0.034	0.160
9	60	1.192	0.034	0.169
9	20	1.150	0.034	0.162
9	0	1.194	0.033	0.193

NR; not recorded.

A-45. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 10 in 2013.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
10	0	1.168	0.037	0.271
10	60	1.228	0.040	0.258
10	20	1.149	0.035	0.219
10	40	1.169	0.036	0.249
10	80	1.297	0.035	0.263
10	0	1.338	0.037	0.194
10	40	1.593	0.037	0.170
10	60	1.211	0.036	0.236
10	80	1.403	0.036	0.229
10	20	1.277	0.035	0.145
10	40	1.146	0.037	0.239
10	0	1.447	0.035	0.175
10	60	1.296	0.036	0.280
10	20	1.292	0.039	0.224
10	80	1.405	0.035	0.209
10	40	1.274	0.037	0.234
10	80	1.145	0.038	0.264
10	60	0.999	0.036	0.248
10	20	1.146	0.038	0.275
10	0	1.083	0.037	0.165

A-46. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 30, 60, and 135 lb P a$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 11 in 2013. Mean, CV (%), and LSD at alpha (α) = 0.05.

Site	P Rate	Dry weight	Moisture	P
	lb P a^{-1}	lb	%	
11	0	1.138	0.653	0.157
11	60	1.280	0.612	0.216
11	120	1.301	0.635	0.198
11	30	1.068	0.621	0.185
11	0	1.112	0.604	0.187
11	60	1.324	0.619	0.194
11	120	1.185	0.632	0.232
11	30	1.256	0.592	0.213
11	0	NR	NR	NR
11	60	1.138	0.616	0.207
11	120	1.474	0.588	0.235
11	30	1.368	0.575	0.179
11	0	1.074	0.635	0.149
11	60	1.295	0.650	0.216
11	120	1.379	0.629	0.165
11	30	1.280	0.606	0.192

NR; not recorded.

A-47. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 12 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	%	
12	60	1.017	0.731	0.340
12	20	0.843	0.759	0.340
12	80	0.772	0.751	0.290
12	0	1.027	0.743	0.280
12	40	0.939	0.733	0.260
12	60	0.756	0.750	0.300
12	40	0.709	0.764	0.340
12	80	0.642	0.764	0.350
12	0	0.598	0.746	0.340
12	20	0.647	0.751	0.310
12	20	0.601	0.752	0.320
12	60	0.898	0.756	0.350
12	80	0.577	0.785	0.360
12	0	0.810	0.745	0.310
12	40	0.780	0.750	0.280
12	0	0.736	0.744	0.300
12	40	0.748	0.747	0.300
12	20	0.639	0.744	0.310
12	80	0.619	0.742	0.350
12	60	0.805	0.745	0.320

A-48. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 13 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
13	60	0.868	0.751	0.370
13	20	0.729	0.741	0.330
13	80	0.911	0.731	0.320
13	0	0.920	0.739	0.280
13	40	0.774	0.726	0.380
13	60	0.595	0.690	0.360
13	40	0.716	0.696	0.370
13	80	0.558	0.686	0.370
13	0	0.736	0.674	0.330
13	20	0.459	0.672	0.350
13	20	0.645	0.664	0.360
13	60	0.829	0.681	0.380
13	80	0.598	0.664	0.410
13	0	0.844	0.709	0.390
13	40	0.673	0.710	0.270
13	0	0.710	0.723	0.290
13	40	0.387	0.677	0.300
13	20	0.450	0.674	0.290
13	80	0.668	0.685	0.310
13	60	0.668	0.699	0.270

A-49. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 14 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
14	60	1.209	0.651	0.410
14	20	1.243	0.666	0.370
14	80	1.123	0.647	0.430
14	0	1.276	0.661	0.390
14	40	1.315	0.671	0.490
14	60	1.057	0.659	0.400
14	40	1.069	0.641	0.370
14	80	1.305	0.658	0.430
14	0	1.046	0.654	0.390
14	20	1.188	0.644	0.410
14	20	1.417	0.678	0.400
14	60	1.240	0.684	0.480
14	80	1.465	0.653	0.510
14	0	1.333	0.643	0.470
14	40	1.062	0.662	0.520
14	0	1.446	0.682	0.460
14	40	1.294	0.670	0.470
14	20	1.116	0.607	0.500
14	80	1.619	0.665	0.530
14	60	1.377	0.649	0.550

A-50. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 15 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
15	60	1.292	0.763	0.430
15	20	1.786	0.762	0.400
15	80	1.477	0.757	0.400
15	0	1.227	0.761	0.390
15	40	1.545	0.775	0.380
15	60	1.205	0.758	0.480
15	40	1.550	0.748	0.430
15	80	1.456	0.742	0.440
15	0	1.542	0.743	0.370
15	20	1.620	0.736	0.400
15	20	1.540	0.737	0.350
15	60	1.166	0.752	0.350
15	80	1.250	0.734	0.460
15	0	1.418	0.755	0.360
15	40	1.303	0.747	0.400
15	0	1.359	0.736	0.330
15	40	1.311	0.746	0.390
15	20	1.481	0.749	0.390
15	80	1.141	0.756	0.420
15	60	1.262	0.761	0.350

A-51. Soybean biomass (1 meter of row) dry weight , moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 16 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
16	60	1.072	0.712	0.360
16	20	0.962	0.741	0.350
16	80	1.256	0.738	0.350
16	0	1.069	0.759	0.360
16	40	1.085	0.749	0.360
16	60	1.246	0.719	0.360
16	40	1.134	0.741	0.360
16	80	1.131	0.745	0.370
16	0	1.082	0.746	0.370
16	20	0.981	0.725	0.350
16	20	1.154	0.737	0.350
16	60	1.267	0.730	0.340
16	80	1.035	0.742	0.370
16	0	1.122	0.735	0.360
16	40	1.035	0.729	0.350
16	0	1.216	0.741	0.350
16	40	1.184	0.728	0.350
16	20	0.960	0.758	0.380
16	80	1.203	0.745	0.380
16	60	1.249	0.755	0.360

A-52. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 17 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
17	60	1.188	0.653	0.340
17	20	0.773	0.747	0.390
17	80	0.726	0.718	0.360
17	0	0.811	0.737	0.370
17	40	0.908	0.736	0.360
17	60	0.727	0.729	0.350
17	40	0.915	0.740	0.330
17	80	1.015	0.731	0.360
17	0	0.845	0.736	0.380
17	20	1.012	0.736	0.340
17	20	0.943	0.746	0.360
17	60	1.054	0.751	0.380
17	80	0.877	0.655	0.370
17	0	1.213	0.724	0.320
17	40	1.019	0.725	0.360
17	0	0.975	0.746	0.350
17	40	1.086	0.738	0.370
17	20	0.771	0.740	0.410
17	80	0.787	0.741	0.380
17	60	0.861	0.754	0.360

A-53. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P a^{-1}. Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 18 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
18	60	0.950	0.611	0.240
18	20	1.019	0.660	0.230
18	80	0.819	0.638	0.230
18	0	1.029	0.571	0.210
18	40	1.102	0.623	0.250
18	60	0.986	0.669	0.250
18	40	0.961	0.688	0.240
18	80	0.879	0.709	0.280
18	0	1.177	0.656	0.250
18	20	0.968	0.649	0.220
18	20	0.881	0.659	0.220
18	60	1.042	0.678	0.220
18	80	1.015	0.677	0.240
18	0	1.208	0.668	0.210
18	40	0.968	0.666	0.200
18	0	0.893	0.657	0.190
18	40	1.046	0.661	0.230
18	20	0.843	0.686	0.240
18	80	0.870	0.615	0.210
18	60	0.900	0.634	0.220

A-54. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P a$^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 19 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
19	60	0.714	0.660	0.240
19	20	0.630	0.638	0.220
19	80	0.608	0.666	0.220
19	0	0.754	0.654	0.250
19	40	0.691	0.680	0.250
19	60	0.820	0.677	0.210
19	40	0.656	0.655	0.210
19	80	0.680	0.679	0.240
19	0	0.678	0.692	0.240
19	20	1.115	0.711	0.230
19	20	0.854	0.688	0.220
19	60	0.832	0.635	0.240
19	80	0.705	0.683	0.260
19	0	0.876	0.741	0.230
19	40	0.985	0.703	0.270
19	0	0.865	0.675	0.210
19	40	1.110	0.416	0.240
19	20	0.682	0.648	0.230
19	80	0.836	0.678	0.240
19	60	0.846	0.675	0.260

A-55. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 20 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— %	———
20	60	0.855	0.705	0.260
20	20	0.627	0.720	0.290
20	80	0.475	0.714	0.300
20	0	0.737	0.714	0.280
20	40	0.837	0.697	0.290
20	60	0.720	0.712	0.280
20	40	0.840	0.718	0.330
20	80	0.974	0.725	0.290
20	0	0.439	0.711	0.290
20	20	0.525	0.705	0.300
20	20	0.833	0.715	0.250
20	60	0.780	0.723	0.290
20	80	0.692	0.723	0.290
20	0	1.046	0.720	0.260
20	40	0.848	0.717	0.280
20	0	0.549	0.731	0.270
20	40	0.510	0.750	0.310
20	20	0.826	0.732	0.280
20	80	0.786	0.731	0.290
20	60	0.804	0.709	0.280

A-56. Soybean biomass (1 meter of row) dry weight, moisture and phosphorus (P) concentration for phosphorus (P) fertilizer rates of 0, 20, 40, 60, and 80 lb P $a^{-1.}$ Fertilizer rates applied pre-plant broadcast in the spring. Biomass was collected at full seed (R6.5-R7) for site 21 in 2014.

Site	P rate	Dry Weight	Moisture	P
	lb P a^{-1}	lb	——— % ———	
21	60	1.276	0.686	0.250
21	20	1.407	0.674	0.280
21	80	1.140	0.674	0.270
21	0	1.155	0.684	0.250
21	40	0.858	0.685	0.260
21	60	1.071	0.696	0.270
21	40	1.676	0.696	0.300
21	80	1.022	0.706	0.290
21	0	1.097	0.693	0.230
21	20	0.924	0.690	0.300
21	20	1.355	0.697	0.240
21	60	1.186	0.696	0.310
21	80	1.074	0.686	0.260
21	0	1.352	0.702	0.220
21	40	1.173	0.683	0.130
21	0	1.441	0.691	0.260
21	40	1.332	0.701	0.260
21	20	1.169	0.705	0.250
21	80	1.458	0.690	0.230
21	60	0.870	0.678	0.250

R Codes:

```
TP13=read.csv("TP13.csv", header=TRUE)
head(TP13)


#Converting Block and Prate to factor variables
TP13$Blk = factor(TP13$Blk)
TP13$Prate = factor(TP13$Prate)
str(TP13)

## Creating a loop function to run simple RCBD ANOVA for 10 Locations
require (agricolae)
a=list()
b= list()

for(i in levels(TP13$Loc)){
   id= which(TP13$Loc==i)
  dat1=data.frame(TP13[id,])
  mod= aov(TP~ Blk + Prate, data=dat1)
  a[i]= summary(mod)
  comp= list(LSD.test(mod,"Prate", console=F))
  b[i]=comp
}

# ANOVA Tables for all 10 locations
a
# LSD test for all 10 locations
b

#combined Anova across Loc and LSD tests
mod2 = aov(TP ~ Loc*Prate + Loc/Blk, data=TP13)
summary(mod2)

#LSD tests
comp1= LSD.test(mod2,"Prate", console=F)
comp1
comp2= LSD.test(mod2,trt=list("Loc"), console=F)
comp2
comp3= LSD.test(mod2,trt=list("Loc", "Prate"), console=F)
comp3
```