PHOSPHORUS MANAGEMENT FOR NO-TILL WINTER WHEAT PRODUCTION IN NORTH CENTRAL OKLAHOMA

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Abstract:

Phosphorus deficiency in no-till winter wheat (Triticum aestivum L.) production can result in drastically reduced yields in north central Oklahoma. As a result, many producers are attempting to increase phosphorus application efficiency through the implementation of best management practices (BMP's) such as, soil test based fertility recommendations. Regardless of product source or application rate, phosphorus management may be confounded by the fact that current sampling methods and rate recommendations in Oklahoma were developed utilizing fields under conventional tillage. During the 2014 and 2015 winter growing seasons, nine on farm studies were established across north central Oklahoma with varying soil types representative of the region. Locations had an initial Mehlich III extractable soil P concentrations ranging from 1 – 39 mg kg^{-1} in the top 15.24 cm of soil at planting. Soil pH ranged from 4.6 to 6.8 across the nine locations (Table 1.3). Phosphorus fertilizer was surface applied at planting in the form of triple super phosphate. Application rates included an OSU Soil Test recommended rate which utilized the current soil test P index, and eleven phosphorus rates ranging from 0 kg P ha^{-1} up to 48.9 kg P ha^{-1} in increments of 4.89 kg P ha^{-1} (Table 1.1). Grain test weight and moisture were not significantly affected by the addition of surface applied phosphorus. Wheat grain phosphorus concentrations were on average increased with the addition of phosphorus fertilizers but the response varied across treatment rates (Table 3.1). Wheat grain yield was on average significantly increased by the addition of surface applied phosphorus fertilizer (Table 1.3). However, individual site specific issues did arise and each location is discussed individually (Table 3.3). Across the nine locations soil pH and Mehlich III soil phosphorus concentrations were significantly affected by the sampling depth. As sampling depth increased soil pH increased and Mehlich III soil extractable P decreased. Soil pH of the 0 - 5.08 cm sampling depth was the best indicator of responsiveness of no-till winter wheat.

Table of Contents

List of Tables

List of Figures

Chapter I

Introduction

Background and Problem Definition

Producers are continually striving to improve profitability and sustainability in all aspects of production. Producers can increase profitability by maximizing return on investment of inputs, increased yields, or by reducing input quantities and costs. Phosphorus fertilizer can account for a significant amount of production costs for winter wheat in Oklahoma. Phosphorus fertilizer costs in north central Oklahoma are currently \$0.93 kg^{-1} P in the form of mono-ammonium phosphate and \$1.01 kg^{-1} P as di-ammonium phosphate (Two Rivers Coop., 2017). Unfortunately, phosphorus mines have a finite amount of phosphorus and as world food production has increased so has agricultures consumption of phosphorus. Since 1900 the United States rock phosphate production has increased by roughly 3300 percent. Currently the United States is producing roughly 30 million Mg of rock phosphate each year and in 1900 production was only 0.885 million Mg. Current price for raw rock phosphate is \$60.00 Mg^{-1}, which is roughly a 1900 percent increase from 1900 (Figure 1.1). In 2014, the south central region of the United States phosphate fertilizer price, was on average \$509.84 Mg^{-1}, which was slightly below the national average price of \$563.36 Mg^{-1} (Figure 1.2). Since 2001, the national phosphate fertilizer price has increased by 231 percent, and the south central average price has increased 263 percent (Figure 1.2). As Oklahoma producers' fertilizer usage increases, along with the increase in phosphorus fertilizer price, it will become increasingly more difficult to maximize return on investments with respect to phosphorus fertility.

Over the last 117 years of production in the State of Oklahoma, harvested acres have ranged from 0.4 million ha in 1907 to 2.8 million ha in 1982 (Figure 1.3). In 2016 Oklahoma farmers only harvested 1.4 million ha of winter wheat. In 1900, Oklahoma Producers' harvested 0.6 million ha of winter wheat for grain production and average yield across those 0.6 million ha was 1.1 Mg ha^{-1}. As technology has advanced over the last 100 plus years, all aspects of our production systems have become more precise. Producers across the state harvested 1.4 million ha in 2016 with an average yield of 3.64 Mg ha^{-1} of grain (Figure 1.3). These statistics show that through excellent wheat breading and more precise soil fertility mean wheat yields in Oklahoma have more than doubled in roughly the last 100 years and the volatility in harvested acres can be attributed to grain prices and the ever decreasing number of farmable acres across the state and the nation.

This study aimed at increasing producer profitability by maximizing the return on investment of phosphorus fertilizer applied to no-till winter wheat. In 2014 and 2015 a total of nine on farm field studies were established in the north central region of Oklahoma, in an effort to evaluate Oklahoma States current winter wheat phosphorus recommendations (Macnack, 2011; Zhang, 2013(2)) and the crop's response to fertilizer in both sufficient and deficient soils (Zhang, 2006).

Fertility programs in Oklahoma are based on three different concepts, sufficiency, build-up and maintenance. The sufficiency approach is when fertilizer rates are applied on the likelihood of achieving a yield response. The build-up and maintenance approaches are both based on fertilizing the soil versus the crop. Maintenance approach is one in which fertilizer is added based on crop removal in an effort to limit soil nutrient reductions. Build-up approach is one in which fertilizer is applied in an effort to increase the soil concentration to a specific level. Frequently the build-up and maintenance approaches are combined in order to ensure adequate nutrient availability (Macnack, 2011).

With respect to phosphorus management in Oklahoma, current P fertility recommendations are based on the Mitscherlich sufficiency concept. Oklahoma State University phosphorus fertilizer recommendations are based off of soil test data and the current sufficiency index which has been built by the Soil, Water, and Forage Analytical Lab at Oklahoma State University. OSU sufficiency index suggests that for winter wheat production a soil test value of 32 mg P kg^{-1} soil is 100 percent sufficient (Zhang, 2013(2)). Oklahoma Cooperative Extension Service recommends a soil sampling depth of 0 – 15.24 cm be collected from fields where nutrient fertility is of concern, including phosphorus fertilizer (Zhang, 2013(1)). Recommendations for no-till winter wheat production, as published by Oklahoma State University, suggest that P fertility in no-till should follow methods and applications as they are published by Oklahoma Cooperative Extension for P management (Warren, 2013).

Traditionally Oklahoma winter wheat producers have applied phosphorus fertilizer either preplant or at planting. A preplant application is commonly defined as either all or part of the required phosphorus fertilizer supplied prior to the time of planting the crop. Use of this application time to supply all the fertilizer phosphorus allows Oklahoma producers ample time to cover all or as much of their ground as needed. At planting application is defined as applying the fertilizer at the time the seed is placed in the ground. Winter wheat planting for grain production in Oklahoma occurs between the third week of September and the third week of November. Planting dates in Oklahoma vary drastically from year to year and are determined by soil moisture and temperature.

Two methods of applying phosphorus for no-till winter wheat production exist, surface or sub-surface, and the common sources used are liquid or dry granular products. Surface broadcasting of granular or liquid products evenly distributes the product across the surface of the soil, with the advantage of this method being speed. The second method of application is sub-surface banding. Sub-surface banding is the placement of the product in the furrow with the seed at planting. This is achieved with the utilization of grain drills or air seeders equipped with liquid and or dry fertilizer systems. The most common application method in Oklahoma production systems for P fertilization is in-furrow application.

The drastic reduction in wheat yields due to phosphorus deficiencies can have a significant effect on farming profitability. With phosphorus fertilizer prices continuing to increase (Figure 1.1; Figure 1.2) and the volatility of production (Figure 1.3) and current grain markets it has become even more important to obtain the largest return on investment of all fertilizers.

This study was conducted to evaluate the current recommendation methods and the effect of surface applied phosphorus on no-till winter wheat in north central Oklahoma. Wheat variables evaluated were grain yield, test weight, and grain minerals. The second objective of this project included intensive soil sampling from the research plots in an effort to evaluate the effect no-till practices have on the stratification of soil phosphorus and pH in the soil profile. This portion of the project aided in the evaluation of the third objective, evaluating alternative soil characteristics for a more precise method of predicting wheat grain yield response to added phosphorus fertilizer, to help improve Oklahoma's current P recommendations.

Objectives and Hypotheses

Objective 1. Evaluate the effect of surface applied phosphorus fertilizer rates on wheat grain yield response in central Oklahoma soils with sub-optimum soil test phosphorus concentrations utilizing current Oklahoma State recommended sampling and testing methods.

Objective 2. Determine if the addition of phosphorus fertilizer will effect wheat grain harvest components, specifically test weight and grain phosphorus concentration.

Objective 3. Determine if soil pH, and soil test phosphorus concentrations under no-till soils in central Oklahoma become stratified throughout the soil profile.

Objective 4. To determine if alternative sampling methods or analysis methods provide better accuracy at predicting no-till winter wheat responsiveness.

Research Approach

Between 2014 and 2015, nine field experiments were established on no-till farms across north central Oklahoma with soils representative of the region (Table 1.1). Design structure was a randomized complete block arrangement of treatments with four replications. Due to field size constraints at Stillwater 2, the study was only replicated three times. Treatment rates included an OSU recommended rate, which did not include the OSU pH adjustment (Zhang, 2014), a zero phosphorus fertilizer check and ten phosphorus rates ranging from 4.89 kg P ha^{-1} up to 48.9 kg P ha^{-1} in increments of 4.89 kg ha^{-1} (Table 1.2). Prior to planting 0 – 15 cm composite soil samples were collected from each location so that initial Mehlich III extractable soil phosphorus concentrations could be measured and the current OSU Phosphorus index used to determine the OSU recommended rate (Table 1.1). The Mehlich III procedure followed for analysis was that of J. Thomas Sims, University of Delaware (SERA-IEG 17, 2000) and was analyzed on a Spectro Model-Blue ICP-OES (Spectro, 2017) for solution total phosphorus.

Planting operations were conducted utilizing producer’s equipment and suitable seeding rates and varieties at each location were chosen by the farm managers (Table 1.3). Upon planting 3.05 meter by 10.1 meter plots were established. Soil samples were collected from each plot to a depth of 30.48 cm prior to treatment application. The phosphorus fertilizer source applied at all locations was triple super phosphate (0-46-0). Triple super phosphate was utilized because it is a water soluble sources. Lathwell et al. (1960) compared fertilizer sources for crops with dry and solid formulations. They reported that P response was similar to the same material applied as a liquid and dry source. It was also noted that response to liquid P sources were similar to granular superphosphate, a highly water soluble compound, but that liquid may perform better when compared to less water soluble dry fertilizers. Treatments were applied to the soil surface and were made following planting on the same day. In both 2014 and 2015 at all sites, all other nutrients except pH and phosphorus, were managed to prevent the limitation of yield response due to other nutrients.

Plots were harvested following physiological maturity (Table 1.3) to measure grain yield, test weight, and grain phosphorus concentrations. Harvest was completed using a Massey Ferguson 8-XP plot combine (Kincaid Equipment Manufacturing; Haven, KS). Grain weight and moisture content were recorded by the onboard Harvest Master data collection system (Juniper Systems; Logan, UT) and grain samples were collected as each plot was harvested. Plot weights were standardized to 13% moisture and reported as Mg ha^{-1}.

Grain samples were oven dried at 60° C for a minimum of one week to remove all moisture and facilitate grinding. Grain samples were ground to pass through a 0.5 mm sieve using a Wiley Mill #3. Grain samples were then submitted to Oklahoma State University's Soil Water and Forage Analytical Laboratories for analysis of grain mineral content. Oklahoma State

University Soil, Water, and Forage Analytical Labs follows the methods as described by the Soil Science Society of America and the Western States Laboratory Proficiency Testing Program to determine grain mineral concentrations (SSSA, 1990) and (Western States Lab. Prof. Testing Program, 1997).

After planting and prior to fertilizer application additional soil samples were collected. Soil samples were collected with a 4.45 cm diameter hydraulic probe from each plot. Four cores per plot were taken randomly from the plot and to a depth of 30.48 cm. The top 15.24 cm of sample was split into three 5.08 cm segments; 0-5.08 cm, 5.09 - 10.16 cm, 10.17 - 15.24 cm, and the bottom 15.24 cm's were kept as a composite sample. Soil samples were air dried at 21° C for a minimum of one week before processing. Samples were ground using a BICO pulverizer type UA, so that they would pass through a 2 mm sieve. Samples were then stored until analyses could be conducted.

Soil pH, Mehlich III extractable P, a total phosphorus analysis, and a soil phosphorus fractionation method were conducted on the sectioned soil samples. The Mehlich III procedure followed for analysis was that of J. Thomas Sims, University of Delaware as publish in the Methods of Phosphorus Analysis for Soil, Sediments, Residuals, and Waters Book (SERA-IEG 17, 2000) and was analyzed on a Spectro Model-Blue ICP-OES, for solution total phosphorus.

Soil pH analysis was measured following the Soil and Waste pH Method as published in the EPA Publication SW-846 (EPA 2015) and were analyzed on a Mettler Toledo pH/Ion meter model Seven Compact.

Total soil phosphorus was measure with and acid digestion method. The acid digestion method followed was EPA 3050b as it is published in the EPA SW-846, Test Methods for Evaluating Solid Waste, Third Edition (EPA, 2015). Due to time and lab constraints a subset of 18 samples were analyzed for total phosphorus. Samples included the top three soil depths, 0 – 5.08 cm, 5.09 – 10.16 cm and 10.17 – 15.24 cm depths, taken from the 48.9 kg P ha-1 plot, treatment 12, from three replications at each location. Extracts were submitted to the Soil, Water, and Forage Analytical Laboratory (SWFAL) at Oklahoma State University for Analysis on the ICP, Spectro Model Blue.

A modified Change Jackson Soil Phosphorus Fractionation Method as published in the SERA-IEG 17 (2000) Method of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396 was followed for soil phosphorus fractionation. Multiple modifications had to be made to the method for analytical purposes due to interferences during sample analysis. Samples were analyzed following the Murphy Riley Method (Murphy, 1962) on a spectrophotometer at 880nm wavelength. The spectrophotometer utilized for this analysis was a Milton Roy SPECTRONIC 21D spectrophotometer.

Modifications made to the method are as follows; Extract B was analyzed at a 3:1 dilution ratio as described by Murphy and Riley. 5 ml of extract was diluted with 7 ml of 0.8 M H_3BO_3 to counter act the fluoride interaction.

Extract E was titrated to a pH of 3 using 0.1 molar NaOH to determine mole requirement to neutralize the acidity of the sulfuric acid in the sample. It was determined that 2 ml of a 1.15 molar NaOH solution was required for a 10 ml sample of extract. 10 ml of Extract E was then pipetted into 30 ml spectrophotometer tubes and 2 ml of 1.15 molar NaOH solution was added for a 1.5:1 dilution ratio per Murphy Riley. Samples were vortexed prior to adding Reagent B.

Extract C was titrated to a pH of 3 using 0.1 molar HCl to determine mole requirement to neutralize the NaOH in the sample. It was determined that 2 ml of a 0.25 molar HCl solution was required for a 10 ml sample of extract. 10 ml of Extract C was then pipetted into 30 ml spectrophotometer tubes and 2 ml of 0.25 molar HCl solution was added for a 1.5:1 dilution ratio per Murphy Riley. Samples were vortexed prior to adding Reagent B.

Extract D requires modifications as described by R.M. Weaver (1974). Extracts require the oxidation of any remaining sodium dithionite remaining in solution or the precipitation of elemental sulfur will occur. To counteract the precipitation of sulfur bubble air through each sample for a minimum of 24 hours prior to processing. Record weights of sample storage bottles prior to bubbling air so that weight loss through evaporation can be added back with DI H_2O. In addition, an ammonium molybdate solution must be added prior to the addition of Reagent B to prevent citrate interference with Reagent B (Weaver, 1974). Pipette 5 ml of the air oxidized sample into a 30 ml spectrophotometer tube. Add 13 ml of DI H_2O and vortex. Next, add 3 ml of a 5% ammonium molybdate solution and vortex. Add 5 ml of Murphy Riley Reagent B and vortex. Allow the color to develop for 5 minutes and then analyze. Final dilution factor was 5.2:1.

Tables

Table 1.1. Year, location, initial soil test P concentration and soil type description for the nine locations established to evaluate the response to phosphorus applied to no-till winter wheat in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

Year	Location	County	Soil Type	Initial Soil Mehlich III P 0-15 cm depth mg P / kg soil	Soil pH	OSU Rate kg P ha^{-1}
2014	Stillwater	Payne	Huska silt loam	1	6.6	36.2
	Red Rock 1	Noble	Bethany silt loam	10.13	5.3	19.5
	Red Rock 2		Kirkland silt loam	18.5	4.6	11.3
	Red Rock 3		Bethany silt loam	20	5.4	10.2
	Waukomis 1	Garfield	Port silt loam	34	4.8	0
	Waukomis 2		Grant silt loam	10	5.7	19.6
2015	Stillwater	Payne	Huska silt Loam	5	6.8	29.4
	Garber	Garfield	Kirkland silt loam	39	5.5	0
	Waukomis		Grant silt loam	23	5.1	7.4

* OSU rate does not include the P adjustment for acidic soil conditions

Table 1.2. Treatment structure implemented to evaluate the response to surface applied phosphorus in no-till winter wheat at nine locations across north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

Treatment	Phosphorus Application Rate ----(kg P ha^{-1})----
1	Oklahoma State Soil Test Recommended Rate
2	0
3	4.89
4	9.79
5	14.68
6	19.58
7	24.47
8	29.37
9	34.26
10	39.16
11	44.05
12	48.95

* OSU rate was determined by composite soil samples taken at each location prior to planting and utilized the current phosphorus soil test index.

Table 1.3. Year, location, initial soil test P concentration and soil type description for the nine locations established to evaluate the response to phosphorus applied in no-till winter wheat. All sites were located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

Year	Location	County	Variety	Seeding Rate kg ha $^{-1}$	Planting Date	Harvest Date
2014	Stillwater	Payne	Iba	72.9	10/03/14	6/20/15
	Red Rock 1	Noble	Ruby Lee	95.3	9/29/14	6/23/15
	Red Rock 2		Billings	84.1	9/26/14	6/11/15
	Red Rock 3		Billings	84.1	9/26/14	6/11/15
	Waukomis 1	Garfield	Garrison	100.9	10/1/14	6/22/15
	Waukomis 2		Gallagher	100.9	10/03/14	6/22/15
2015	Stillwater	Payne	Double Stop	89.7	10/07/14	6/07/16
	Garber	Garfield	Billings	89.7	11/15/14	6/11/16
	Waukomis		Gallagher	100.9	11/13/14	6/11/16

Figures

Figure 1.1. United States rock phosphate production and usage from 1900-2014 (USGS, 2017).

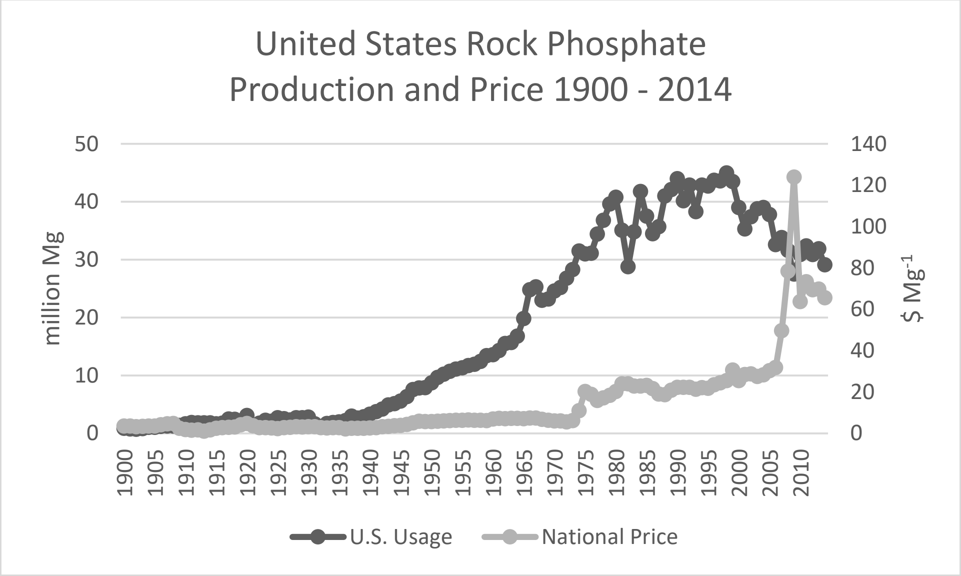
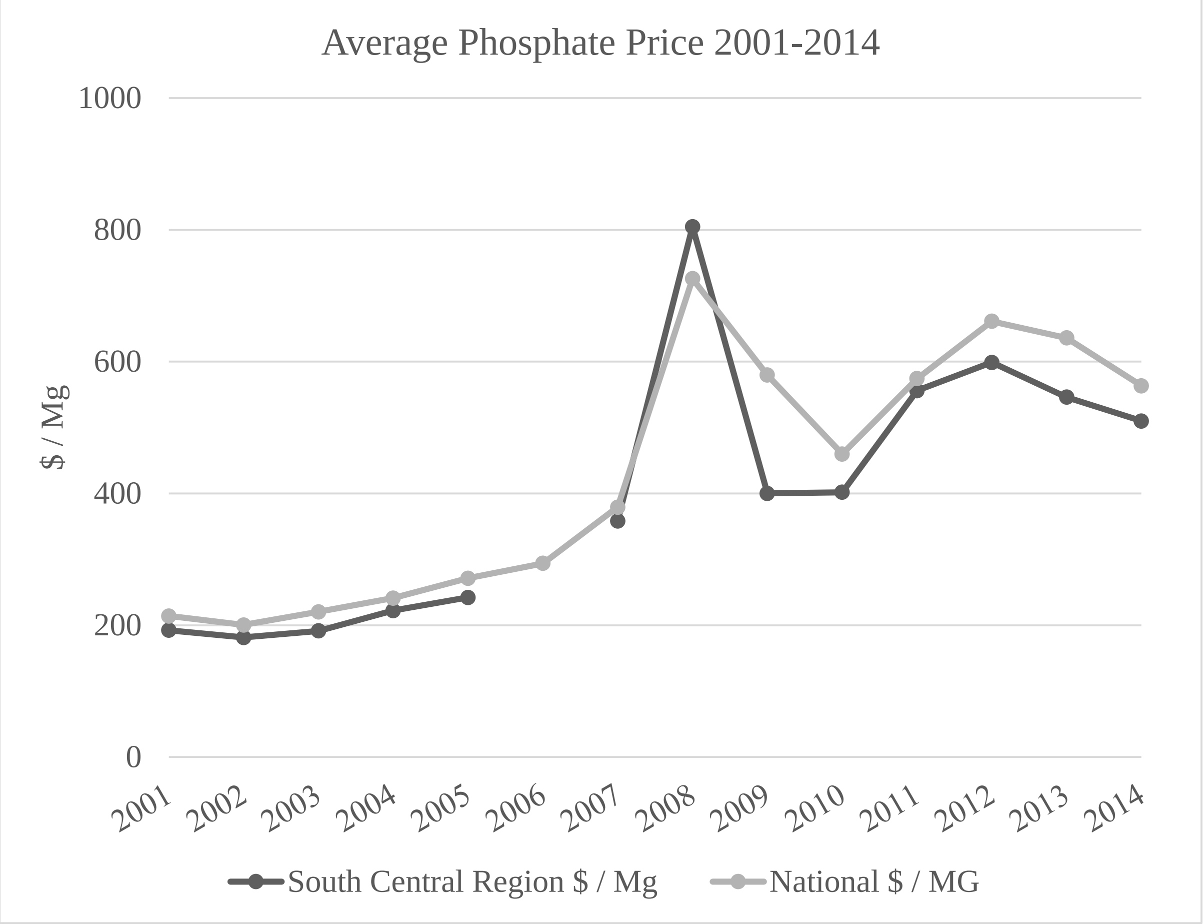
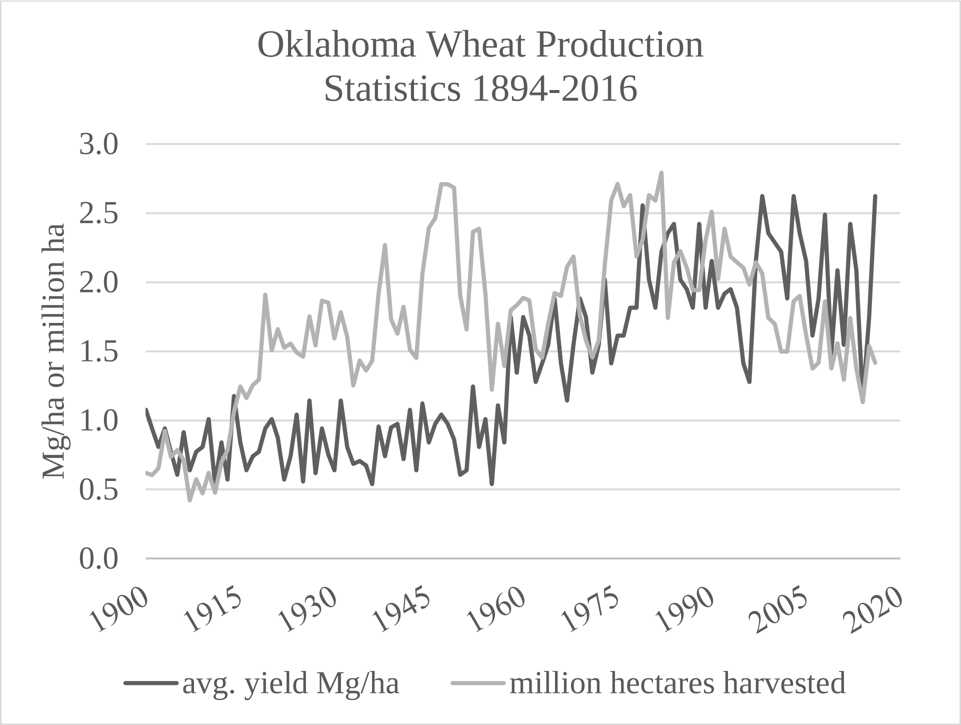


Figure 1.2. Yearly mean price per mega gram of rock phosphate for the United States and the South Central Region, which includes Oklahoma, from 2001-2014 (USDA, 2017).



* The south central region does not have an average recorded price for 2006.

Figure 1.3. Oklahoma winter wheat yearly production, hectares planted and average yield from 1900 to 2016 (USDA, 2017).



References

EPA. 2015. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, EPA publication SW-846, Third Edition, Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015).

Lathwell, D. J., J. T. Cope, Jr., and J. R. Webb. 1960. Liquid fertilizers as sources of phosphorus for field crops. Agron. J. 52:251-253.

Macnack, N., B.K. Chim, B. Amedy, and B. Arnall. 2011. Fertilization based on Sufficiency, Build-up and Maintenance concepts. PSS-2266 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Murphy, J., J.P. Riley. 1962 A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta. 27. 31-36.

SERA-IEG 17. 2000. Method of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396.

Soil Science Society of America. 1990. Soil Testing and Plant Analysis. 3rd Ed. pp.404-411.

Two Rivers Coop. 2017. http://www.tworiversks.coop/pages/custom.php?id=19995. (accessed March 30, 2017).

USDA, National Agricultural Statistics Service. 2017. http://www.nass.usda.gov/ Data (accessed March 15, 2017).

USGS. 2017. U.S. Geological Survey, Mineral Commodity Summaries, January 2017. https://minerals.usgs.gov/minerals/pubs/mcs/2017/mcs2017.pdf (accessed March 15, 2017).

Warren, J., S. Alspach, B. Arnall, J. Vitale, R. Taylor, M. Schrock, R. Wolf, F. Epplin, H. Zhang, A. Post, R. Hunger, J. Damicone, T. Royer, J. Edwards, R. Bowman, R. Kochenower, J. Bushong, S. Osborne. 2013. No-till Cropping Systems in Oklahoma. E-996 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Weaver, R. M. 1974. A simplified determination of reductant-soluble phosphate in soil phosphate fractionation schemes. Soil Sci. Soc. Amer. Proc., Vol. 38

Western States Laboratory Proficiency Testing Program. 1997 Soil and Plant Analytical Methods. Ver 4.00. pp. 117-119.

Zhang, H. and B. Raun. 2006. Oklahoma Soil Fertility Handbook, Sixth Edition. Published by: Department of Plant and Soil Sciences Oklahoma Agricultural Experiment Station.

Zhang, H., B. Raun, B. Arnall. 2013(1). How to Get a Good Soil Sample. PSS-2207 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Zhang, H., B. Raun, B. Arnall. 2013(2). OSU Soil Test Interpretations. PSS-2225 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Zhang, H., J. Edwards, B. Carver, B. Raun. 2014. Managing acid soils for wheat production. PSS-2240 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Chapter II

Literature Review

Introduction

Historically in Oklahoma winter wheat (Triticum aestivum L.) production has accounted for the largest percentage of arable land (USDA 2017). Its cultivation can be classified by three tillage systems; no-till, conservation tillage, or conventional tillage. These three tillage systems accounted for the 1.4 million ha^{-1} of wheat planted in Oklahoma during the 2016 growing season (Figure 1.3).

Currently in Oklahoma there has been a push for the adoption and implementation of no-till practices. Oklahoma's phosphorus fertility recommendations are based off of data collected from intensive tillage practices that were conducted in the early to mid-1900's. Unfortunately, the data on which our current recommendations are based no longer exist for the simple fact that most of the work was completed by extension specialists and was never made published. Regardless, there is the simple fact that the recommendations currently used in no-till production were established from and for a conventional tillage management system.

During the past decade in the southern grain belt region of the United States, there has been increased interest in phosphorus conservation and improvement in phosphorus management driven by two factors. First and foremost is economics. In 2008, phosphorus prices in the southern grain belt experienced a dramatic increase reaching approximately \$804.67 Mg^{-1} P_2O_5 and an average national price of \$725.75 Mg^{-1} P_2O_5 (Figure 1.3). This price increase affected producers' profitability and influenced decisions about how much P to use and how to apply it. The second factor is environmental legislation; The 2014 Integrated Water Quality Assessment Report by the Oklahoma Department of Environmental Quality showed 8,383 miles of Oklahoma streams and 485,736 acres of lake impaired. The pollutant of concern in many of these impairments was phosphorus, an essential plant nutrient found in fertilizer and human and animal wastes (Oklahoma DEQ, 2014).

The focus of promoting efficient fertilization in Oklahoma was strengthened in the early 2000's with the Oklahoma State Waters Protection Act, 2001 OK H.B. 2349 (Oklahoma, 2001) and the U.S. E.P.A.'s Federal pollution control act of 1972 (E.P.A, 2002). This act and subsequent regulations were established to help reduce phosphorus loading of waters from non-point and point sources. In Oklahoma this mandated that producers inside of identified water shed areas to complete NMP's, nutrient management plans, if inside of a NLW, nutrient limited watershed, and to reduce phosphorus applications based upon current water loading and state recommendations (Oklahoma, 2001).

There is substantial research linking agricultural practices to non-point source phosphorus pollution on in-land surface water quality. There is a well-known relationship between soil test P levels and dissolved P concentration of runoff waters (Sharpley, 1994). In 1998 Sims et al. concluded that P leaking might be another significant component of P transfer to water bodies in soils with low P sorption capacities. Regardless of the pathway or original source P pollution in in-land water is an ever growing concern.

Phosphorus Research

Researchers have focused and continue to focus on ways in which the application of phosphorus can be improved for winter wheat production. To present the paths in which improvements have been made the manuscript will follow the 4-R approach to proper nutrient application (IPNI, 2017). The 4-R nutrient stewardship approach is: apply the right source of nutrient, at the right rate, at the right time, and in the right place.

Placement and Source of Phosphorus Fertilizer

Working with the 4-R's theory, much research has been conducted identifying the proper zone of application and source of fertilizer for many crops. A study conducted by Sweeney et al. (2008) reported on a three-year study (2003-2005) in the upland region of the eastern Great Plains. In this study, the researchers compared the effects of placement of N-P (liquid UAN applications with added phosphorous) applications (dribbled vs. injected), on corn yields. Over the three-year period of the study, sub-surface injection of the fertilizer significantly increased corn grain yields compared to surface dribbling. A significant increase in the number of kernels per ear was also seen when the fertilizer was sub-surface injected compared to surface applied (Sweeney, 2008).

In 1990 a study was conducted by Tracey et al. in Nebraska investigating the effect of tillage systems on winter wheat production. They found that tillage practice effected the mineralization rate of N P S concentrations above a depth of 5 cm but not in depths ranging from 5 – 15 cm. Net P in the surface 5 cm sampling depths of no-till soils were greater than the 5-15 cm sampling indicating that placement can have an impact on availability (Tracey, 1990).

In 1956 Lawton et al. conducted both field and green house studies evaluating the effect of fertilizer source on yield and dry matter production. It was concluded that for maximum crop production placement, applied in rows or in bands, the degree to which yield and dry matter production was related to the concentration of the phosphorus fertilizer that was in a water soluble form. They recommended for maximum crop production placement was not as important as was the percentage of fertilizer to be water soluble (Lawton, 1957).

A study evaluating rate and placement of phosphorus fertilizer on small grain production was investigated by Lutz et al. in 1961. Two sources of phosphorus fertilizer, a high water soluble and low water soluble form, were utilized to investigate placement and timing effects on grain yield. It was noted that fertilizer placement with the seed resulted in higher P content than if place independent of the seed (Lutz, 1961).

Kiessel et al. (1980) performed a study investigating the effect of method of N and P applications on winter wheat growth and yield. Two P sources were used, diammonium phosphate and ammonium polyphosphate at various rates through banded and knifed applications. They found that there was no difference in yield due to application method and phosphorus source.

Lawton and Davis (1960) found that uptake of phosphorus fertilizer during early growth stages was increased when fertilizer was placed in contact with the seed or directly under it compared to a side banded placement. They noted that wheat plants did not absorb an appreciable amount of fertilizer phosphorus from a side placed band until the third week after planting.

A study was conducted in 1961 evaluating the placement of phosphorus fertilizer on corn production. Terman et al. concluded that banding phosphorus as compared to incorporation just prior to planting resulted in a greater response for the first year following application but was less dominate for the subsequent years (Terman, 1961).

Currently in central Oklahoma there are only three sources commonly available. Two dry sources are common depending on the location of the region, monoammoium phosphate (MAP) and diamonnium phosphate (DAP). The liquid product that is currently available to farmers is ammonium poly phosphate (APP). These three sources all contain a nitrogen component and as a result were not used for this study. This study incorporated the use of triple super phosphate due to the fact that it did not contain any other nutrients and allowed for all other nutrients to be easily balanced.

Murphy et al. (1978) performed multiple studies on the dual application of nitrogen and phosphorus. Treatments were knifed in prior to planting as well as banded and broadcasted. Results showed that the knifed applications of nitrogen and phosphorus applied simultaneously produced consistently higher yields than either the banded or broadcasted treatments.

Lathwell et al. (1960) compared fertilizers for crops with dry solid fertilizers. The reported that P response was similar to the same material applied both as liquid and dry sources. They also noted that liquid P response was similar to superphosphate, a highly water soluble compound, but that liquid may perform better when compared to less water soluble dry fertilizers.

Right Time

One example of the impact of application timing is a study conducted by Sweeney et al. (2008) who reported on a three-year study (2003-2005) in the upland region of the Eastern Great Plains. In this study, the researchers compared the effects of timing of N-P (liquid UAN applications with added phosphorous) applications (spring vs. fall), and application methods (dribbled vs. injected), on corn yields. Over the three-year period of the study, corn yield and the number of kernels per ear, significantly increased when fertilizer was applied in the spring compared to the fall (Sweeney, 2008). In 1961 Terman et al. evaluated the timing of phosphorus fertilizer on corn production. Terman et al. concluded that banding phosphorus as compared to incorporation just prior to planting resulted in a greater response for the first year following application but was less dominate for the subsequent years (Terman, 1961).

Unfortunately, application timing for Oklahoma producers is limited to following harvest in June or July up to wheat planting in the fall from September through December. Historically phosphorus was surface broadcast and incorporated into the soil during tillage operations and limited application timing to July and August. Currently, application during planting has become popular as grain drills have increased in size and now include fertilizer attachments for in furrow and banded applications.

Right Rate

Currently in Oklahoma, phosphorus rates are determined from soil sample analysis and the use of the OSU soil test phosphorus index (Zhang, 2006). Many studies have researched the concept of proper rates, but identifying the proper rate for any given year is only an estimate due to the inability to predict growing season weather conditions following the application. On average, adequate research has been conducted to identify proper rates based upon composite soil samples to a depth of 15.24 cm's, but the rates in Oklahoma are based on conventional tillage practices (Zhang, 2006). As the adoption of no-till management increases evaluation of our current recommendations is needed. Much difficulty remains in quantifying the cycling and availability of phosphorus fertilizers in different soil types (Guo and Yost 1998). Due to the complexity of the chemistry and soil mineralogy of soil P estimates of plant response have been all but reliable (Wolf et al. 1985; Guo and Yost 1998). Many methods exist for estimating soil P with soil test methods (Kamprath and Watson 1980; Fixen and Grove 1990; McCollum 1991; Mehlich 1953; Mehlich 1984; Bray and Kurtz 1945; Olsen et al. 1954) fractionation procedures (Chang and Jackson 1957; William et al. 1971; Syers et al. 1972; Hedley et al. 1982) and mechanistic approaches (Parfitt 1978; Barrow 1980 McLaughlin et al. 1981; Goldberg and Sposito 1985; Prafitt 1989) have been attempted to estimate plant response to soil P. Upon review of these methods it has become clear that the ability of any single method to estimate crop response is all but reliable and evaluation of methodology for specific regions is needed.

Current Testing Methods

As the environmental and agronomic concerns of proper phosphorus management have grown so has our ability to accurately test for phosphorus. The are many current methods of determining soil phosphorus and each test approaches the estimation of soil phosphorus in a different manner. P sorption indices such as Mozaffari and Sims (1994) and Simard et al. (1994) or the isotopic method of Frossard et al. (1993) were shown to be reliable methods for ranking and estimating soils P-fixing capacity. Early work estimating soil labile P pools used isotopic methods (Holford et al. 1974; Fardeau and Jappe 1978). Many soil test methods have been developed, soil test P-Mehlich I and III, Bray, Olsen, calcium chloride, and water, have been shown to be reliable methods for estimating labile P pools. Iron oxide strip and anion exchange resin were also suggested as valuable environmental soil testing methods (Gartley and Sims, 1994; Simard et al. 1995). In 1995 a study concluded that the relationship between dissolved P concentration of runoff water and soil P concentrations was not unique and will vary with soil type (Sharpley, 1995; Hue and Fox, 2010). One thing is very clear that soil test P concentrations may not be the most accurate way to predict crop response and it has been suggested that P indices need to include two factors, intensity and capacity, for the potential of a reliable crop response estimate.

Conclusion

This literature review has made one thing very evident; there is a tremendous amount of data regarding phosphorus management all of which have varying results. Many of the current phosphorus recommendations were developed from data collected under tillage practices. As no-till farming increases in popularity it will be imperative to reevaluate our current recommendations for no-till practices. This literature review has also identified that in no-till production there is the possibility of stratification to occur with soil nutrients and soil properties, such as pH. In Oklahoma there has been no published research outside of extension fact sheets on proper phosphorus management for no-till winter wheat production. In addition, the question of soil nutrient and soil pH stratification has arisen. The focus of this study will be to evaluate the current OSU phosphorus recommendations for no-till winter wheat. Also, the possibility of stratification of soil phosphorus and soil pH will be investigated.

References

Assessment [305(b)/303(d)]. http://www.deq.state.ok.us/wqdnew/305b_303d/ Retrieved April 5, 2017.

Barrow, N. J. 1980. Evaluation and utilization of residual phosphorus in soil. In the role of phosphorus in agriculture. ASA, CSA, SSSA, Madison, WI, pp 333-359.

Bray, RH and Kurtz, LT 1945, Determination of total, organic, and available forms of phosphorus in soils. Soil Science, 59: 39-45.

Chang, S. C. and M. L. Jackson. 1957. Fractionation of soil phosphorus. Soil Sci. 84: 133-144.

Environmental Protection Agency, United States. 2002. Federal water pollution control act. Retrieved, April 5, 2017.

Fixen, P. E. and J. H. Grove. 1990. Testing soils for phosphorus. In soil testing and plant analysis. R.L. Westerman (ed.). Soil Sci. Soc. Am., Madison, WI. pp 141-172.

Fardeau, J. C. and Jappe, J. 1978 Analysis per dilution isotopique de la fertilite et de la fertilization phosphorique de quelques sols du Quebec. Can. J. Soil Sci. 58; 251-258.

Gartley, K. L. and Sims, J. T. 1994 Phosphorus soil testing: environmental uses and implications. Coomun. Soil Sci. Plant Anal. 25: 1565-1582.

Goldberg, S. and G. Sposito. 1985. On the mechanism of specific phosphate adsorption by hydroxylated mineral surfaces: A review. Commun. Soil Sci. Plant Anal. 16:801-821.

Guo, Fengmao and Yost, R. S. 1998. Partitioning soil phosphorus into three discrete pools of differing availability. Soil Sci. 163: 822-833.

Hedley, M. J. Stewart, J. W. B. and Chauhan, B. S. 1982. Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. Soil Sci. Soc. Am. J. 46:970-976.

Hue, N. V. and Fox, R. L. 2010 Predicting plant phosphorus requirements for Hawaii Soils using a combination of phosphorus sorption isotherms and chemical extraction methods. Comm. Soil Sci. Plant Anal. 41: 133-143.

IPNI (International Plant Nutrition Institute). 2013. 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition. http://www.ipni.net/ipniweb/portal.nsf/0/231EA9CAE05F5D24852579B200725EA2. Viewed: April 6, 2017.

Jolford, I. C., Wedderburn, R. W. M. and Mattingly, G. E. G. 1974. A Langmuir two-surface equation as a model for phosphate adsorption by soils. J. Soil Sci. 25: 242-255.

Kamprath, E. J. and Watson, M. E. 1980. Conventional soil and tissue tests for assessing phosphorus status of soils. In the role of phosphorus in agriculture. F.E. Khasawenh, E.C. Sample, and E.J. Kamprath (eds.) ASA, CSA, and SSSA, Madison, WI. pp 471-514.

Kissel, D. E., R. E. Lamond, R. B. Ferguson, T. M. Maxwell, and M. Cabrera. 1980. Effects of method of appli~ation on N and P and Pirate or winter wheat. Kansas Fertiliz.er Research Report of Progress. Manhattan, Kansas Agricultural Experiment Station, Report of Progress 389:18-19.

Lathwell, D. J., J. T. Cope, Jr., and J. R. Webb. 1960. Liquid fertilizers as sources of phosphorus for field crops. Agron. J. 52:251-253.

Lawton, K., C. Apostolakis, R. L. Cook, and W. 1. Hill. 1956. Influence of particle size, water solubility, and placement of fertilizers on the nutrient value of phosphorus in mixed fertilizers. Soil Sci. 82:465-475.

Lawton, K., and J. F. Davis. 1960. Influence of fertilizer analysis and placement on the emergence, growth, and nutrient absorption by wheat seedlings in the greenhouse. Agron. J. 52:326-328.

Lutz, J. A., Jr., G. 1. Terman, and J. L. Anthony. 1961. Rate and placement of phosphorus for small grains. Agron. J. 53: 303-305.

McCollum, R. E. 1991. Buildup and deciline in soil phosphorus: 30-year trends on a Typic Umbraqult. Agron. J. 83:77-85.

McLaughlin, J. R. Ryden, J. C. and Syers, J. K. 1981. Sorption of inorganic phosphate by iron-and-aluminum containing components. J. Soil. Sci. 72:581-589.

Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH4. North Carolina Soil Test Division (Mimeo 1953).

Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of the Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15: 1409-1416.

Mozaffari, M. and Sims, J. T. 1994. Phosphorus availability and sorption in an Atlantic coastal plain watershed dominated by animal-based agriculture. Soil Sci. 157: 97-107.

Murphy, L. S., D.R. Leikam, R. E. Lamaond, and P. J. Gallagher. 1978. Dual application of N and P - better agronomics and economics? Fertilizer Solutions 22.

Oklahoma DEO. 2014. Oklahoma Department of Environmental Quality. Integrated Water Quality

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939. USDA, Washington, DC.

Parfitt. R. L. 1978. Anion adsorption by soils and soil minerals Adv. Agron. 30:1-50.

Parfitt, R. L. 1989. Phosphate reactions with natural allophane, ferrihydrite, and goethite. J. Soil. Sci. 40:359-369.

Sharpley, a. N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus. J. Environ. Qual. 24: 920-926.

Sharpley, A. N., Chapra, S. C., Weldepohl, R., Sims, J. T., Daniel, T. C. and Reddy, K. R. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23: 437-451.

Simard. R. R., Cluis, D., Gangbazo, G. and Beauchemin, S. 1995. Phosphorus status of forest and agricultural soils from a watershed of high animal density. J. Environ. Qual. 24: 1010-1017.

Simard. R. R., Cluis, D., Gangbazo, G. and Pesant, A. R. 1994. Phosphorus sorption and desorption indices in soil. Commun. Soil Sci. Plant Anal. 25: 1483-1494.

Sims, J. T., Simard, R. R. and Joern, B. C. 1998. Phosphorus losses in agricultural drainage: historical perspective and current research. J. Environ. Qual. 27: 277-293.

State Waters Protection Act, 2001. Bill Text OK H.B. 2349.

Sweeney, D. W., Kilgore, G. L., and Kelley, K. W. 2008. Fertilizer management for short-season corn grown in reduced, strip-till, and no-till systems on claypan soil. Online. Crop Management doi:10.1094/CM-2008-0725-01-RS.

Syers, J. K. Smillie, G. W. abd Williams, J. D. H. 1972. Calcium fluoride formation during extraction of calcareous soils with fluoride: I. Implications to inorganic P fractionation schemes. Soil. Sci. Sci. Am. Proc. 36:20-25.

Tennan, G. L., J. D. Dement, and 0. P. Engelstad. 1961. Crop response to fertilizers varying in solubility of the phosphorus, as affected by rate, placement and seasonal environment. Agron. J. 53:221-224.

Tracey, R. W. Westfall, D. G. Elliot, E. T. Peterson, G. A. and C. V. Cole. 1990. Carbon, nitrogen, phosphorus, and sulfur mineralization in plow and no-till cultivation. Soil Sci. Soc. Am. J. 54: 457-461.

Williams, J. D. Syers, J. K. Harris, R. F. and Armstrong, D. E. 1971. Fractionation of inorganic phosphate in calcareous lake sediments. Soil Sci. Soc. Am. Proc. 35:250-255.

Wolf, A.M. and D.E. Baker. 1985. Comparison of soil test phosphorus by the Olsen, Bray PI, Mehlich 1 and Mehlich 3 methods. Commun. Soil Sci. Plant Anal. 16:467-484.

Chapter III

Evaluation of Surface Applied Phosphorus Fertilizer on Winter Wheat Grain Yield, Grain Test Weight, and Wheat Grain Phosphorus Concentration.

Introduction

The objective of this portion of the study was to identify whether surface applied phosphorus fertilizer had an effect on wheat grain yield, test weight, and grain phosphorus concentration. The three hypotheses tested were: 1) surface applied phosphorus fertilizer, on soils would not affect wheat grain yield; 2) surface applied phosphorus fertilizer would not affect wheat grain test weight; 3) surface applied phosphorus fertilizer would not affect wheat grain phosphorus concentration. Hypotheses were tested across years and locations to identify if wheat production was responsive to surface applied phosphorus fertilizer and included initial 0-15 cm soil phosphorus concentrations of each plot as a covariate in the analysis when required. Locations were also grouped by initial soil phosphorus concentrations as either being sufficient or deficient for crop production. Sufficient and deficient locations will be identified and evaluated individually in an effort to evaluate the OSU phosphorus recommended rate and yield responsiveness to phosphorus fertilizer within each location. Where appropriate preplant

Mehlich III extractable soil phosphorus will be included as a covariate in the analysis. Yield was analyzed using the generalized linear mixed model method of analysis with preplant phosphorus as a covariate when appropriate. Protected Tukey multiple comparisons were used. All tests were done at the 0.05 level. The data analysis for this paper was generated using SAS/STAT software, Version 9.4 of the SAS System for Windows. Copyright © 2012 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Results and Discussion

Phosphorus fertilization was generally required at all locations based upon the positive grain yield response due to added phosphorus (Table 3.1). An analysis of all locations with year and location as random variables determined that treatment had a significant effect on yield ($p \leq 0.05$). Preplant phosphorus concentration were determined to not have a significant effect on yield when included as a covariate ($p = 0.0917$). The analysis of wheat yield for treatment determined that the OSU recommended rate, as well as treatments 5 - 12 yielded significantly more than the check treatment ($p \leq 0.05$) (Table 3.1). The OSU rate was not significantly different from any other treatment which supplied phosphorus ($p \leq 0.05$), however, treatments 5 - 12 yielded significantly more than treatments 2 - 4 (Table 3.1). This indicates that on average the Oklahoma Soil Test Phosphorus Index and phosphorus rate recommendations will not cause a reduction in grain yield when compared to other application rates. Across all locations, treatment was found to not significantly affect grain test weight $p > 0.05$ (Table 3.2).

Also, the applied rates of P fertilizer had no significant effect on wheat grain moisture $p > 0.05$ (Table 3.2). Preplant soil phosphorus was found to be significant as a covariate $p = 0.0175$ in the analysis of grain phosphorus concentration. Including pre plant soil P as a covariate and utilizing an equal slopes model, treatment was found to have a significant effect on grain phosphorus concentration, $p = 0.0012$. The analysis found that all treatments significantly increased wheat grain P concentrations above the unfertilized check, treatment #2 (Table 3.2).

Composite preplant soil tests indicated that of the nine locations, seven were considered to be sub optimum and two were considered to have sufficient soil phosphorus for crop production, Waukomis 1 and Garber (Table 1.1). Due to the large variability in pre plant soil P between locations (Table 1.1) as well as within locations (Table 4.2, each location will be discussed in further detail.

At Garber in 2015 Mehlich III 0 – 15 cm pre plant soil P concentrations were 29.37 kg P ha^{-1} and were determine to be more than 100% sufficient for crop production based upon the OSU Soil Test P Index.. Soil phosphorus concentrations within the study location ranged from 3.7 mg P kg^{-1} to 112.2 mg P kg^{-1} depending on sampling depth (Table 4.2). During the 2015 production year Garber received slightly below average rain fall, 52.51 cm season total compared to 61.26 cm season average (Table 3.3). Preplant soil test phosphorus was determined to have no significant effect as a covariate ($p = 0.5042$), and treatment had no effect on winter wheat grain yield ($p = 0.8132$) (Table 3.4). Mean yield at Garber for the 2015 growing season was 3.29 Mg ha^{-1} and all treatments yielded higher than the Oklahoma 2015 growing season average yield of 2.6 Mg ha^{-1} (Table 3.4 and Figure 1.3).

In both 2014 and 2015 growing seasons, the Stillwater locations were considered to be extremely deficient in soil phosphorus, 70% and 51% respectively (Table 1.1). Soil phosphorus concentrations within the Stillwater 1 location ranged from 2.2 mg P kg^{-1} to 43.3 mg P kg^{-1}, and Stillwater 2 ranged from 2.0 mg P kg^{-1} to 56.3 mg P kg^{-1} depending on sampling depth (Table 4.2). Both locations received above average rainfall (Table 3.3), and initial soil pH was 6.6 and 6.8 respectively (Table 1.1). Preplant soil test phosphorus had no significant effect on treatment response when included as a covariate, p = 0.2094 and p = 0.4567 respectively. The Stillwater site in 2014 had no significant effect on yield due to treatment (p = 0.5086) and in 2015 there was again no significant effect of treatment on yield (p = 0.0898) (Table 3.2). During the 2014 growing season the Stillwater location on average yielded 2.8 metric tons per hectare, a 64% increase over the 2014 state average wheat yield of 1.7 metric tons per hectare. In the 2015 growing season, the Stillwater location on average again yielded 4% higher than the state average, 2.7 and 2.6 metric tons per hectare, respectively.

The two site locations at Waukomis in 2014 received above average rainfall, 86.98 cm, for the growing season (Table 3.3). Waukomis 1 was found to be over 100% sufficient on soil phosphorus and had an initial soil pH of 4.8 which would have required the additional 14.68 kg P ha^{-1} to be applied in an effort to alleviate aluminum toxicity (Table 1.1). Soil phosphorus concentrations within the Waukomis 1 location ranged from 3.5 mg P kg^{-1} to 95.5 mg P kg^{-1} depending on sampling depth (Table 4.2). Average yield for Waukomis 1 was greater than the state average, 2.1 Mg ha^{-1} and 1.7 Mg ha^{-1} respectively. Preplant soil phosphorus was found to be insignificant as a covariate in the analysis, p = 0.5271, and treatment was found to have a significant effect on wheat grain yield, p = 0.225. At this location it was found that 4.89 kg P ha^{-1} of additional phosphorus, treatment 3, significantly increased grain yield when compared to the check (Table 3.4). However, the yield range of treatments was only 0.53 Mg ha^{-1} with the unfertilized check, treatment 2, yielding the lowest and treatment 3, 4.89 kg P ha^{-1} soil, yielding the highest.

At Waukomis 2, composite soil pH was 5.7 and had an initial soil concentration of 29.38 kg P ha^{-1} which was determined to be 80% sufficient. Soil phosphorus concentrations within the study location ranged from 3.7 mg P kg^{-1} to 60 mg P kg^{-1} depending on sampling depth (Table 4.2). Mean wheat yield at Waukomis 2 was 1.8 Mg ha^{-1}, which was a 6% increase over the state average of 1.7 Mg ha^{-1}. Preplant phosphorus concentration was determined to be a significant covariate $p = 0.0154$, and an unequal slopes model was fit. Treatment was determined to have a significant effect on wheat grain yield, $p = 0.0036$ at the mean preplant soil P concentration of 18.08 mg P kg^{-1}. Treatments 4 – 12 were found to have significantly greater yields than treatment 2, the check. The maximum yield at this location was 2.03 Mg ha^{-1}, which was achieved with 29.37 kg P ha^{-1} rate, treatment 8. The OSU recommended rate of 19.58 kg P ha^{-1} was found to be significantly greater than the check but to not be significantly different than any other treatment.

Waukomis 3 received 88% of the average growing season rainfall in 2015, 56.75 cm (Table 3.3) and had a composite soil pH of 5.1 (Table 1.1). Pre-plant soil phosphorus at Waukomis 3 was determined to be 96.2% sufficient with initial phosphorus concentrations ranging from 4.2 mg P kg^{-1} to 51.5 mg P kg^{-1} (Table 4.2). Pre-plant phosphorus was not significant as a covariate, $p = 0.2650$. Treatment had no effect on wheat grain yield during the 2015 growing season, $p = 0.0692$. Average yield at Waukomis 3 was 3.5 Mg ha^{-1}, and the state average was 2.6 Mg ha^{-1}.

Red Rock 1, 2, and 3 experienced average rainfall for the 2014 growing season. Red Rock 1 had an initial composite soil pH of 5.3 with a soil p concentration of 10.13 mg P / kg soil in the top 15 cm. The initial soil P concentration is considered to be 80% sufficient according to the OSU Soil Test P Index. Soil phosphorus concentrations within the location ranged from 1.7 mg P kg^{-1} to 57.2 mg P kg^{-1} depending on sampling depth. Mean yield was 2.2 Mg ha^{-1} and was greater than the state average of 1.7 Mg ha^{-1} for the 2014 growing season. Preplant phosphorus concentrations were determined to be insignificant as a covariate to treatment response, $p = 0.9618$. Treatment was found to have a significant effect on wheat grain yield, $p < 0.0001$ (Table 3.4). At Red Rock 1, 29.37 kg P ha^{-1}, treatment 8, had the highest yield, 3.06 Mg ha^{-1}, and was significantly greater than the unfertilized check, treatment 2. The non pH adjusted OSU recommended rate of 19.46 kg P ha^{-1} yielded 2.02 Mg ha^{-1} which was not significantly greater than any other treatments, including the unfertilized check, treatment 2. Treatment 2 resulted in the lowest yield, 1.34 Mg ha^{-1}.

Red Rock 2 had initial composite soil pH of 4.6 and a soil P concentration of 18.5 mg P kg^{-1} soil. The initial soil P concentration results in the site being 92.75% sufficient for winter wheat production according to OSU STP. Soil phosphorus concentrations within the study location ranged from 1.8 mg P kg^{-1} to 55.4 mg P kg^{-1} depending on sampling depth (Table 4.2). The mean yield was 3.6 Mg ha^{-1}, an increase of 1.9 Mg ha^{-1} above the state average in 2014. Preplant soil P was found to be insignificant as a covariate, $p = 0.2382$, and treatment had a significant effect on wheat grain yield, $p <0.0001$. On average as phosphorus rate increased so did yield (Table 3.4), with the unfertilized check having the lowest yield, 2.87 Mg ha^{-1}. Treatment 9, 34.26 kg P ha^{-1}, yield 4.16 Mg ha^{-1}, which was the highest yield for this location. The non pH adjusted OSU recommended rate of 11.26 kg P ha^{-1} was not statistically different from any of the other treatments and resulted in a 3.52 Mg ha^{-1} yield.

Red Rock 3 had an initial soil pH of 5.4. Initial soil phosphorus concentration was 20 mg P kg soil in the top 15 cm's. This translated into a 95% sufficiency for crop production based upon OSU's STP. Soil phosphorus concentrations within the location ranged from 3.2 mg P kg^{-1} to 59.1 mg P kg^{-1} depending on sampling depth (Table 4.2). Mean yield at Red Rock 3 was 3.5 Mg ha^{-1}, which was 205% above the state average of 1.7 Mg ha^{-1}. The highest yield of 3.75 Mg ha^{-1} resulted from the 34.26 kg P ha^{-1} application rate, treatment 9, and the lowest yield of 2.84 Mg ha^{-1}, resulted from the 4.89 kg P ha^{-1} rate, treatment 3. The non pH adjusted OSU recommended rate of 10.18 kg P ha^{-1} was significantly greater than the lowest yielding treatment, treatment 3, but was not statistically different from any other treatment (Table 3.4).

Conclusions

Although there was, on average, a positive response from increased phosphorus rates, proper phosphorus management and maximized phosphorus efficiency will fall upon producers knowing and managing fields appropriately. The results of this study suggests there is a significant response to added fertilizer. However, upon investigation of each site it can be seen that there are not always positive responses to phosphorus fertilizer. The Stillwater locations which are extremely deficient in phosphorus, based on OSU's STP, had no response to the addition of phosphorus fertilizer.

Over the nine locations, no-till winter wheat yields were observed to be highly variable, even within locations. Wheat yields across all locations ranged from 0.8 Mg ha^{-1} to 3.9 Mg ha^{-1} for the check treatment, treatment 2. Yields ranged from 1.8 Mg ha^{-1} to 4.3 Mg ha^{-1} for the 48.95 kg P ha^{-1} rate, Treatment 12. One thing has become evident; achieving optimum yields is dependent on more than proper soil phosphorus estimation utilizing OSU’s current method. Soil type, pH, field history, and proper nutrient management all play a major role in phosphorus use efficiency and crop response. Even though the current OSU soil test phosphorus recommendations perform to an acceptable standard, site specific phosphorus management is extremely important in properly managing nutrient applications, and estimating and evaluating crop response, in order to increase phosphorus use efficiency and eliminating any environmental concerns of over application.

Tables

Table 3.1. No-till winter wheat mean grain yield by treatment across all nine locations in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

Treatment											
1	2	3	4	5	6	7	8	9	10	11	12
kg P ha^{-1}											
OSU	0	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1	48.9
yield Mg ha^{-1}											
2.76	2.44	2.58	2.56	2.76	2.91	2.95	2.88	3.02	2.96	3.01	3.00
ab	c	bc	bc	ab	a	a	a	a	a	a	a

Means in each row with different lettering beneath are significantly different at $p \leq 0.05$.

Table 3.2. No-till winter wheat grain test weight, moisture, and grain phosphorus concentration means for each phosphorus application rate for all nine north central Oklahoma locations during the 2014-2015 and 2015-2016 cropping seasons.

	treatment 1	2	3	4	5	6	7	8	9	10	11	12
	kg P ha^{-1} OSU	0	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1	48.9
Test Weight	2.76	2.44	2.58	2.56	2.76	2.91	2.95	2.88	3.02	2.96	3.01	3.00
Moisture (%)	7.99	8.18	8.14	8.17	8.11	8.17	8.39	7.96	8.11	8.05	8.16	8.39
Grain P (mg/kg)	4377	4215	4333	4511	4365	4675	4612	4613	4694	4746	4741	4752
	ab	b	ab	ab	ab	ab	ab	ab	a	a	a	a

Means in each row with different lettering beneath are significantly different at $p \leq 0.05$.

Table 3.3. Monthly rainfall accumulations during the 2014, and 2015 growing seasons and each north central Oklahoma location's 13-year mean growing seasons rainfall total.

Growing Season	Location	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Season Total
					Precipitation cm							
2014												
	Stillwater	10.64	5.54	5.31	1.54	2.57	1.24	3.43	9.88	23.37	8.08	71.60
	Red Rock 1, 2, & 3	7.54	8.61	4.85	1.70	1.88	0.51	2.67	10.46	25.86	7.49	71.57
	Waukomis 1 & 2	5.54	6.58	4.75	1.78	2.64	0.53	2.72	12.73	40.03	9.68	86.98
2015												
	Stillwater	8.99	9.47	13.36	8.10	0.43	2.67	7.29	14.12	7.32	4.88	76.63
	Garber	3.76	2.29	9.63	5.33	1.88	1.68	2.62	13.59	6.60	5.13	52.51
	Waukomis 3	2.00	3.30	9.20	6.81	1.73	2.24	4.62	13.49	7.06	6.30	56.75
Avg. 2003-2016												
	Stillwater	6.10	6.71	5.35	2.99	2.41	4.04	6.39	9.90	11.45	12.39	67.72
	Garber	4.28	7.53	4.23	2.34	2.09	3.25	6.16	8.61	10.25	12.51	61.26
	Red Rock	8.33	7.52	4.35	3.07	2.54	3.61	6.68	9.53	11.82	12.65	70.09
	Waukomis	5.21	7.17	3.95	2.6	2.3	4.01	6.15	7.95	12.32	13.07	64.72

Table 3.4. No-till winter wheat grain yield and applied phosphorus rate for each of the nine no-till locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

			Applied Phosphorus (kg P ha^{-1})											
Year	Location	OSU Rate	OSU	0	4.9	9.8	14.7	19.6	24.5	29.4	34.3	39.2	44.1	48.9
		kg P ha^{-1}	yield Mg ha^{-1}											
2014	Stillwater	36.2	2.93	2.84	2.71	2.57	3.01	2.85	2.88	2.43	3.02	3.00	2.86	2.50
	Red Rock 1	19.5 *	2.02 abc	1.34 c	1.46 c	1.44 c	2.02 abc	2.30 abc	1.81 bc	3.06 a	2.79 ab	2.37 abc	2.98 ab	2.84 ab
	Red Rock 2	11.3 *	3.52 abcd	2.87 d	2.99 cd	3.38 bcd	3.40 abcd	3.71 abc	3.58 abcd	3.59 abcd	4.16 a	3.83 ab	3.59 abcd	3.99 ab
	Red Rock 3	10.2 *	3.46 abcd	2.97 de	2.84 e	3.19 bcde	3.21 cde	3.93 ab	3.59 abcde	3.39 abcde	3.75 a	3.83 abc	3.68 abcd	3.76 ab
	Waukomis1	0 *	2.06 ab	1.86 b	2.39 a	1.94 b	2.06 ab	2.02 ab	2.22 ab	1.92 b	2.05 ab	2.08 ab	2.16 ab	1.98 ab
	Waukomis 2	19.6	1.82 abc	1.29 d	1.58 cd	1.68 bc	1.72 bc	1.84 abc	1.81 abc	2.03 a	1.83 abc	1.84 abc	1.97 ab	1.95 ab
2015	Garber	0	3.33	3.20	3.13	3.19	3.30	3.47	3.79	3.21	3.20	3.14	3.20	3.25
	Stillwater	29.4	2.23	2.34	2.53	2.24	2.75	2.60	3.74	2.72	2.68	2.97	2.84	3.03
	Waukomis 3	7.4 *	3.31	3.24	3.57	3.29	3.48	3.41	3.72	3.59	3.65	3.56	3.80	3.69

Means in each row with different lettering beneath are significantly different at $p \leq 0.05$.

OSU Rate with * indicates that current recommendations would have required an additional 14.68 kg P ha^{-1} application due to soil pH.

Chapter IV

Stratification of Soil Phosphorus and Soil pH Throughout the Soil Profile of No-Till Fields in Central Oklahoma

Introduction

Soil testing protocols for Oklahoma State University, and private companies throughout the great plains region, commonly recommend sampling depths of 0 – 15 cm (Zhang, 2013; Zhang, 2006; Agvise Laboratories, 2017; Franzen, 1998) while others recommend composite samples deeper than 15 cm (Ferguson, 2007; Ward Laboratories, 2017; Servi-Tech Laboratories, 2017) for standard fertility and pH analysis. Upon the conversion to no-till farming mechanical homogenization of soil to tillage depth ceases to exist. This change in practice suggest that there is the potential for stratification of immobile nutrients and pH to occur. This possibility has resulted in other regions of the country suggesting a shallower depth for sampling be used to calculate lime and immobile nutrient requirements (Anderson, 2010; PennState Extension, 2016).

This study explored how the conversion of historically tilled fields to no-till, effected the stratification of Mehlich III soil extractable phosphorus (SERA-IEG 17, 2000) and pH (EPA,

2015) throughout the soil profile. Soil samples were collected from multiple depths within nine locations. All locations have been under no-till management for a minimum of seven years prior to sampling. The objective of this portion of the study was to identify whether the depth of soil sampling in no-till fields in north central Oklahoma had an effect on Mehlich III extractable phosphorus and soil pH. The two hypotheses tested were: 1) Mehlich III extractable soil phosphorus will not be effected by soil sampling depth; 2) soil pH will not be effected by soil sampling depth. Hypotheses were tested across years and locations to identify if soil sampling depth had an effect on soil P concentration and pH. Soil pH and Mehlich III extractable soil phosphorus concentrations were analyzed using the repeated generalized linear mixed model method of analysis with depth as the repeated variable. Protected Tukey multiple comparisons were used. All tests were done at the 0.05 level. The data analyses for this paper was generated using SAS/STAT software, Version 9.4 of the SAS System for Windows. Copyright © 2012 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA.

Results and Discussion

Sampling depth utilized for the collection of soil for pH and soil phosphorus concentrations can have a significant effect on the measurements observed. The nine site locations were representative of five soil types in the state, (Table 1.1). Across nine locations in the north central part of Oklahoma, sampling depth had a significant effect on Mehlich III extractable soil phosphorus ($p < 0.001$). As the depth of the sample increased, extractable soil P was significantly decreased from the above sampling depths (Table 4.1). On average the surface 0 - 5.08 cm depth had 162% greater soil phosphorus than the second sampling depth of 5.09 – 10.16. The second sampling depth on average was 167% greater than the third sampling depth of 10.17-15.24. The third sampling depth was 260% greater than the deepest sampling depth of 15.25 - 30.48 cm's. The gradient of soil P concentration was observed at all nine locations (Figure 4.1), however the magnitude of change between depths was different for each of the nine site locations.

Soil pH was also significantly affected by sampling depth, $p < 0.001$. The top two sampling depths, 0 – 5.08 cm and 5.09 – 10.16 cm, were not significantly different from each other, $p = 0.7799$ (Table 4.2). Both of these sampling depths however were significantly different than the third and fourth depths, $p < 0.001$ (Table 4.1). The third sampling depth, 10.17 – 15.24 cm, was also significantly less than the fourth sampling depth, $p < 0.001$ (Table 4.1). These results show that in no-till fields there is an acidification of the surface soil horizons, soil depth of 0 – 10.16 cm, when compared to the soil depth of 10.17 – 15.24 cm.

Conclusion

It is not the intent of this paper to determine the reason for the stratification but to identify that in fact the conversion to no-till, in north central Oklahoma, results in the stratification of Mehlich III extractable soil phosphorus as well as soil pH. Upon review of the nine locations, representing five soil types in north central Oklahoma (Table 1.1), both Mehlich III extractable soil phosphorus and soil pH have become stratified through the soil profile of no-till fields (Table 4.1). When fields are converted from tillage to no-till the lack of mechanical homogenization exists. This lack of mechanical homogenization of the soil surface profile, 0-15.24 cm depth or tillage depth, allows for the stratification to occur. The resulting stratification can have a significant result on the quantities of phosphorus fertilizer and lime that are recommended when compared to a composite sampling depth of 0-15.24 cm (Table 1.1). All nine locations showed similar trends in pH and soil P concentrations however yield variability within each location exists (Table 3.4) and the range of pH and initial soil P by depth can be large within locations (Table 4.2). The difference in the magnitude of change within a location can be attributed to many factors including management and nutrient applications which can have a huge impact. Although the magnitude of change is different between locations all locations experience a decrease in Mehlich III extractable soil P with respect to sampling depth. Also, as sampling depth increased so did the measured soil pH. The shallowest two sampling depths on average were not significantly different. The evidence provided in this paper is justification for the evaluation of alternative sampling depths for pH and soil P concentrations when making agronomic recommendations. Currently Oklahoma State Universities recommendations for soil sampling depth for nutrient recommendations is 15.24 cm. Composite samples taken to this depth may result in the lack of identification of the acidification that can occur in the surface 10.16 cm's of the soil profile (Table 4.1 and 4.2). Since pH is considered the master variable, the stratification of soil pH can have a huge impact on both measureable as well as plant available nutrients. As a result, the identified stratification of soil pH in no-till fields may also provide justification for the evaluation of the affect sampling depth has on other nutrients and any soil based recommendations made in the agronomic field.

Tables

Table 4.1. Mehlich III extractable soil phosphorus and soil pH by soil depth averaged across all nine locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

	Soil Sampling Depth (cm)			
	0 – 5.08	5.09 – 10.16	10.17 – 15.24	15.25 – 30.48
	mg P / kg soil			
Soil P Conc.	38.07	23.38	13.99	5.39
	a	b	c	d
Soil pH	5.84	5.84	6.03	6.88
	a	a	b	c

Means in each row with different lettering beneath are significantly different at $p \leq 0.05$.

Table 4.2. Minimum, maximum, and mean soil pH and Mehlich III soil phosphorus concentrations for each sampling depth at each of the nine no-till locations in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

Year	Location	Soil Sampling Depth	Mehlich III Soil P			Soil pH		
			Min.	Max	Mean	Min.	Max	Mean
		cm		mg kg^{-1}				
2014	Stillwater 1	0 – 5.08	2.2	41.1	11.8	5.89	8.13	6.88
		5.09 – 10.16	2.9	43.3	7.3	6.26	8.15	7.26
		10.17 – 15.24	2.3	12.7	4.9	6.23	8.21	7.32
		15.24 – 30.48	1.5	5.3	2.7	6.64	9.06	7.81
	Red Rock 1	0 – 5.08	15.5	57.2	26.8	4.93	5.54	5.18
		5.09 – 10.16	7.1	20.2	12.5	5.11	5.90	5.54
		10.17 – 15.24	2.3	26.3	7.5	5.54	6.65	5.84
		15.24 – 30.48	1.7	11.6	3.7	5.15	6.89	6.48
	Red Rock 2	0 – 5.08	1.8	55.4	38.9	4.56	6.65	5.17
		5.09 – 10.16	4.9	43.9	19.2	4.40	6.98	5.19
		10.17 – 15.24	6.1	23.8	9.8	4.50	6.01	5.24
		15.24 – 30.48	1.9	38.6	3.9	5.02	7.08	5.97
	Red Rock 3	0 – 5.08	37.4	59.1	47.0	5.21	6.21	5.86
		5.09 – 10.16	21.3	39.5	29.2	5.43	7.55	5.91
		10.17 – 15.24	7.0	20.5	13.2	5.64	6.55	6.08
		15.24 – 30.48	3.2	9.3	4.5	5.65	7.76	7.00
	Waukomis1	0 – 5.08	42.9	95.5	63.1	4.43	5.39	4.91
		5.09 – 10.16	28.4	63.1	41.0	4.58	7.68	4.97
		10.17 – 15.24	17.8	38.8	26.8	4.73	7.01	5.33
		15.24 – 30.48	3.5	13.9	6.1	4.69	7.99	6.95
	Waukomis 2	0 – 5.08	13.9	60.0	23.8	5.44	7.05	6.14
		5.09 – 10.16	9.6	30.6	17.0	5.33	6.61	5.82
		10.17 – 15.24	6.4	27.1	13.3	5.50	6.85	6.20
		15.24 – 30.48	3.7	28.3	6.8	6.61	8.45	7.26
2015	Garber	0 – 5.08	37.6	99.4	68.6	5.48	6.79	6.13
		5.09 – 10.16	18.1	112.2	43.6	5.09	5.83	5.47
		10.17 – 15.24	14.1	46.1	19.3	5.09	6.16	5.58
		15.24 – 30.48	3.7	15.3	8.4	5.57	7.03	6.27
	Stillwater 2	0 – 5.08	7.9	56.3	20.7	5.99	7.44	6.93
		5.09 – 10.16	2.7	47.1	8.6	6.74	8.11	7.58
		10.17 – 15.24	2.4	26.6	5.2	6.79	8.42	7.53
		15.24 – 30.48	2.0	5.5	3.2	7.23	8.83	8.08
	Waukomis 3	0 – 5.08	24.4	51.5	37.6	5.06	6.89	5.60
		5.09 – 10.16	17.2	37.7	28.2	5.00	6.19	5.25
		10.17 – 15.24	9.5	24.5	17.1	5.16	6.45	5.49
		15.24 – 30.48	4.2	24.1	8.7	5.13	7.31	6.40

References

Agvise Laboratories. 2017. Soil Sampling Guide. Agvise Laboratories, Northwood, ND. http://www.agvise.com/wp-content/uploads/2012/12/Soil-Sampling-Guide.pdf (accessed March 31, 2017).

Anderson, N.P., et al. 2010. Evaluating soil nutrients and pH by depth in situations of limited or no-tillage in western Oregon. Oregon State Univ. Ext. Serv., Covallis.

EPA. 2015. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, EPA publication SW-846, Third Edition, Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015).

Ferguson, R.B., G.W. Herget, C.A. Shapiro, and C.S. Wortman. 2007. Guidelines for soil sampling. Publ. G1740. Univ. of Nebraska-Lincoln Ext., Inst. For Agric. And Nat Resour., Lincoln.

Franzen, D.W., and L.J. Cihacek. 1998 Soil Sampling as a basis for fertilizer application. Publ. SF-990 (revised). NDSU Ext. Serv., North Dakota State Univer. Fargo.

PennState Extension. 2017. Soil Sampling and testing. In the agronomy guide. PennState College of Agri. Sci., College Station, PA. http://extension.psu.edu/agronomy-guide/cm/sec2/sec24b#section-1 (accessed March 31, 2017).

SERA-IEG 17. 2000. Method of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396.

Servi-Tech Laboratories. 2017. Soil Sampling Procedures. Servi-Tech Laboratories, Dodge City, KS. http://www.servitechlabs.com/tabid/118/Default.aspx (accessed March 31, 2017).

Ward Laboratories. 2017. Proper soil sampling techniques. Ward Laboratories, Kearney, NE. http://www.wardlab.com/samplinginfo/propersampling.aspx#soil (accessed March 31, 2017).

Zhang, H. and B. Raun. 2006. Oklahoma Soil Fertility Handbook, Sixth Edition. Published by: Department of Plant and Soil Sciences Oklahoma Agricultural Experiment Station.

Zhang, H., B. Raun, B. Arnall. 2013. How to Get a Good Soil Sample. PSS-2207 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Chapter V

Alternative variables to predict wheat grain yield response to surface applied phosphorus fertilizer.

Introduction

Soil testing protocols for Oklahoma State University and private companies throughout the great plains region commonly recommend sampling depths of 0 – 15 cm (Zhang, 2013(2); Zhang, 2006; Agvise Laboratories, 2017; Franzen, 1998) while others recommend composite samples deeper than 15 cm (Ferguson, 2007; Ward Laboratories, 2017; Servi-Tech Laboratories, 2017) for standard fertility and pH analysis. Upon the conversion to no-till farming mechanical homogenization of soil to tillage depth ceases to exist. This change in practice suggest that there is the potential for stratification of immobile nutrients and pH to occur. This possibility has resulted in other regions of the country suggesting a shallower depth for sampling be used to calculate lime and immobile nutrient requirements (Anderson et al., 2010; PennState Extension, 2016).

In 2014 and 2015 a total of nine on farm field studies were established in the north central region of Oklahoma, in an effort to evaluate Oklahoma States current winter wheat phosphorus recommendations (Macnack, 2011), (Zhang, 2013 (1)) and the crops response to fertilizer in both sufficient and deficient soils (Zhang 2006). Alternative sampling depths and soil extraction methods were utilized in evaluating a more effective variable for estimating no-till winter wheat responsiveness to surface applied soil phosphorus in north central Oklahoma. Variables of interest included Mehlich III extractable soil phosphorus (SERA_IEG 17,2000), Change and Jackson soil phosphorus fractionations (SER_IEG 17, 2000), pH (EPA, 2015), and the EAP 3050b method for total soil phosphorus (EPA, 2015) for each of the four sampling depths collected.

The objective of this portion of the study was to identify alternative variables could be used to predict no-till winter wheat responsiveness to surface applied phosphorus fertilizer. The two hypotheses tested were: 1) wheat yield responsiveness would not be affect by the sampling depth for soil phosphorus. 2) wheat yield responsiveness would not be affected by extraction methods used to measure plant available soil phosphorus. Hypotheses were tested across years and locations to identify if soil sampling depth and combinations of analytical methods were able to better predict wheat responsiveness. Responsiveness is defined as: (high P rate yield / check plot yield) – 1. Responsiveness is presented as an increase from the check yield due to added P fertilizer. Values above zero indicate a positive response in yield to P fertilizer while values at or below zero indicate no response to P fertilizer. Variables were evaluated using Regression Analysis. The data analysis for this paper was generated using SAS/STAT software, Version 9.4 of the SAS System for Windows. Copyright © 2012 SAS Institute Inc. SAS and all other SAS Institute Inc. product or service names are registered trademarks or trademarks of SAS Institute Inc., Cary, NC, USA. Variables contribution to wheat yield responsiveness will be discussed.

Results and Discussion

Total soil phosphorus as measured by the EPA 3050b method was not significant when regressed against responsiveness across all depths and combinations of depths $p > 0.05$. The soil fractionation data collected for all depths and combinations of depths were not significant with respect to responsiveness $p > 0.05$. Analysis of soil pH had mixed results. The surface sampling depth explained a significant amount of variation in responsiveness, $b = -0.20787$, $t(33) = -2.05$, $p = 0.0484$. Soil pH on a 0 - 5.08 cm sampling depth explained a portion of variance in responsiveness, $R^2 = 0.1130$ (Figure 5.1). Soil pH for a sampling depth of 0 – 5.08 cm was also found to be the best fit of the two best fitting models. All other sampling depths that pH was measured were found to be not significant, $p > 0.05$.

The current OSU soil sampling recommended depth of 15.24 cm and extraction with Mehlich III, when regressed with responsiveness was found to be not significant, $b = -0.20787$, $t(33) = -1.70$, $p = 0.0982$ (Figure 5.2). Of the four sectioned soil sampling depths all sampling depths were found to be not significant, $p > 0.05$. Sampling depth of 5.09 – 10.16 cm was found to explain the most amount of variability of responsiveness and had the best fitting model of all the Mehlich III extracted depths, $b = -0.01196$, $t(33) = 0.00657$, $p = 0.0778$ (Figure 5.2). Mehlich III extracted soil phosphorus from the sampling depth of 5.09 – 10.16 cm core explained a portion of variance of responsiveness, $R^2 = 0.1130$, $F(1, 33) = 4.20$, $p < 0.0484$ (Figure 5.3).

Mehlich III soil extractable phosphorus was compared between the OSU soil sampling depth of 0 – 15.24 cm and all other sampling depths and combinations of depth. The sampling depth of 0 – 5.08 cm was highly correlated to the 0 – 15.24 cm depth, $p < 0.001$, and explained a significant portion of variance in the data, $R^2 = 0.9107$, $p < 0.001$ (Figure 5.4). The sampling depth of 5.08 – 10.16 cm was highly correlated to the 0 – 15.24 cm depth, $p < 0.001$, and explained a significant portion of variance in the data, $R^2 = 0.8939$, $p < 0.001$ (Figure 5.5). The sampling depth of 10.16 – 15.24 cm was highly correlated to the 0 – 15.24 cm depth, $p < 0.001$, and explained a significant portion of variance in the data, $R^2 = 0.7691$, $p < 0.001$ (Figure 5.6). The sampling depth of 0 – 10.16 cm was highly correlated to the 0 – 15.24 cm depth, $p < 0.001$, and explained a significant portion of variance in the data, $R^2 = 0.9830$, $p < 0.001$ (Figure 5.7).

Conclusions

As a result of this study, Mehlich III extractable soil phosphorus taken from a 0 – 15.24 cm depth, which is the current OSU soil sampling depth recommendation, predicted only %8 of yield responsiveness in no-till winter wheat production of north central Oklahoma. A sampling depth of 5.09 – 10.16 cm provided the best prediction of responsiveness when extracted with Mehlich III, $R^2=0.0913$. This sampling depth coincides with the previously identified depth at which pH was significantly different than the other depths. The relationship between the 5.09 – 10.16 cm depth and that of 0 – 15.24 cm was highly significant indicating the potential to use current recommendation rates with altered sampling techniques. The implementation of alternative sampling depths in combination with current soil test phosphorus rate recommendations appears to be a viable option according to this study. Other soil P measurement methods of initial interest failed to show any significant relationship with responsiveness across all sampling depths. Coincidentally, of all variables measured soil pH from a sampling depth of 0 – 5.08 cm had the best prediction of no-till winter wheat responsiveness. In conclusion no-till winter wheat responsiveness was affected by soil sampling depth and wheat responsiveness was affect by soil P extraction methods. As a result of this study it is recommended that alternative sampling depths and extraction methods need to be further investigated and could potentially be as effective, if not more, at predicting no-till winter wheat responsiveness to P fertilizer. If the current testing method of Mehlich III extractable soil P is utilized in the evaluation of depth it appears that the correlation between different depths will allow the use of alternative sampling depths with our current recommendations.

Figures

Figure 5.1. Regression analysis of responsiveness in no-till winter wheat yield by soil pH for a soil sampling depth of 0 – 5.08 cm across the nine locations located in north central Oklahoma during the 2014-2015 and 2015 - 2016 cropping seasons.

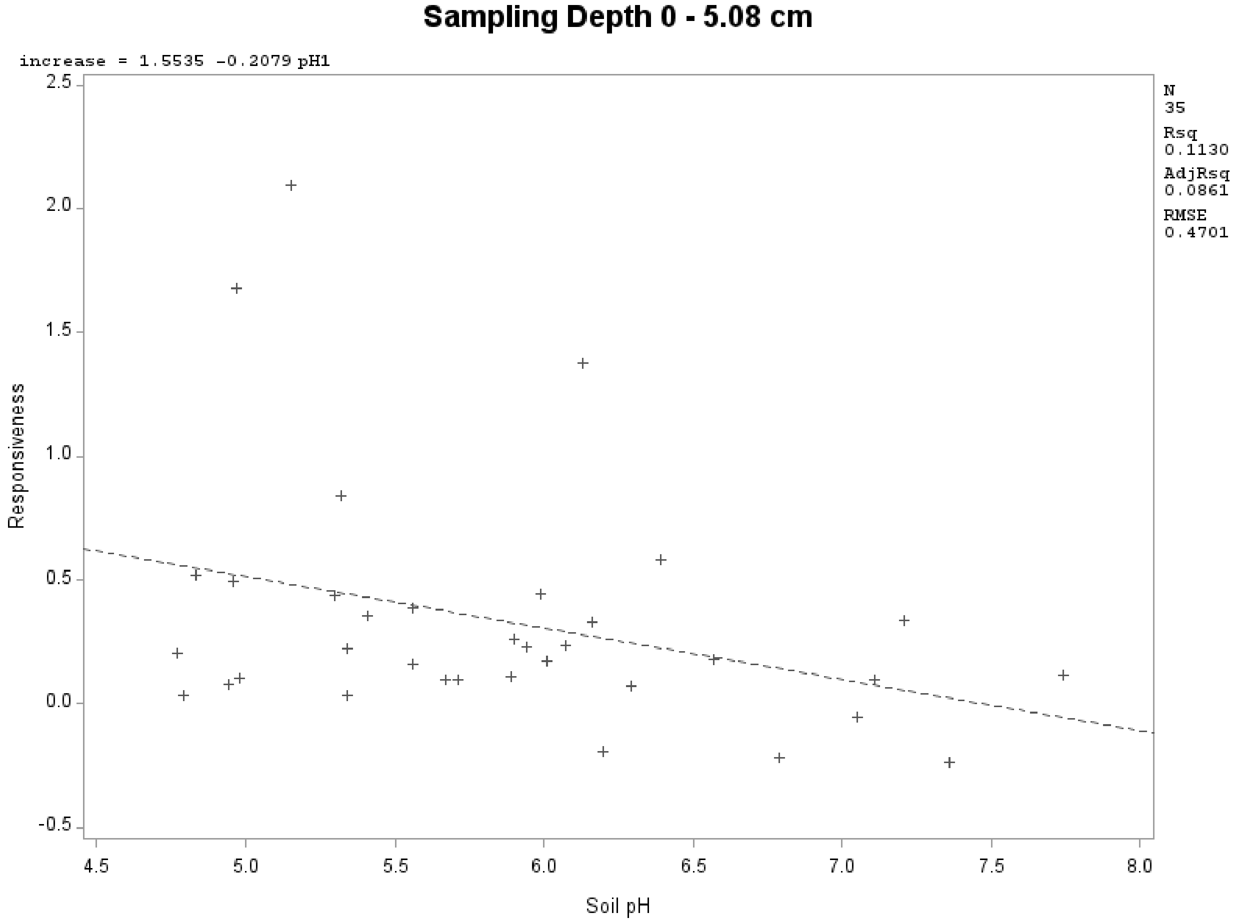


Figure 5.2. Regression analysis of responsiveness in no-till winter wheat yield by Mehlich III extractable phosphorus for a soil sampling depth of 0 – 15.24 cm across the nine locations located in north central Oklahoma during the 2014-2015 and 2015 - 2016 cropping seasons.

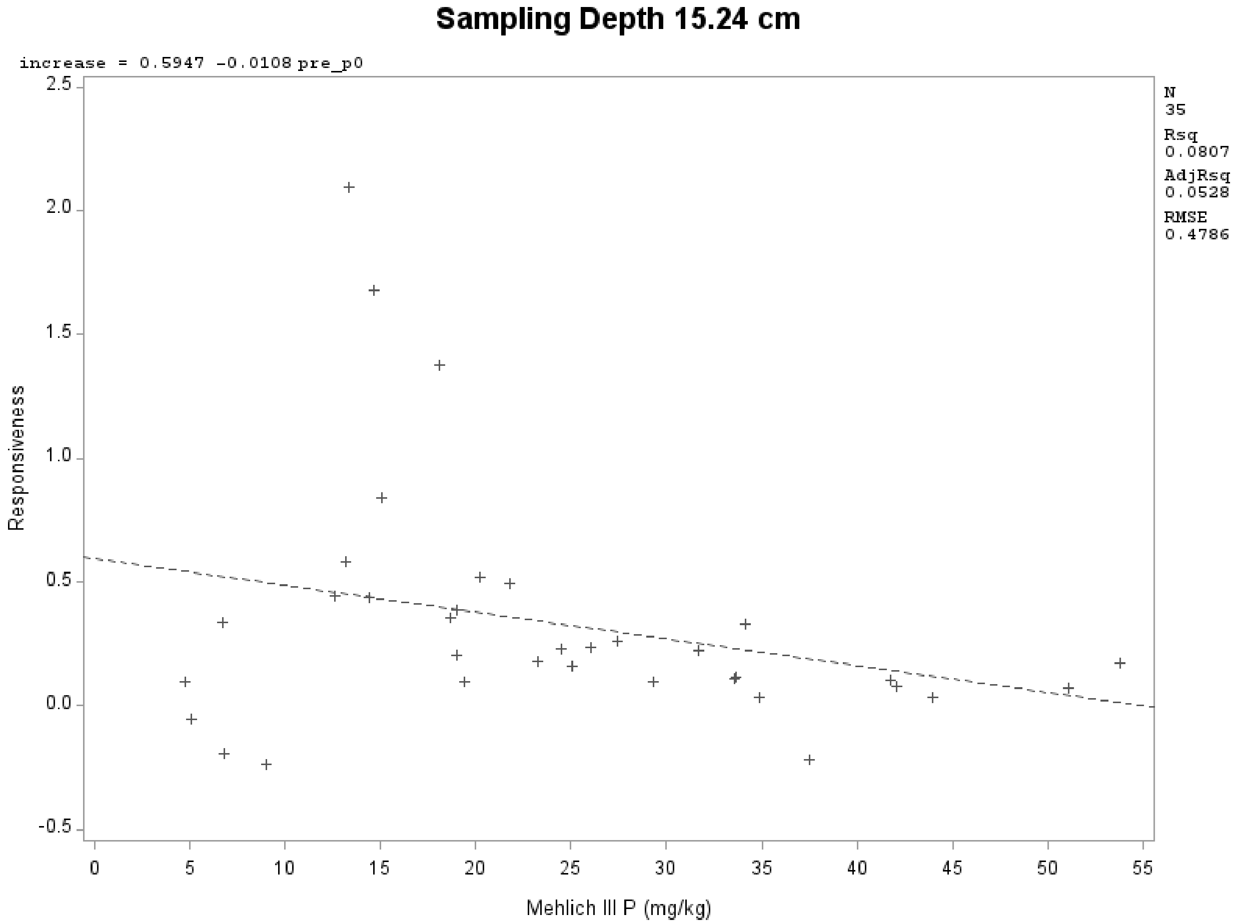


Figure 5.3. Regression analysis of responsiveness in no-till winter wheat yield by Mehlich III extractable phosphorus for a soil sampling depth of 5.08 – 10.16 cm across the nine locations located in north central Oklahoma during the 2014-2015 and 2015 - 2016 cropping seasons.

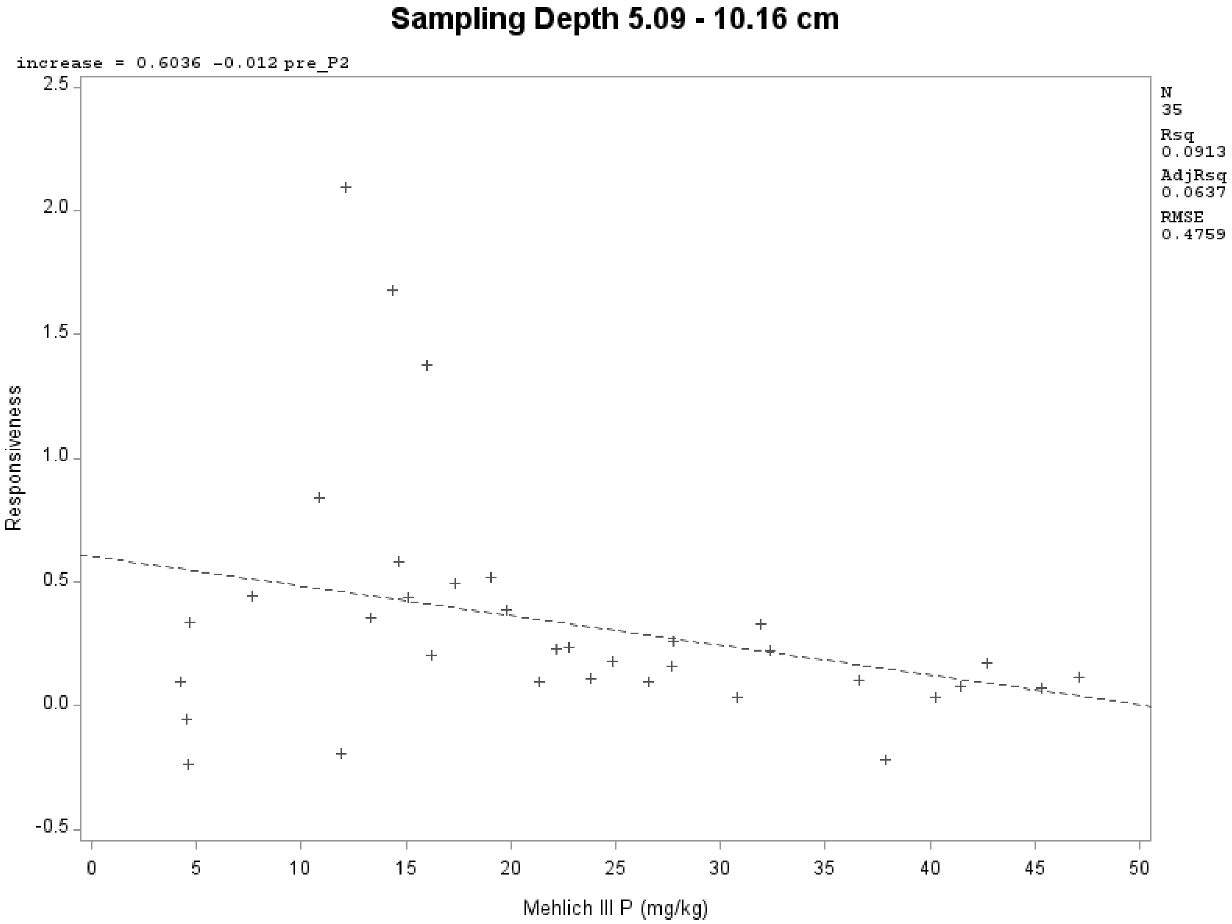


Figure 5.4. Correlation of Mehlich III extractable phosphorus for a soil sampling depth of 0 – 15.24 cm by Mehlich III extractable phosphorus for a soil sampling depth of 0 – 5.08 cm across the nine no-till locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

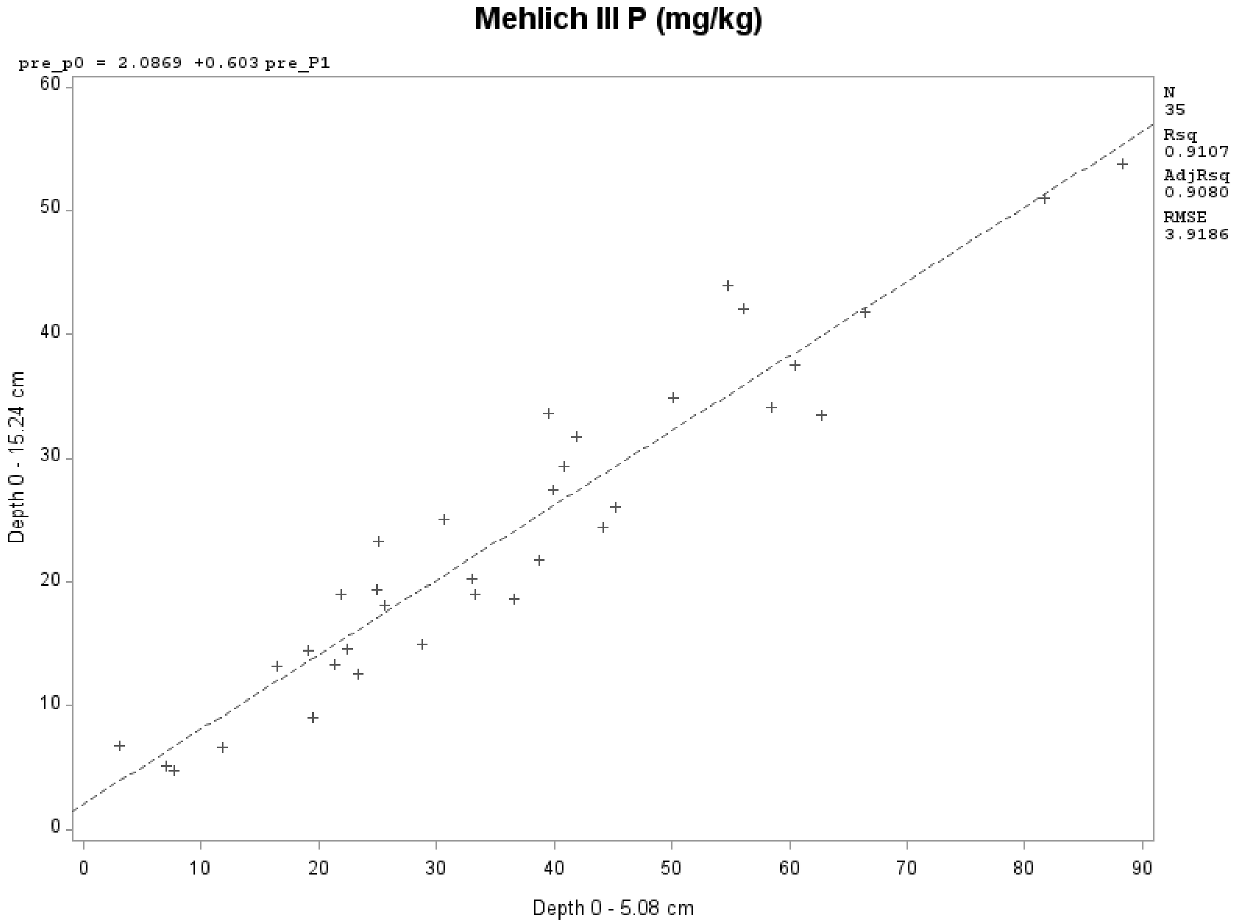


Figure 5.5. Correlation of Mehlich III extractable phosphorus for a soil sampling depth of 0 – 15.24 cm by Mehlich III extractable phosphorus for a soil sampling depth of 5.08 – 10.16 cm across the nine no-till locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

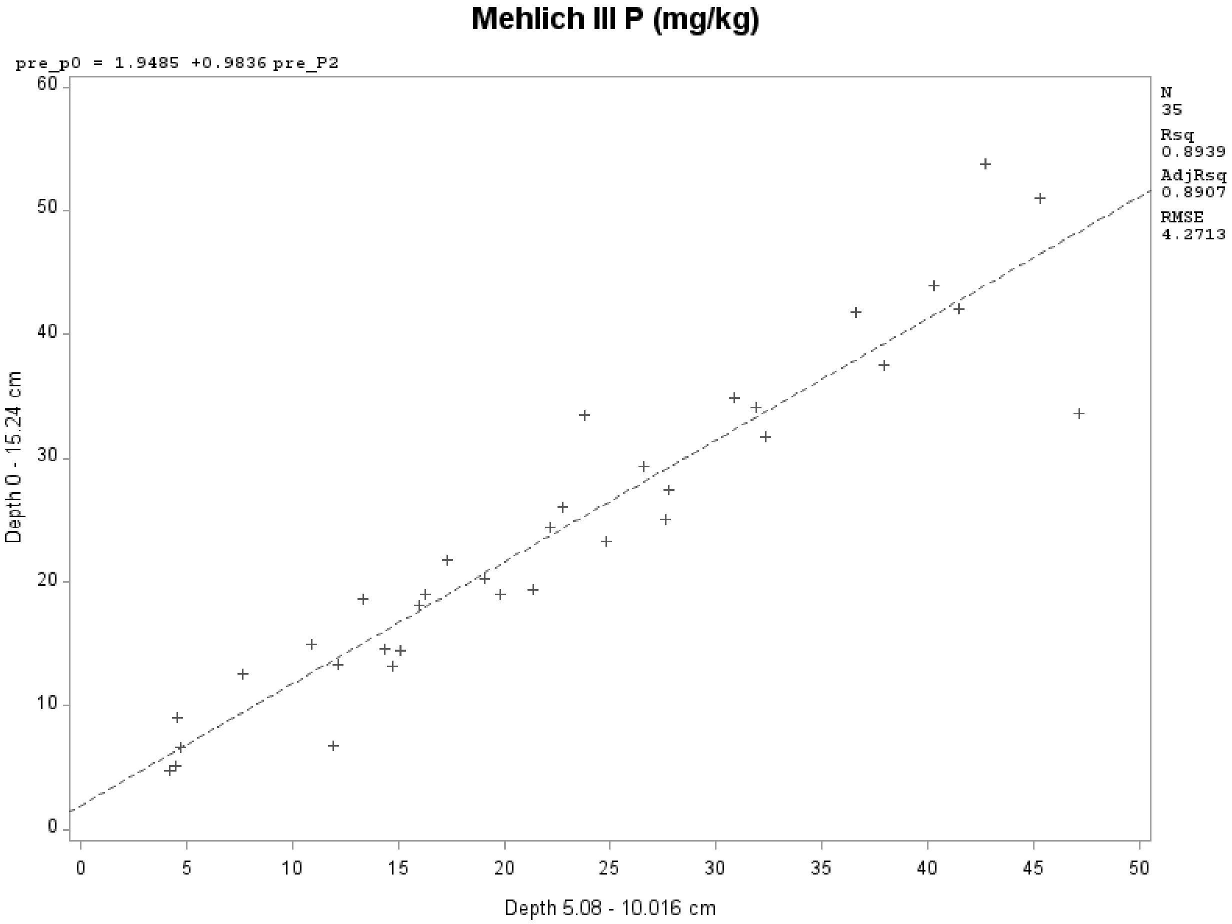


Figure 5.6. Correlation of Mehlich III extractable phosphorus for a soil sampling depth of 0 – 15.24 cm by Mehlich III extractable phosphorus for a soil sampling depth of 10.16 – 15.24 cm across the nine no-till locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.

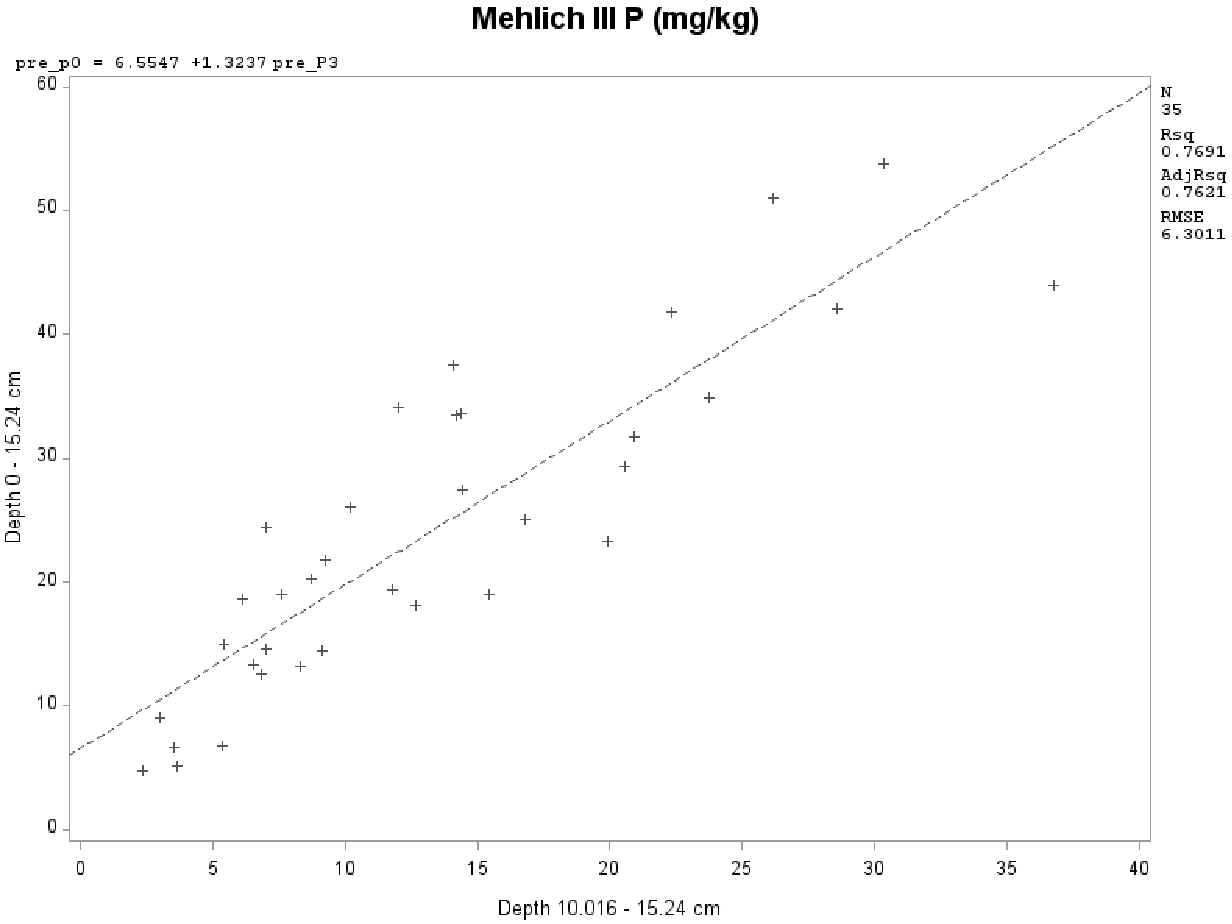
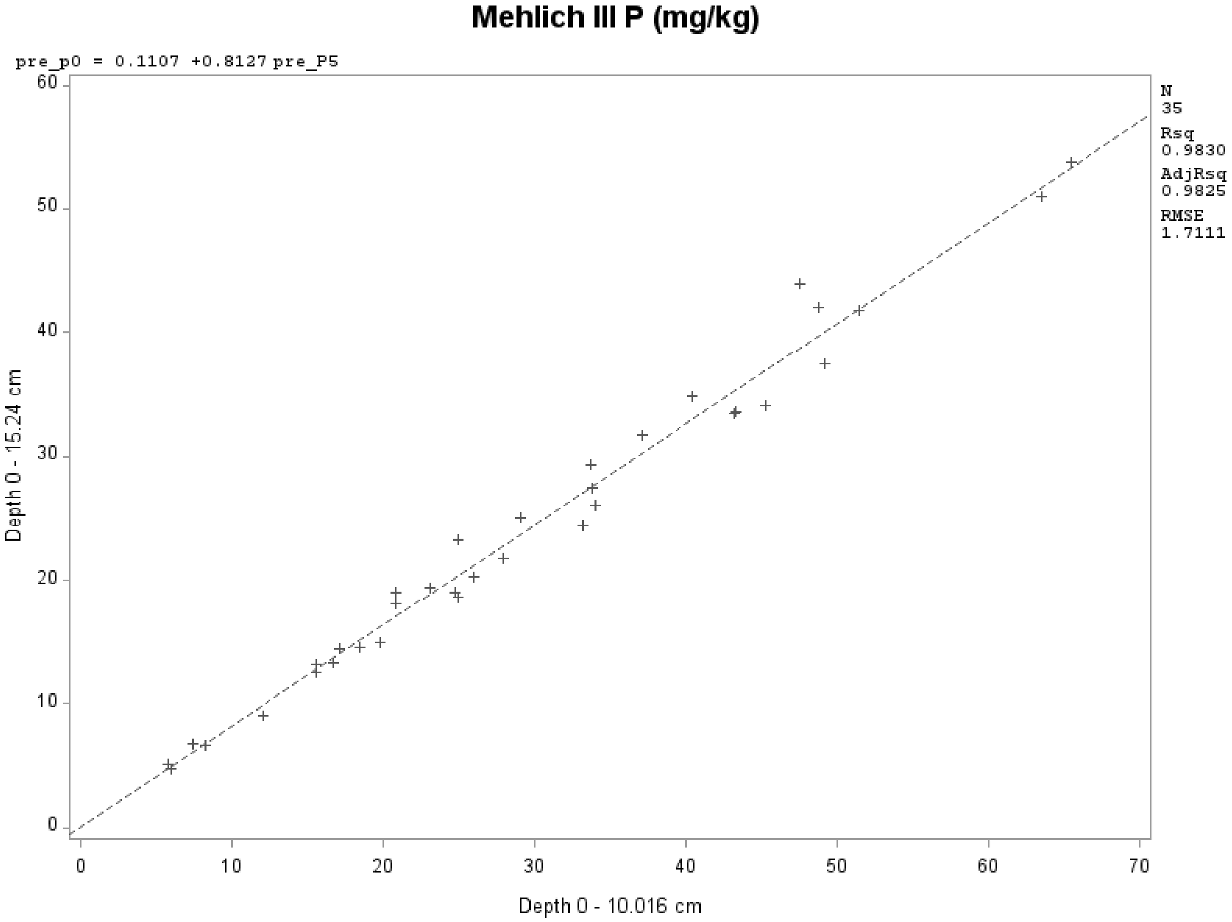


Figure 5.7. Correlation of Mehlich III extractable phosphorus for a soil sampling depth of 0 – 15.24 cm by Mehlich III extractable phosphorus for a soil sampling depth of 0 – 10.16 cm across the nine no-till locations located in north central Oklahoma during the 2014-2015 and 2015-2016 cropping seasons.



References

Agvise Laboratories. 2017. Soil Sampling Guide. Agvise Laboratories, Northwood, ND. http://www.agvise.com/wp-content/uploads/2012/12/Soil-Sampling-Guide.pdf (accessed March 31, 2017).

Anderson, N.P., et al. 2010. Evaluating soil nutrients and pH by depth in situations of limited or no-tillage in western Oregon. Oregon State Univ. Ext. Serv., Covallis.

EPA. 2015. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, EPA publication SW-846, Third Edition, Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015).

Franzen, D.W., and L.J. Cihacek. 1998 Soil Sampling as a basis for fertilizer application. Publ. SF-990 (revised). NDSU Ext. Serv., North Dakota State Univ. Fargo.

Ferguson, R.B., G.W. Herget, C.A. Shapiro, and C.S. Wortman. 2007. Guidelines for soil sampling. Publ. G1740. Univ. of Nebraska-Lincoln Ext., Inst. For Agric. And Nat. Resour., Lincoln NE.

Macnack, N., B. Chim, B. Amedy, B. Arnall. 2011. Fertilization Based on Sufficiency, Build-up, and Maintenance Concept. PSS-2266 Okla. Coop. Ext. Serv. Okla. State Univ. Stillwater, OK.

PennState Extension. 2017. Soil Sampling and testing. In the agronomy guide. PennState College of Agri. Sci., College Station, PA. http://extension.psu.edu/agronomy-guide/cm/sec2/sec24b#section-1 (accessed March 31, 2017).

SERA-IEG 17. 2000. Method of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396.

Servi-Tech Laboratories. 2017. Soil Sampling Procedures. Servi-Tech Laboratories, Dodge City, KS. http://www.servitechlabs.com/tabid/118/Default.aspx (accessed March 31, 2017).

Ward Laboratories. 2017. Proper soil sampling techniques. Ward Laboratories, Kearney, NE. http://www.wardlab.com/samplinginfo/propersampling.aspx#soil (accessed March 31, 2017).

Zhang, H., B. Raun. 2006. Oklahoma Soil Fertility Handbook, Sixth Edition. Published by: Department of Plant and Soil Sciences Oklahoma Agricultural Experiment Station Oklahoma Cooperative Extension Service Division of Agricultural Sciences and Natural Resources Oklahoma State University.

Zhang, H., B. Raun, B. Arnall. 2013 (1). OSU Soil Test Interpretations, Oklahoma Cooperative Extension Service Factsheet. PSS-2225 Okla. Coop. Ext. Serv. Okla. State Univ. Stillwater OK.

Zhang, H., B. Raun, and B. Arnall. 2013 (2). How to get a good soil sample. PSS-2207 Okla. Coop. Ext. Serv. Okla. State Univ. Stillwater OK.

Chapter VI

Future Research and Concluding Remarks

Upon review of the data, it has become evident that crop response to phosphorus fertilizer in north central Oklahoma is highly variable. Oklahoma State University's current soil test phosphorus recommendations on average prevented yield loss across all nine locations. However, on a more site specific bases the current recommendations are less then reliable at predicting winter wheat yield response. The investigation into the possibility stratification of soil pH and soil P in no-till fields of north central Oklahoma has proven to be extremely valuable. In north central Oklahoma, on average, soil phosphorus concentrations significantly decreased with sampling depth while soil pH increased with sampling depth. Soil pH was not statistically different in the top two sampling depths, 0 – 5.08 cm and 5.09 - 10.16 cm but both of these depths had significantly different pH's than the 10.17 – 15.24 cm sampling depth when analyzed across all nine locations.

When these three facts are combined it becomes evident that our current soil sampling recommendations for no-till fields can be improved greatly. Variability in responsiveness of no-till winter wheat to phosphorus fertilizer increased drastically as soil pH decreased in the 0 – 5.08 cm sampling depth. The predictability of responsiveness of Mehlich III soil P concentrations of the 0 – 5.08 cm sampling depth was the best of all P measurements analyzed, however, it was not significant. Soil pH was the only significant model in predicting responsiveness of no-till winter wheat to phosphorus fertilizer. Further investigation into the effect of sampling method on predictability of no-till winter wheat responsiveness needs to be conducted.

The implications from this study, and future research on phosphorus, may have a huge impact on producers' phosphorus use efficiency and could prove to be extremely beneficial at helping to reduce environmental P affects in high risk management zones as environmental regulations continue to increase in the state. However, it will be imperative that future research be conducted further investigating the stratification of soil pH, soil P, and other nutrients in no-till production systems with respect to sampling depth. Also, the investigation into the effects stratified soil pH have on current testing methods and fertility recommendations will be extremely important as new recommendations are developed. Alternative testing methods such as water soluble P, adsorption isotherms and desorption isotherms could prove to be extremely beneficial in predicting crop response. In conclusion, the spatial variability of soil phosphorus and soil pH, both vertically and horizontally poses a challenge to future research and must be considered.

Bibliography

Agvise Laboratories. 2017. Soil Sampling Guide. Agvise Laboratories, Northwood, ND. http://www.agvise.com/wp-content/uploads/2012/12/Soil-Sampling-Guide.pdf (accessed March 31, 2017).

Anderson, N.P., et al. 2010. Evaluating soil nutrients and pH by depth in situations of limited or no-tillage in western Oregon. Oregon State Univ. Ext. Serv., Covallis.

Assessment [305(b)/303(d)]. http://www.deq.state.ok.us/wqdnew/305b_303d/ Retrieved April 5, 2017.

Barrow, N. J. 1980. Evaluation and utilization of residual phosphorus in soil. In the role of phosphorus in agriculture. ASA, CSA, SSSA, Madison, WI, pp 333-359.

Bray, RH and Kurtz, LT 1945, Determination of total, organic, and available forms of phosphorus in soils. Soil Science, 59: 39-45.

Chang, S. C. and M. L. Jackson. 1957. Fractionation of soil phosphorus. Soil Sci. 84: 133-144.

Environmental Protection Agency, United States. 2002. Federal water pollution control act. Retrieved, April 5, 2017.

EPA. 2015. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, EPA publication SW-846, Third Edition, Final Updates I (1993), II (1995), IIA (1994), IIB (1995), III (1997), IIIA (1999), IIIB (2005), IV (2008), and V (2015).

Fardeau, J. C. and Jappe, J. 1978 Analysis per dilution isotopique de la fertilite et de la fertilization phosphorique de quelques sols du Quebec. Can. J. Soil Sci. 58; 251-258.

Ferguson, R.B., G.W. Herget, C.A. Shapiro, and C.S. Wortman. 2007. Guidelines for soil sampling. Publ. G1740. Univ. of Nebraska-Lincoln Ext., Inst. For Agric. And Nat Resour., Lincoln.

Fixen, P. E. and J. H. Grove. 1990. Testing soils for phosphorus. In soil testing and plant analysis. R.L. Westerman (ed.). Soil Sci. Soc. Am., Madison, WI. pp 141-172.

Franzen, D.W., and L.J. Cihacek. 1998 Soil Sampling as a basis for fertilizer application. Publ. SF-990 (revised). NDSU Ext. Serv., North Dakota State Univer. Fargo.

Gartley, K. L. and Sims, J. T. 1994 Phosphorus soil testing: environmental uses and implications. Coomun. Soil Sci. Plant Anal. 25: 1565-1582.

Goldberg, S. and G. Sposito. 1985. On the mechanism of specific phosphate adsorption by hydroxylated mineral surfaces: A review. Commun. Soil Sci. Plant Anal. 16:801-821.

Guo, Fengmao and Yost, R. S. 1998. Partitioning soil phosphorus into three discrete pools of differing availability. Soil Sci. 163: 822-833.

Hedley, M. J. Stewart, J. W. B. and Chauhan, B. S. 1982. Changes in inorganic and organic soil phosphorus fractions induced by cultivation practices and by laboratory incubations. Soil Sci. Soc. Am. J. 46:970-976.

Hue, N. V. and Fox, R. L. 2010 Predicting plant phosphorus requirements for Hawaii Soils using a combination of phosphorus sorption isotherms and chemical extraction methods. Comm. Soil Sci. Plant Anal. 41: 133-143.

IPNI (International Plant Nutrition Institute). 2013. 4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition. http://www.ipni.net/ipniweb/portal.nsf/0/231EA9CAE05F5D24852579B200725EA2. Viewed: April 6, 2017.

Jolford, I. C., Wedderburn, R. W. M. and Mattingly, G. E. G. 1974. A Langmuir two-surface equation as a model for phosphate adsorption by soils. J. Soil Sci. 25: 242-255.

Kamprath, E. J. and Watson, M. E. 1980. Conventional soil and tissue tests for assessing phosphorus status of soils. In the role of phosphorus in agriculture. F.E. Khasawenh, E.C. Sample, and E.J. Kamprath (eds.) ASA, CSA, and SSSA, Madison, WI. pp 471-514.

Kissel, D. E., R. E. Lamond, R. B. Ferguson, T. M. Maxwell, and M. Cabrera. 1980. Effects of method of appli~ation on N and P and Pirate or winter wheat. Kansas Fertiliz.er Research Report of Progress. Manhattan, Kansas Agricultural Experiment Station, Report of Progress 389:18-19.

Lathwell, D. J., J. T. Cope, Jr., and J. R. Webb. 1960. Liquid fertilizers as sources of phosphorus for field crops. Agron. J. 52:251-253.

Lawton, K., C. Apostolakis, R. L. Cook, and W. 1. Hill. 1956. Influence of particle size, water solubility, and placement of fertilizers on the nutrient value of phosphorus in mixed fertilizers. Soil Sci. 82:465-475.

Lawton, K., and J. F. Davis. 1960. Influence of fertilizer analysis and placement on the emergence, growth, and nutrient absorption by wheat seedlings in the greenhouse. Agron. J. 52:326-328.

Lutz, J. A., Jr., G. 1. Terman, and J. L. Anthony. 1961. Rate and placement of phosphorus for small grains. Agron. J. 53: 303-305.

Macnack, N., B.K. Chim, B. Amedy, and B. Arnall. 2011. Fertilization based on Sufficiency, Build-up and Maintenance concepts. PSS-2266 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

McCollum, R. E. 1991. Buildup and deciline in soil phosphorus: 30-year trends on a Typic Umbraqult. Agron. J. 83:77-85.

McLaughlin, J. R. Ryden, J. C. and Syers, J. K. 1981. Sorption of inorganic phosphate by iron-and-aluminum containing components. J. Soil. Sci. 72:581-589.

Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH4. North Carolina Soil Test Division (Mimeo 1953).

Mehlich, A. 1984. Mehlich 3 soil test extractant: A modification of the Mehlich 2 extractant. Commun. Soil Sci. Plant Anal. 15: 1409-1416.

Mozaffari, M. and Sims, J. T. 1994. Phosphorus availability and sorption in an Atlantic coastal plain watershed dominated by animal-based agriculture. Soil Sci. 157: 97-107.

Murphy, L. S., D.R. Leikam, R. E. Lamaond, and P. J. Gallagher. 1978. Dual application of N and P - better agronomics and economics? Fertilizer Solutions 22.

Murphy, J., J.P. Riley. 1962 A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta. 27. 31-36.

Oklahoma DEO. 2014. Oklahoma Department of Environmental Quality. Integrated Water Quality

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. USDA Circ. 939. USDA, Washington, DC.

Parfitt. R. L. 1978. Anion adsorption by soils and soil minerals Adv. Agron. 30:1-50.

Parfitt, R. L. 1989. Phosphate reactions with natural allophane, ferrihydrite, and goethite. J. Soil. Sci. 40:359-369.

PennState Extension. 2017. Soil Sampling and testing. In the agronomy guide. PennState College of Agri. Sci., College Station, PA. http://extension.psu.edu/agronomy-guide/cm/sec2/sec24b#section-1 (accessed March 31, 2017).

SERA-IEG 17. 2000. Method of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters. Southern Cooperative Series Bulletin No. 396.

Servi-Tech Laboratories. 2017. Soil Sampling Procedures. Servi-Tech Laboratories, Dodge City, KS. http://www.servitechlabs.com/tabid/118/Default.aspx (accessed March 31, 2017).

Sharpley, a. N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus. J. Environ. Qual. 24: 920-926.

Sharpley, A. N., Chapra, S. C., Weldepohl, R., Sims, J. T., Daniel, T. C. and Reddy, K. R. 1994. Managing agricultural phosphorus for protection of surface waters: issues and options. J. Environ. Qual. 23: 437-451.

Simard. R. R., Cluis, D., Gangbazo, G. and Beauchemin, S. 1995. Phosphorus status of forest and agricultural soils from a watershed of high animal density. J. Environ. Qual. 24: 1010-1017.

Simard. R. R., Cluis, D., Gangbazo, G. and Pesant, A. R. 1994. Phosphorus sorption and desorption indices in soil. Commun. Soil Sci. Plant Anal. 25: 1483-1494.

Sims, J. T., Simard, R. R. and Joern, B. C. 1998. Phosphorus losses in agricultural drainage: historical perspective and current research. J. Environ. Qual. 27: 277-293.

Soil Science Society of America. 1990. Soil Testing and Plant Analysis. 3rd Ed. pp.404-411.

State Waters Protection Act, 2001. Bill Text OK H.B. 2349.

Sweeney, D. W., Kilgore, G. L., and Kelley, K. W. 2008. Fertilizer management for short-season corn grown in reduced, strip-till, and no-till systems on a claypan soil. Online. Crop Management doi:10.1094/CM-2008-0725-01-RS.

Syers, J. K. Smillie, G. W. abd Williams, J. D. H. 1972. Calcium fluoride formation during extraction of calcareous soils with fluoride: I. Implications to inorganic P fractionation schemes. Soil. Sci. Sci. Am. Proc. 36:20-25.

Tennan, G. L., J. D. Dement, and 0. P. Engelstad. 1961. Crop response to fertilizers varying in solubility of the phosphorus, as affected by rate, placement and seasonal environment. Agron. J. 53:221-224.

Tracey, R. W. Westfall, D. G. Elliot, E. T. Peterson, G. A. and C. V. Cole. 1990. Carbon, nitrogen, phosphorus, and sulfur mineralization in plow and no-till cultivation. Soil Sci. Soc. Am. J. 54: 457-461.

Two Rivers Coop. 2017. http://www.tworiversks.coop/pages/custom.php?id=19995. (accessed March 30, 2017).

USDA, National Agricultural Statistics Service. 2017. http://www.nass.usda.gov/ Data (accessed March 15, 2017).

USGS. 2017. U.S. Geological Survey, Mineral Commodity Summaries, January 2017. https://minerals.usgs.gov/minerals/pubs/mcs/2017/mcs2017.pdf (accessed March 15, 2017).

Ward Laboratories. 2017. Proper soil sampling techniques. Ward Laboratories, Kearney, NE. http://www.wardlab.com/samplinginfo/propersampling.aspx#soil (accessed March 31, 2017).

Warren, J., S. Alspach, B. Arnall, J. Vitale, R. Taylor, M. Schrock, R. Wolf, F. Epplin, H. Zhang, A. Post, R. Hunger, J. Damicone, T. Royer, J. Edwards, R. Bowman, R. Kochenower, J. Bushong, S. Osborne. 2013. No-till Cropping Systems in Oklahoma. E-996 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Weaver, R. M. 1974. A simplified determination of reductant-soluble phosphate in soil phosphate fractionation schemes. Soil Sci. Soc. Amer. Proc., Vol. 38

Western States Laboratory Proficiency Testing Program. 1997 Soil and Plant Analytical Methods. Ver 4.00. pp. 117-119.

Williams, J. D. Syers, J. K. Harris, R. F. and Armstrong, D. E. 1971. Fractionation of inorganic phosphate in calcareous lake sediments. Soil Sci. Soc. Am. Proc. 35:250-255.

Wolf, A.M. and D.E. Baker. 1985. Comparison of soil test phosphorus by the Olsen, Bray PI, Mehlich 1 and Mehlich 3 methods. Commun. Soil Sci. Plant Anal. 16:467-484.

Zhang, H. and B. Raun. 2006. Oklahoma Soil Fertility Handbook, Sixth Edition. Published by: Department of Plant and Soil Sciences Oklahoma Agricultural Experiment Station.

Zhang, H., B. Raun, B. Arnall. 2013 (1). OSU Soil Test Interpretations. PSS-2225 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Zhang, H., B. Raun, B. Arnall. 2013 (2). How to Get a Good Soil Sample. PSS-2207 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Zhang, H., J. Edwards, B. Carver, B. Raun. 2014. Managing acid soils for wheat production. PSS-2240 Okla. Coop. Ext Serv. Okla. State Univ. Stillwater OK.

Appendices

A: Initial 0 – 15.24 cm Mehlich III soil phosphorus, yield, test weight, moisture, and grain phosphorus concentrations.

year	location	plot	block	trt	pre_p mg/kg	Yield kg/ha	moisture	tst_weight	grain_p mg / kg
2014	North 40	101	1	10	4.25	3170.00	8.64	55.49	3660
2014	North 40	102	1	8	5.19	2888.60	8.44	56.33	3320
2014	North 40	103	1	5	5.01	3050.00	7.92	55.47	4410
2014	North 40	104	1	3	4.64	2955.53	8.12	55.38	3980
2014	North 40	105	1	9	6.35	3434.91	8.70	56.11	4310
2014	North 40	106	1	1	6.05	2998.21	7.92	57.02	4000
2014	North 40	107	1	12	6.76	2899.75	8.25	56.17	3690
2014	North 40	108	1	7	8.50	3406.53	7.66	57.13	4140
2014	North 40	109	1	2	9.42	3598.01	7.81	56.16	4380
2014	North 40	110	1	6	6.78	2521.65	10.14	56.82	3520
2014	North 40	111	1	11	8.70	3540.99	9.14	55.40	4470
2014	North 40	112	1	4	5.19	2107.26	9.05	57.62	2570
2014	North 40	201	2	12	9.04	2514.51	10.93	57.01	3800

2014	North 40	202	2	7	10.59	2997.71	8.41	55.11	4050
2014	North 40	203	2	5	9.13	2481.28	8.46	55.92	3260
2014	North 40	204	2	11	11.60	2677.30	8.27	55.19	4630
2014	North 40	205	2	3	13.09	2907.28	9.62	56.25	4440
2014	North 40	206	2	4	17.55	2835.01	7.67	56.04	4310
2014	North 40	207	2	1	14.91	3275.64	7.69	56.56	4120
2014	North 40	208	2	9	18.83	3001.76	7.97	55.90	4080
2014	North 40	209	2	8	18.20	2379.14	8.23	58.00	2940
2014	North 40	210	2	10	17.41	2756.72	8.03	56.80	3470
2014	North 40	211	2	2	11.31	3298.55	7.63	56.80	3990
2014	North 40	212	2	6	17.55	3191.86	7.41	55.53	3900
2014	North 40	301	3	12	4.74	2684.43	7.67	55.95	4430
2014	North 40	302	3	8	4.99	1736.98	7.80	56.29	3960
2014	North 40	303	3	3	4.38	2264.52	8.69	56.91	5020
2014	North 40	304	3	2	5.23	2445.70	8.25	57.34	5090
2014	North 40	305	3	7	5.19	2479.02	14.07	56.64	4390
2014	North 40	306	3	9	6.09	2988.17	7.59	56.12	4500
2014	North 40	307	3	10	5.23	3053.64	7.81	56.01	4290
2014	North 40	308	3	1	4.93	2990.07	8.17	55.88	4630
2014	North 40	309	3	11	5.29	3323.45	7.66	56.39	4850
2014	North 40	310	3	4	4.89	2981.36	7.64	56.24	4700
2014	North 40	311	3	6	5.52	3183.25	7.81	56.07	4370
2014	North 40	312	3	5	5.07	3275.70	8.27	56.46	4000

2014	North 40	401	4	2	6.12	2024.62	11.76	55.01	3810
2014	North 40	402	4	9	6.68	2654.43	7.63	55.61	4330
2014	North 40	403	4	3	5.79	2715.90	8.36	54.64	3900
2014	North 40	404	4	11	4.57	1895.57	8.90	55.69	3650
2014	North 40	405	4	12	5.09	1910.52	12.89	59.98	4210
2014	North 40	406	4	4	7.28	2370.85	10.87	56.26	4810
2014	North 40	407	4	6	6.18	2512.78	7.49	58.14	4350
2014	North 40	408	4	7	6.56	2627.70	8.02	55.20	4560
2014	North 40	409	4	1	6.05	2474.67	7.94	56.92	3340
2014	North 40	410	4	10	7.41	3024.02	8.08	56.44	3630
2014	North 40	411	4	5	6.86	3235.52	7.65	55.07	4180
2014	North 40	412	4	8	7.06	2715.58	7.67	55.56	4660
2014	Red Rock 1	101	1	2	13.84	934.87	7.66	43.50	4130
2014	Red Rock 1	102	1	1	14.67	1368.61	7.50	45.87	5050
2014	Red Rock 1	103	1	7	18.27	2097.95	8.12	51.04	4520
2014	Red Rock 1	104	1	6	11.00	1715.47	7.71	46.37	4070
2014	Red Rock 1	105	1	4	13.84	1864.04	7.54	48.85	4070
2014	Red Rock 1	106	1	10	15.74	2441.54	7.77	50.83	4520
2014	Red Rock 1	107	1	12	13.34	2893.36	8.06	53.10	4290
2014	Red Rock 1	108	1	8	13.83	3037.30	7.95	52.14	3920
2014	Red Rock 1	109	1	11	16.47	3067.78	8.17	53.37	4630
2014	Red Rock 1	110	1	9	14.77	3151.92	8.28	52.91	3940
2014	Red Rock 1	111	1	5	16.66	2418.35	8.02	54.04	4310

2014	Red Rock 1	112	1	3	14.40	2346.17	8.11	53.70	4230
2014	Red Rock 1	201	2	4	14.64	1262.64	7.58	49.15	5210
2014	Red Rock 1	202	2	5	16.76	1158.88	7.50	46.40	3890
2014	Red Rock 1	203	2	2	12.98	1205.55	7.52	47.56	3740
2014	Red Rock 1	204	2	12	15.02	2220.12	8.01	50.94	4460
2014	Red Rock 1	205	2	7	16.32	2008.19	7.56	49.43	4540
2014	Red Rock 1	206	2	3	11.18	1445.68	7.33	46.85	3920
2014	Red Rock 1	207	2	6	16.11	2082.85	7.78	51.27	3870
2014	Red Rock 1	208	2	1	19.90	1485.62	7.79	49.70	4210
2014	Red Rock 1	209	2	9	15.90	2658.68	7.86	51.94	4300
2014	Red Rock 1	210	2	10	13.25	3206.07	8.30	53.63	3920
2014	Red Rock 1	211	2	8	16.03	3033.45	8.00	54.39	4320
2014	Red Rock 1	212	2	11	21.39	3114.60	8.38	53.69	3920
2014	Red Rock 1	301	3	10	19.38	1844.00	7.77	49.60	4260
2014	Red Rock 1	302	3	3	12.53	733.83	6.73	33.43	4030
2014	Red Rock 1	303	3	12	14.42	2777.08	8.21	51.35	3790
2014	Red Rock 1	304	3	7	13.86	1527.96	7.61	47.61	4090
2014	Red Rock 1	305	3	4	17.47	1692.28	7.41	48.86	4350
2014	Red Rock 1	306	3	5	14.35	1840.17	7.60	49.60	4480
2014	Red Rock 1	307	3	1	10.82	2274.59	7.77	52.05	3900
2014	Red Rock 1	308	3	8	12.60	3052.84	8.22	53.13	4060
2014	Red Rock 1	309	3	2	14.57	1930.68	7.84	50.49	3710
2014	Red Rock 1	310	3	6	13.02	2907.26	8.32	53.32	3970

2014	Red Rock 1	311	3	11	15.77	3203.35	8.19	54.92	3890
2014	Red Rock 1	312	3	9	20.05	2887.91	8.32	54.06	3500
2014	Red Rock 1	401	4	2	23.74	1301.56	7.63	47.83	4060
2014	Red Rock 1	402	4	4	10.56	961.01	7.30	43.87	4570
2014	Red Rock 1	403	4	9	19.60	2464.60	8.15	50.49	4140
2014	Red Rock 1	404	4	7	20.49	1622.87	8.13	47.10	4010
2014	Red Rock 1	405	4	3	25.69	1326.70	7.41	47.05	4190
2014	Red Rock 1	406	4	10	10.89	1994.42	7.65	50.50	5100
2014	Red Rock 1	407	4	11	13.80	2526.84	7.78	50.61	4460
2014	Red Rock 1	408	4	12	14.63	3484.80	8.09	52.97	4140
2014	Red Rock 1	409	4	1	14.20	2941.67	8.10	52.64	3790
2014	Red Rock 1	410	4	6	14.40	2478.26	7.98	52.12	3980
2014	Red Rock 1	411	4	8	16.25	3103.11	8.23	53.72	4010
2014	Red Rock 1	412	4	5	19.31	2658.53	8.27	53.25	3720
2014	Red Rock 2	101	1	7	25.45	4227.88	7.07	55.94	5260
2014	Red Rock 2	102	1	11	23.26	4080.72	6.97	57.33	4470
2014	Red Rock 2	103	1	8	22.63	3652.62	7.08	56.81	4910
2014	Red Rock 2	104	1	3	22.77	2940.84	6.95	57.43	3790
2014	Red Rock 2	105	1	12	21.73	4319.25	6.79	56.26	5370
2014	Red Rock 2	106	1	5	24.33	3774.07	6.92	56.69	4490
2014	Red Rock 2	107	1	9	19.69	4110.85	6.88	55.66	5410
2014	Red Rock 2	108	1	4	17.96	3350.08	6.92	56.87	4020
2014	Red Rock 2	109	1	2	20.97	2885.47	6.71	55.06	4560

2014	Red Rock 2	110	1	1	18.26	3448.79	6.94	55.65	3730
2014	Red Rock 2	111	1	10	22.07	3806.71	6.89	56.43	5120
2014	Red Rock 2	112	1	6	21.77	4001.81	6.98	57.12	4390
2014	Red Rock 2	201	2	9	25.30	4394.17	7.09	56.59	4360
2014	Red Rock 2	202	2	1	22.09	3532.44	7.08	56.48	4320
2014	Red Rock 2	203	2	6	25.04	3066.43	6.95	56.22	4170
2014	Red Rock 2	204	2	5	22.98	3187.70	6.77	56.57	4430
2014	Red Rock 2	205	2	4	21.05	3606.96	6.91	56.89	4430
2014	Red Rock 2	206	2	3	24.75	3124.32	6.94	55.69	4390
2014	Red Rock 2	207	2	11	21.07	3827.54	7.02	55.08	5320
2014	Red Rock 2	208	2	7	22.50	3618.59	6.88	56.18	4380
2014	Red Rock 2	209	2	12	19.02	3853.83	6.89	55.53	5630
2014	Red Rock 2	210	2	2	23.84	3193.47	7.06	56.78	3750
2014	Red Rock 2	211	2	8	21.77	3682.62	6.85	56.00	4810
2014	Red Rock 2	212	2	10	27.25	3557.28	6.84	56.29	4280
2014	Red Rock 2	301	3	9	36.24	3730.61	7.09	56.96	4070
2014	Red Rock 2	302	3	10	23.53	3731.01	7.08	57.54	5360
2014	Red Rock 2	303	3	4	19.93	2952.41	7.08	56.97	4530
2014	Red Rock 2	304	3	2	20.22	2774.88	6.90	56.54	4290
2014	Red Rock 2	305	3	5	24.17	3535.56	6.86	56.19	4550
2014	Red Rock 2	306	3	11	29.91	3253.41	6.69	55.17	5310
2014	Red Rock 2	307	3	3	23.83	2951.90	7.26	55.96	3930
2014	Red Rock 2	308	3	8	21.57	3599.40	6.97	56.26	4820

2014	Red Rock 2	309	3	6	25.62	3833.72	7.25	57.27	5020
2014	Red Rock 2	310	3	7	23.13	3473.09	6.99	56.56	4510
2014	Red Rock 2	311	3	12	20.26	4211.51	6.97	56.96	5440
2014	Red Rock 2	312	3	1	29.34	3719.73	6.97	57.03	4150
2014	Red Rock 2	401	4	1	29.40	3386.72	6.92	57.08	4550
2014	Red Rock 2	402	4	3	25.33	2935.29	6.96	56.10	4150
2014	Red Rock 2	403	4	8	7.16	3436.04	6.86	56.02	5030
2014	Red Rock 2	404	4	11	21.04	3200.35	6.40	54.92	5450
2014	Red Rock 2	405	4	9	18.97	4401.29	7.05	57.11	5260
2014	Red Rock 2	406	4	5	19.89	3119.88	6.76	55.37	4800
2014	Red Rock 2	407	4	7	24.51	3015.44	7.07	55.66	5420
2014	Red Rock 2	408	4	12	18.66	3578.47	6.97	57.69	4960
2014	Red Rock 2	409	4	4	25.28	3598.82	7.12	57.04	4520
2014	Red Rock 2	410	4	6	23.38	3929.25	6.84	56.88	5450
2014	Red Rock 2	411	4	2	19.17	2641.43	6.99	56.59	4700
2014	Red Rock 2	412	4	10	18.54	4233.34	6.95	57.19	6140
2014	Red Rock 3	101	1	3	23.26	2451.85	6.84	55.23	4670
2014	Red Rock 3	102	1	11	24.77	3650.01	6.88	56.45	4720
2014	Red Rock 3	103	1	8	27.78	3259.71	6.81	55.66	5690
2014	Red Rock 3	104	1	12	24.44	3331.29	6.86	56.41	5270
2014	Red Rock 3	105	1	1	31.76	3658.91	6.92	56.76	5180
2014	Red Rock 3	106	1	6	26.39	3825.70	6.81	56.87	4440
2014	Red Rock 3	107	1	4	26.90	2844.78	6.84	55.67	5130

2014	Red Rock 3	108	1	5	28.42	3460.78	7.18	56.38	4550
2014	Red Rock 3	109	1	9	29.48	4179.77	7.21	57.75	5370
2014	Red Rock 3	110	1	10	31.27	3613.93	6.73	56.41	5510
2014	Red Rock 3	111	1	2	27.90	2704.77	7.15	56.14	4200
2014	Red Rock 3	112	1	7	32.11	3507.38	7.19	57.37	5170
2014	Red Rock 3	201	2	11	24.08	3684.60	6.80	56.19	6050
2014	Red Rock 3	202	2	5	25.36	3656.37	7.25	58.26	4440
2014	Red Rock 3	203	2	3	28.27	3136.13	7.21	56.63	4590
2014	Red Rock 3	204	2	1	28.13	3491.72	7.19	57.56	4230
2014	Red Rock 3	205	2	4	35.68	3634.85	7.00	56.79	4710
2014	Red Rock 3	206	2	10	32.40	4106.93	6.85	56.71	5600
2014	Red Rock 3	207	2	7	29.22	3223.02	6.81	56.06	5590
2014	Red Rock 3	208	2	12	34.15	3886.29	7.24	58.47	4110
2014	Red Rock 3	209	2	9	30.01	3995.88	7.36	57.73	4000
2014	Red Rock 3	210	2	6	34.06	3902.95	7.34	58.60	4820
2014	Red Rock 3	211	2	2	27.33	2921.73	7.39	57.73	4410
2014	Red Rock 3	212	2	8	28.10	3340.36	7.19	57.45	4910
2014	Red Rock 3	301	3	11	28.25	3853.27	7.03	57.42	4930
2014	Red Rock 3	302	3	12	27.38	4288.14	7.01	57.23	4760
2014	Red Rock 3	303	3	10	27.93	3767.22	6.96	56.64	5210
2014	Red Rock 3	304	3	6	36.05	4034.52	7.07	57.42	4900
2014	Red Rock 3	305	3	2	37.24	3401.53	7.23	56.61	4080
2014	Red Rock 3	306	3	7	34.52	4080.18	7.22	57.79	5360

2014	Red Rock 3	307	3	3	33.00	3276.74	7.07	56.29	3640
2014	Red Rock 3	308	3	9	30.47	3109.22	7.39	57.49	4650
2014	Red Rock 3	309	3	5	33.71	2813.21	7.19	56.74	4720
2014	Red Rock 3	310	3	8	27.99	3920.70	7.29	56.81	5100
2014	Red Rock 3	311	3	4	25.92	2860.18	7.19	57.34	4640
2014	Red Rock 3	312	3	1	26.78	3341.41	7.45	57.29	4740
2014	Red Rock 3	401	4	2	23.99	2856.81	6.96	56.35	4660
2014	Red Rock 3	402	4	4	30.91	3437.64	7.10	56.57	4400
2014	Red Rock 3	403	4	9	30.25	3714.10	6.98	57.55	5290
2014	Red Rock 3	404	4	7	37.07	3545.44	7.15	57.06	4260
2014	Red Rock 3	405	4	6	34.90	3952.83	7.27	58.03	4820
2014	Red Rock 3	406	4	8	34.08	3055.96	6.95	56.52	4470
2014	Red Rock 3	407	4	11	32.52	3522.37	7.07	57.14	4860
2014	Red Rock 3	408	4	5	27.56	2900.89	7.39	57.66	4050
2014	Red Rock 3	409	4	3	31.80	2483.17	7.43	57.57	4310
2014	Red Rock 3	410	4	1	27.38	3335.86	7.17	56.82	3680
2014	Red Rock 3	411	4	12	26.06	3522.75	7.06	56.91	5040
2014	Red Rock 3	412	4	10	32.50	3827.24	6.90	56.93	4460
2014	Waukomis 1	101	1	7	43.81	1945.77	8.91	46.44	
2014	Waukomis 1	102	1	1	47.22	2061.17	8.31	51.43	
2014	Waukomis 1	103	1	6	43.54	2157.04	8.41	50.54	
2014	Waukomis 1	104	1	12	43.95	1812.08	8.33	50.31	
2014	Waukomis 1	105	1	8	60.55	2202.94	8.06	51.73	

2014	Waukomis 1	106	1	2	37.32	1756.20	8.04	48.90	
2014	Waukomis 1	107	1	9	41.49	1957.47	8.14	49.44	
2014	Waukomis 1	108	1	5	41.30	2305.91	9.06	51.23	
2014	Waukomis 1	109	1	10	41.53	2250.54	7.99	50.94	
2014	Waukomis 1	110	1	4	39.46	1958.38	8.09	51.55	
2014	Waukomis 1	111	1	3	43.30	2516.94	8.63	49.79	
2014	Waukomis 1	112	1	11	37.43	2446.29	7.85	50.19	
2014	Waukomis 1	201	2	4	45.45	2012.01	10.56	46.80	
2014	Waukomis 1	202	2	5	55.06	1761.69	8.69	50.49	
2014	Waukomis 1	203	2	6	58.20	1612.99	8.19	48.48	
2014	Waukomis 1	204	2	2	41.86	1951.44	8.50	49.20	
2014	Waukomis 1	205	2	1	41.23	1958.57	8.04	49.61	
2014	Waukomis 1	206	2	11	51.77	1994.68	8.69	49.79	
2014	Waukomis 1	207	2	7	54.71	2282.01	8.18	51.19	
2014	Waukomis 1	208	2	10	41.99	2020.01	7.96	49.96	
2014	Waukomis 1	209	2	3	38.91	2508.33	8.50	50.22	
2014	Waukomis 1	210	2	12	41.77	2157.69	8.59	50.79	
2014	Waukomis 1	211	2	9	42.87	2192.57	8.06	49.82	
2014	Waukomis 1	212	2	8	36.79	1967.95	7.99	52.13	
2014	Waukomis 1	301	3	8	50.78	1901.72	7.96	48.05	
2014	Waukomis 1	302	3	9	56.01	2213.62	8.27	51.22	
2014	Waukomis 1	303	3	7	47.79	2598.21	8.41	50.72	
2014	Waukomis 1	304	3	2	47.99	1969.81	8.26	51.03	

2014	Waukomis 1	305	3	4	46.74	2099.32	8.26	50.59	
2014	Waukomis 1	306	3	10	39.36	2130.50	7.98	50.80	
2014	Waukomis 1	307	3	12	42.03	2129.52	8.25	50.29	
2014	Waukomis 1	308	3	6	37.25	2118.13	9.49	50.73	
2014	Waukomis 1	309	3	11	52.39	2208.35	8.22	48.95	
2014	Waukomis 1	310	3	5	35.84	2066.27	8.10	52.45	
2014	Waukomis 1	311	3	1	38.25	2249.18	8.43	50.83	
2014	Waukomis 1	312	3	3	41.70	2341.43	8.20	52.56	
2014	Waukomis 1	401	4	6	58.79	2210.35	7.99	49.31	
2014	Waukomis 1	402	4	4	53.23	1680.54	7.91	46.93	
2014	Waukomis 1	403	4	2	40.58	1778.32	7.91	46.88	
2014	Waukomis 1	404	4	11	34.51	1986.12	8.03	49.90	
2014	Waukomis 1	405	4	3	42.63	2200.89	8.35	50.20	
2014	Waukomis 1	406	4	7	33.50	2052.63	8.27	50.24	
2014	Waukomis 1	407	4	8	40.77	1608.24	7.88	49.92	
2014	Waukomis 1	408	4	9	31.27	1830.54	7.76	48.71	
2014	Waukomis 1	409	4	5	42.72	2112.96	8.16	51.67	
2014	Waukomis 1	410	4	10	32.53	1899.14	8.29	50.11	
2014	Waukomis 1	411	4	1	41.44	1964.41	7.78	51.98	
2014	Waukomis 1	412	4	12	34.88	1836.48	9.44	49.22	
2014	Waukomis 2	101	1	11	30.05	2002.12	10.12	49.09	4630
2014	Waukomis 2	102	1	7	22.39	1970.52	9.36	49.23	3600
2014	Waukomis 2	103	1	10	21.82	1895.28	10.29	49.89	4630

2014	Waukomis 2	104	1	5	23.05	1745.03	8.61	48.88	3860
2014	Waukomis 2	105	1	4	21.50	1979.57	8.80	50.27	4570
2014	Waukomis 2	106	1	6	21.06	1760.76	8.90	50.77	4570
2014	Waukomis 2	107	1	12	23.26	2114.84	8.97	46.58	5330
2014	Waukomis 2	108	1	2	23.76	1790.97	10.11	50.66	4020
2014	Waukomis 2	109	1	3	22.22	1923.98	9.46	49.67	4460
2014	Waukomis 2	110	1	9	22.12	2132.09	8.75	50.43	4750
2014	Waukomis 2	111	1	8	19.58	2238.67	8.93	48.18	5160
2014	Waukomis 2	112	1	1	23.45	2170.59	8.48	51.41	4510
2014	Waukomis 2	201	2	7	19.62	1877.75	8.79	50.28	4660
2014	Waukomis 2	202	2	9	12.92	1816.36	9.58	49.69	4360
2014	Waukomis 2	203	2	5	15.80	1943.43	8.95	49.76	4840
2014	Waukomis 2	204	2	12	19.02	2000.60	8.56	49.29	4790
2014	Waukomis 2	205	2	10	18.44	2148.55	8.82	49.24	4920
2014	Waukomis 2	206	2	1	18.77	1870.86	8.57	50.15	4390
2014	Waukomis 2	207	2	4	24.35	1741.32	8.94	50.99	4460
2014	Waukomis 2	208	2	6	24.60	1826.83	9.50	49.27	4230
2014	Waukomis 2	209	2	8	19.28	2212.06	8.60	50.29	4810
2014	Waukomis 2	210	2	11	17.65	2069.85	10.28	49.72	5330
2014	Waukomis 2	211	2	3	23.96	1785.78	9.14	49.45	4370
2014	Waukomis 2	212	2	2	20.84	1443.56	9.70	50.08	4160
2014	Waukomis 2	301	3	12	18.09	1906.65	9.29	49.12	4840
2014	Waukomis 2	302	3	5	14.56	1456.47	12.35	48.88	4060

2014	Waukomis 2	303	3	7	15.05	1655.62	16.79	48.85	4680
2014	Waukomis 2	304	3	9	17.66	1635.02	11.25	48.24	4900
2014	Waukomis 2	305	3	6	15.04	1726.48	8.83	46.74	4410
2014	Waukomis 2	306	3	2	13.28	802.73	8.73	37.40	3500
2014	Waukomis 2	307	3	8	14.09	1902.49	8.87	48.73	4430
2014	Waukomis 2	308	3	3	12.92	1201.44	11.04	50.08	4130
2014	Waukomis 2	309	3	4	13.20	1460.69	8.87	49.94	4050
2014	Waukomis 2	310	3	11	28.01	1890.56	10.07	48.76	4520
2014	Waukomis 2	311	3	1	12.20	1526.17	8.65	48.48	4360
2014	Waukomis 2	312	3	10	13.27	1610.60	8.37	49.33	4500
2014	Waukomis 2	401	4	5	15.78	1745.31	9.82	51.48	4300
2014	Waukomis 2	402	4	2	14.50	1127.30	9.93	48.86	3830
2014	Waukomis 2	403	4	6	20.35	2053.78	10.13	50.23	4600
2014	Waukomis 2	404	4	9	11.99	1732.60	8.59	48.32	4960
2014	Waukomis 2	405	4	8	11.73	1774.77	8.58	48.37	5320
2014	Waukomis 2	406	4	7	10.95	1752.82	8.61	48.98	4630
2014	Waukomis 2	407	4	11	11.15	1912.41	8.65	48.14	4580
2014	Waukomis 2	408	4	10	11.58	1700.03	10.57	48.86	4700
2014	Waukomis 2	409	4	1	14.12	1715.64	8.38	49.10	4540
2014	Waukomis 2	410	4	3	15.36	1392.81	8.74	49.03	3520
2014	Waukomis 2	411	4	4	20.17	1553.32	8.92	48.73	4300
2014	Waukomis 2	412	4	12	13.15	1781.76	9.29	49.51	4590
2015	North 40 2	101	1	2	7.57	2528.26	8.077452	59.246769	3540

2015	North 40 2	102	1	9	7.12	3293.47	8.76614	59.91132	4510
2015	North 40 2	103	1	3	6.09	2309.01	8.357971	59.340214	4370
2015	North 40 2	104	1	11	15.84	3096.99	8.440446	58.720768	4220
2015	North 40 2	105	1	12	33.66	2828.03	9.113923	58.225636	4620
2015	North 40 2	106	1	4	29.87	2263.11	8.334201	58.090584	3770
2015	North 40 2	107	1	6	24.78	2061.83	8.158804	57.128227	4660
2015	North 40 2	108	1	7	20.03	.	.	.	4640
2015	North 40 2	109	1	1	10.77	2213.65	8.019269	58.628052	4230
2015	North 40 2	110	1	10	6.35	2739.06	8.547849	59.076626	4210
2015	North 40 2	111	1	5	20.74	2511.67	8.046868	58.675213	4310
2015	North 40 2	112	1	8	6.09	2145.77	7.953845	58.509388	4390
2015	North 40 2	201	2	10	9.79	3135.09	8.370937	58.805637	3610
2015	North 40 2	202	2	8	8.17	3136.19	8.477376	59.452538	3510
2015	North 40 2	203	2	5	10.63	2794.76	8.187428	59.666435	3400
2015	North 40 2	204	2	3	8.18	2227.14	8.059988	58.982334	4100
2015	North 40 2	205	2	9	9.55	2367.04	8.301746	58.486954	4850
2015	North 40 2	206	2	1	8.82	2161.55	7.783814	58.020046	3930
2015	North 40 2	207	2	12	6.69	2644.56	8.081285	58.600971	4270
2015	North 40 2	208	2	7	10.59	.	.	.	3630
2015	North 40 2	209	2	2	7.24	1979.39	8.865436	59.393612	3200
2015	North 40 2	210	2	6	7.17	2282.37	8.113741	59.17868	4410
2015	North 40 2	211	2	11	6.58	2641.69	8.663731	58.601418	4220
2015	North 40 2	212	2	4	4.31	2143.21	10.258895	58.361721	4450

2015	North 40 2	301	3	12	12.62	3617.03	8.249443	58.210442	3640
2015	North 40 2	302	3	7	8.66	3739.28	8.207531	58.683319	3720
2015	North 40 2	303	3	5	11.64	2957.73	9.21401	58.44825	4070
2015	North 40 2	304	3	11	8.36	2783.10	8.041588	59.344246	3720
2015	North 40 2	305	3	3	8.99	3043.74	8.233088	59.24894	3740
2015	North 40 2	306	3	4	10.21	2324.35	9.615478	58.130482	3640
2015	North 40 2	307	3	1	10.23	2328.56	8.151051	58.780014	4080
2015	North 40 2	308	3	9	21.39	2372.03	9.133848	57.66798	4130
2015	North 40 2	309	3	8	8.18	2882.86	8.541427	58.811539	4310
2015	North 40 2	310	3	10	9.91	3032.01	8.351679	59.037693	3850
2015	North 40 2	311	3	2	6.93	2507.02	9.11391	59.895935	3480
2015	North 40 2	312	3	6	10.52	3443.21	8.217412	59.815796	3920
2015	Garber	101	1	2	44.48	3190.16	8.472216	57.5854	4670
2015	Garber	102	1	1	30.10	2995.23	8.80829	57.461143	4690
2015	Garber	103	1	7	43.29	3840.23	9.287488	56.136162	4770
2015	Garber	104	1	6	41.82	3952.90	8.933463	57.435757	4720
2015	Garber	105	1	4	49.70	3614.46	8.935214	55.643692	5900
2015	Garber	106	1	10	43.76	3344.35	9.204079	56.204361	5390
2015	Garber	107	1	12	51.05	3418.50	10.092157	57.479546	5140
2015	Garber	108	1	8	56.00	3738.39	9.680721	57.529385	5120
2015	Garber	109	1	11	50.49	3799.45	8.732595	56.99609	5300
2015	Garber	110	1	9	56.13	3053.49	9.623213	56.766762	5690
2015	Garber	111	1	5	81.02	.	.	.	5320

2015	Garber	112	1	3	46.33	2983.07	9.13088	56.65184	5750
2015	Garber	201	2	4	53.25	2587.23	8.362313	56.946743	4950
2015	Garber	202	2	5	32.61	2865.57	9.415678	58.313717	5500
2015	Garber	203	2	2	42.81	3327.20	8.907237	57.394539	4450
2015	Garber	204	2	12	53.79	3892.32	9.604251	57.428688	5240
2015	Garber	205	2	7	46.98	4234.70	8.826362	56.473701	5630
2015	Garber	206	2	3	64.26	3187.30	9.313745	57.822323	5210
2015	Garber	207	2	6	61.53	3909.97	9.061056	57.838512	5160
2015	Garber	208	2	1	65.95	3517.48	9.430706	57.645992	5380
2015	Garber	209	2	9	67.09	3649.89	8.452532	57.148621	5070
2015	Garber	210	2	10	65.73	3546.13	8.830614	55.649582	5510
2015	Garber	211	2	8	65.06	.	.	.	4760
2015	Garber	212	2	11	67.58	3789.84	8.182673	56.339172	5180
2015	Garber	301	3	10	40.26	2706.10	9.759655	57.696598	5700
2015	Garber	302	3	3	35.16	2547.28	9.869303	58.354019	5170
2015	Garber	303	3	12	37.48	3027.43	9.456345	57.546196	5170
2015	Garber	304	3	7	31.46	3632.08	9.528828	57.887638	4940
2015	Garber	305	3	4	40.77	3948.81	9.315652	57.274223	5160
2015	Garber	306	3	5	51.33	3378.60	9.851344	56.782452	4770
2015	Garber	307	3	1	45.99	3228.20	10.671946	58.674393	5180
2015	Garber	308	3	8	40.05	2926.13	10.148148	57.053856	5440
2015	Garber	309	3	2	36.96	3862.62	9.898151	57.541321	5040
2015	Garber	310	3	6	37.33	2870.92	10.940638	57.552094	10500

2015	Garber	311	3	11	66.35	2437.50	8.649251	56.533375	4760
2015	Garber	312	3	9	40.83	3063.85	8.204611	56.166931	5050
2015	Garber	401	4	2	25.91	2411.94	9.553349	57.877632	5220
2015	Garber	402	4	4	26.38	2606.84	9.231236	55.749413	4990
2015	Garber	403	4	9	28.76	3042.37	9.93528	58.891041	5180
2015	Garber	404	4	7	29.39	3462.70	8.67675	56.46344	4890
2015	Garber	405	4	3	45.93	3806.52	9.425704	57.48217	.
2015	Garber	406	4	10	37.30	2950.34	10.168453	57.564548	4840
2015	Garber	407	4	11	43.69	2756.39	11.443834	56.936214	5060
2015	Garber	408	4	12	33.55	2678.15	11.271839	56.822666	6730
2015	Garber	409	4	1	38.65	3581.27	11.35844	57.121487	5720
2015	Garber	410	4	6	35.54	3149.60	11.004027	56.530159	4750
2015	Garber	411	4	8	45.85	2979.35	9.048813	57.04472	5200
2015	Garber	412	4	5	36.36	3661.70	8.139597	57.43248	5550
2015	Waukomis 3	101	1	7	29.79	3286.40	7.24	57.33	4090
2015	Waukomis 3	102	1	1	32.53	3187.50	7.32462	57.290154	4160
2015	Waukomis 3	103	1	6	33.78	2990.79	7.289737	56.60696	4980
2015	Waukomis 3	104	1	12	31.72	3398.27	7.302513	57.229771	4370
2015	Waukomis 3	105	1	8	27.35	3214.58	7.26763	55.78397	5360
2015	Waukomis 3	106	1	2	31.32	2772.36	7.565824	58.476593	4410
2015	Waukomis 3	107	1	9	25.11	3499.38	7.341998	56.725918	4960
2015	Waukomis 3	108	1	5	25.78	3275.22	7.25089	56.957493	4350
2015	Waukomis 3	109	1	10	26.02	3270.76	7.258642	56.512203	5170

2015	Waukomis 3	110	1	4	25.82	3140.74	7.526084	56.615036	4230
2015	Waukomis 3	111	1	3	27.22	3049.86	7.405204	57.367764	5080
2015	Waukomis 3	112	1	11	27.31	3756.29	8.357664	57.981594	4900
2015	Waukomis 3	201	2	4	28.13	3061.16	7.733088	59.181255	4710
2015	Waukomis 3	202	2	5	31.60	3984.19	7.080434	56.532314	4000
2015	Waukomis 3	203	2	6	28.03	3590.79	7.142918	57.317577	4850
2015	Waukomis 3	204	2	2	32.33	3293.59	7.415641	58.015259	4970
2015	Waukomis 3	205	2	1	27.65	3420.58	7.365253	58.075413	4660
2015	Waukomis 3	206	2	11	20.39	3584.54	7.418536	57.512512	4880
2015	Waukomis 3	207	2	7	26.97	3794.95	7.37688	57.276749	5070
2015	Waukomis 3	208	2	10	21.29	3817.18	7.281898	56.781738	4650
2015	Waukomis 3	209	2	3	20.19	3579.45	7.395748	57.731365	3940
2015	Waukomis 3	210	2	12	29.32	3612.15	7.312906	57.227943	5280
2015	Waukomis 3	211	2	9	21.04	3720.23	7.402053	57.038486	5100
2015	Waukomis 3	212	2	8	28.22	3927.92	7.329857	57.803406	5120
2015	Waukomis 3	301	3	8	30.73	3728.90	7.407251	58.602001	4630
2015	Waukomis 3	302	3	9	29.86	4109.90	7.183453	57.562294	5190
2015	Waukomis 3	303	3	7	28.39	3731.08	7.146751	56.699879	4530
2015	Waukomis 3	304	3	2	29.63	3240.93	7.622515	58.892025	4190
2015	Waukomis 3	305	3	4	27.66	3274.89	7.837141	56.414959	4640
2015	Waukomis 3	306	3	10	32.18	3569.70	7.299829	57.718246	5110
2015	Waukomis 3	307	3	12	25.01	3756.01	7.373005	57.607834	4290
2015	Waukomis 3	308	3	6	31.54	3572.64	7.301278	56.599167	4540

2015	Waukomis 3	309	3	11	30.74	3585.98	7.209702	56.735634	4850
2015	Waukomis 3	310	3	5	30.56	3668.70	7.390425	57.703838	4350
2015	Waukomis 3	311	3	1	29.63	3392.47	7.332285	57.798775	4000
2015	Waukomis 3	312	3	3	33.32	3956.55	7.332285	57.700638	4960
2015	Waukomis 3	401	4	6	26.94	3467.55	7.239818	57.520824	4570
2015	Waukomis 3	402	4	4	26.61	3692.43	7.225038	57.893677	5040
2015	Waukomis 3	403	4	2	23.58	3653.77	7.327941	58.953026	4410
2015	Waukomis 3	404	4	11	29.56	4288.44	7.167891	58.148636	5210
2015	Waukomis 3	405	4	3	27.29	3694.10	7.282877	57.799789	4000
2015	Waukomis 3	406	4	7	28.56	4056.88	7.249443	57.865044	5240
2015	Waukomis 3	407	4	8	32.80	3484.76	7.220862	57.0597	4510
2015	Waukomis 3	408	4	9	27.51	3271.33	7.431612	57.737713	5300
2015	Waukomis 3	409	4	5	23.98	2980.52	7.358437	57.087292	4340
2015	Waukomis 3	410	4	10	23.72	3565.24	7.156887	57.022549	5810
2015	Waukomis 3	411	4	1	17.58	3247.60	7.270269	56.814018	4230
2015	Waukomis 3	412	4	12	19.36	3999.32	7.147531	57.578262	5610

B: Preplant Mehlich III soil phosphorus concentrations and soil pH by soil sampling depth.

year	location	plot	block	trt	depth_id	pre_p mg P / kg	pH
2014	North 40	101	1	10	1	6.0	5.89
2014	North 40	101	1	10	2	3.6	6.33
2014	North 40	101	1	10	3	3.1	6.75
2014	North 40	101	1	10	4	2.1	6.97
2014	North 40	102	1	8	1	6.2	6.03
2014	North 40	102	1	8	2	3.4	6.40
2014	North 40	102	1	8	3	6.0	6.41
2014	North 40	102	1	8	4	3.8	7.09
2014	North 40	103	1	5	1	5.5	6.19
2014	North 40	103	1	5	2	2.9	6.45
2014	North 40	103	1	5	3	6.6	6.63
2014	North 40	103	1	5	4	2.6	7.55
2014	North 40	104	1	3	1	6.8	6.54
2014	North 40	104	1	3	2	3.2	6.26
2014	North 40	104	1	3	3	4.0	6.36
2014	North 40	104	1	3	4	2.1	7.40

2014	North 40	105	1	9	1	8.4	6.34
2014	North 40	105	1	9	2	4.9	6.56
2014	North 40	105	1	9	3	5.8	6.57
2014	North 40	105	1	9	4	3.9	7.68
2014	North 40	106	1	1	1	9.9	6.14
2014	North 40	106	1	1	2	4.6	6.60
2014	North 40	106	1	1	3	3.6	6.77
2014	North 40	106	1	1	4	4.8	7.26
2014	North 40	107	1	12	1	3.0	6.20
2014	North 40	107	1	12	2	11.9	6.47
2014	North 40	107	1	12	3	5.4	6.72
2014	North 40	107	1	12	4	5.3	7.48
2014	North 40	108	1	7	1	9.5	6.32
2014	North 40	108	1	7	2	6.3	6.31
2014	North 40	108	1	7	3	9.7	6.23
2014	North 40	108	1	7	4	4.1	7.25
2014	North 40	109	1	2	1	12.8	6.08
2014	North 40	109	1	2	2	6.2	6.28
2014	North 40	109	1	2	3	9.3	6.77
2014	North 40	109	1	2	4	3.8	7.57
2014	North 40	110	1	6	1	7.9	6.34
2014	North 40	110	1	6	2	6.2	6.50
2014	North 40	110	1	6	3	6.2	6.74

2014	North 40	110	1	6	4	3.2	7.26
2014	North 40	111	1	11	1	10.2	6.43
2014	North 40	111	1	11	2	8.9	6.57
2014	North 40	111	1	11	3	7.0	6.67
2014	North 40	111	1	11	4	2.1	7.03
2014	North 40	112	1	4	1	7.1	6.40
2014	North 40	112	1	4	2	4.3	6.61
2014	North 40	112	1	4	3	4.1	6.78
2014	North 40	112	1	4	4	1.7	6.64
2014	North 40	201	2	12	1	19.5	7.36
2014	North 40	201	2	12	2	4.6	6.67
2014	North 40	201	2	12	3	3.0	6.96
2014	North 40	201	2	12	4	1.5	7.27
2014	North 40	202	2	7	1	22.7	8.05
2014	North 40	202	2	7	2	4.9	7.16
2014	North 40	202	2	7	3	4.1	7.55
2014	North 40	202	2	7	4	1.6	7.74
2014	North 40	203	2	5	1	15.8	8.31
2014	North 40	203	2	5	2	7.8	7.19
2014	North 40	203	2	5	3	3.8	7.73
2014	North 40	203	2	5	4	2.7	8.36
2014	North 40	204	2	11	1	25.5	6.79
2014	North 40	204	2	11	2	5.5	7.35

2014	North 40	204	2	11	3	3.8	7.48
2014	North 40	204	2	11	4	3.9	8.04
2014	North 40	205	2	3	1	2.2	7.10
2014	North 40	205	2	3	2	24.4	7.78
2014	North 40	205	2	3	3	12.7	7.52
2014	North 40	205	2	3	4	4.8	8.09
2014	North 40	206	2	4	1	3.9	6.78
2014	North 40	206	2	4	2	43.3	7.49
2014	North 40	206	2	4	3	5.4	7.47
2014	North 40	206	2	4	4	2.9	8.12
2014	North 40	207	2	1	1	23.4	6.92
2014	North 40	207	2	1	2	15.8	7.94
2014	North 40	207	2	1	3	5.5	7.79
2014	North 40	207	2	1	4	2.8	8.42
2014	North 40	208	2	9	1	41.1	6.83
2014	North 40	208	2	9	2	9.2	7.50
2014	North 40	208	2	9	3	6.2	7.58
2014	North 40	208	2	9	4	3.0	7.80
2014	North 40	209	2	8	1	39.9	7.03
2014	North 40	209	2	8	2	8.9	7.43
2014	North 40	209	2	8	3	5.9	7.43
2014	North 40	209	2	8	4	2.3	8.34
2014	North 40	210	2	10	1	33.0	7.09

2014	North 40	210	2	10	2	15.8	7.62
2014	North 40	210	2	10	3	3.4	7.67
2014	North 40	210	2	10	4	1.8	7.69
2014	North 40	211	2	2	1	21.2	7.27
2014	North 40	211	2	2	2	6.7	7.40
2014	North 40	211	2	2	3	6.0	7.22
2014	North 40	211	2	2	4	3.0	7.82
2014	North 40	212	2	6	1	22.4	7.23
2014	North 40	212	2	6	2	24.0	7.54
2014	North 40	212	2	6	3	6.2	7.94
2014	North 40	212	2	6	4	2.4	7.63
2014	North 40	301	3	12	1	7.7	7.11
2014	North 40	301	3	12	2	4.2	7.81
2014	North 40	301	3	12	3	2.3	7.58
2014	North 40	301	3	12	4	1.6	8.20
2014	North 40	302	3	8	1	7.5	6.84
2014	North 40	302	3	8	2	3.7	7.58
2014	North 40	302	3	8	3	3.8	7.06
2014	North 40	302	3	8	4	1.7	8.04
2014	North 40	303	3	3	1	7.3	6.88
2014	North 40	303	3	3	2	2.9	7.52
2014	North 40	303	3	3	3	3.0	7.36
2014	North 40	303	3	3	4	2.0	7.92

2014	North 40	304	3	2	1	8.5	7.10
2014	North 40	304	3	2	2	4.0	7.70
2014	North 40	304	3	2	3	3.2	7.68
2014	North 40	304	3	2	4	2.0	7.73
2014	North 40	305	3	7	1	7.5	6.98
2014	North 40	305	3	7	2	4.1	7.37
2014	North 40	305	3	7	3	4.0	7.18
2014	North 40	305	3	7	4	2.3	7.59
2014	North 40	306	3	9	1	9.6	7.03
2014	North 40	306	3	9	2	4.6	7.68
2014	North 40	306	3	9	3	4.1	7.87
2014	North 40	306	3	9	4	2.7	8.45
2014	North 40	307	3	10	1	9.2	6.97
2014	North 40	307	3	10	2	3.7	7.71
2014	North 40	307	3	10	3	2.9	7.67
2014	North 40	307	3	10	4	1.8	8.03
2014	North 40	308	3	1	1	7.5	6.91
2014	North 40	308	3	1	2	4.0	7.46
2014	North 40	308	3	1	3	3.3	7.66
2014	North 40	308	3	1	4	1.7	7.92
2014	North 40	309	3	11	1	7.9	6.98
2014	North 40	309	3	11	2	4.3	7.47
2014	North 40	309	3	11	3	3.7	7.50

2014	North 40	309	3	11	4	2.5	8.09
2014	North 40	310	3	4	1	7.0	7.03
2014	North 40	310	3	4	2	4.3	7.48
2014	North 40	310	3	4	3	3.4	7.89
2014	North 40	310	3	4	4	2.0	8.47
2014	North 40	311	3	6	1	8.2	7.24
2014	North 40	311	3	6	2	4.7	7.36
2014	North 40	311	3	6	3	3.6	7.31
2014	North 40	311	3	6	4	1.8	7.84
2014	North 40	312	3	5	1	7.2	6.89
2014	North 40	312	3	5	2	4.5	7.35
2014	North 40	312	3	5	3	3.5	7.54
2014	North 40	312	3	5	4	2.0	8.45
2014	North 40	401	4	2	1	7.9	6.93
2014	North 40	401	4	2	2	5.8	7.41
2014	North 40	401	4	2	3	4.6	7.82
2014	North 40	401	4	2	4	3.0	8.22
2014	North 40	402	4	9	1	7.6	6.87
2014	North 40	402	4	9	2	6.2	6.86
2014	North 40	402	4	9	3	6.2	6.84
2014	North 40	402	4	9	4	2.3	7.79
2014	North 40	403	4	3	1	7.2	6.38
2014	North 40	403	4	3	2	5.5	6.79

2014	North 40	403	4	3	3	4.7	6.95
2014	North 40	403	4	3	4	2.4	7.26
2014	North 40	404	4	11	1	6.3	6.91
2014	North 40	404	4	11	2	3.8	7.53
2014	North 40	404	4	11	3	3.5	7.35
2014	North 40	404	4	11	4	3.0	7.56
2014	North 40	405	4	12	1	7.1	7.05
2014	North 40	405	4	12	2	4.5	7.54
2014	North 40	405	4	12	3	3.7	7.19
2014	North 40	405	4	12	4	2.4	7.45
2014	North 40	406	4	4	1	12.0	6.98
2014	North 40	406	4	4	2	5.5	7.71
2014	North 40	406	4	4	3	4.4	7.58
2014	North 40	406	4	4	4	4.1	7.75
2014	North 40	407	4	6	1	9.4	7.47
2014	North 40	407	4	6	2	4.7	7.64
2014	North 40	407	4	6	3	4.4	8.01
2014	North 40	407	4	6	4	3.1	7.50
2014	North 40	408	4	7	1	8.8	7.29
2014	North 40	408	4	7	2	5.2	8.14
2014	North 40	408	4	7	3	5.6	8.09
2014	North 40	408	4	7	4	2.4	8.15
2014	North 40	409	4	1	1	8.3	7.33

2014	North 40	409	4	1	2	4.5	8.15
2014	North 40	409	4	1	3	5.3	7.97
2014	North 40	409	4	1	4	2.6	8.14
2014	North 40	410	4	10	1	12.7	6.96
2014	North 40	410	4	10	2	5.4	7.95
2014	North 40	410	4	10	3	4.1	8.21
2014	North 40	410	4	10	4	2.3	8.60
2014	North 40	411	4	5	1	8.6	7.11
2014	North 40	411	4	5	2	6.5	7.86
2014	North 40	411	4	5	3	5.5	7.59
2014	North 40	411	4	5	4	1.9	7.97
2014	North 40	412	4	8	1	10.5	7.30
2014	North 40	412	4	8	2	5.9	7.90
2014	North 40	412	4	8	3	4.8	7.92
2014	North 40	412	4	8	4	2.3	9.06
2014	Red Rock 1	101	1	2	1	24.7	5.00
2014	Red Rock 1	101	1	2	2	13.6	5.51
2014	Red Rock 1	101	1	2	3	3.3	5.54
2014	Red Rock 1	101	1	2	4	10.1	6.28
2014	Red Rock 1	102	1	1	1	26.4	5.05
2014	Red Rock 1	102	1	1	2	10.7	5.57
2014	Red Rock 1	102	1	1	3	6.9	5.98
2014	Red Rock 1	102	1	1	4	2.5	6.82

2014	Red Rock 1	103	1	7	1	36.5	5.25
2014	Red Rock 1	103	1	7	2	10.3	5.61
2014	Red Rock 1	103	1	7	3	8.1	5.65
2014	Red Rock 1	103	1	7	4	3.0	6.32
2014	Red Rock 1	104	1	6	1	20.2	5.08
2014	Red Rock 1	104	1	6	2	7.1	5.52
2014	Red Rock 1	104	1	6	3	5.7	5.73
2014	Red Rock 1	104	1	6	4	2.2	6.34
2014	Red Rock 1	105	1	4	1	26.6	5.12
2014	Red Rock 1	105	1	4	2	9.6	5.57
2014	Red Rock 1	105	1	4	3	5.3	5.86
2014	Red Rock 1	105	1	4	4	3.1	6.54
2014	Red Rock 1	106	1	10	1	28.3	5.11
2014	Red Rock 1	106	1	10	2	13.0	5.59
2014	Red Rock 1	106	1	10	3	5.9	5.87
2014	Red Rock 1	106	1	10	4	2.2	6.73
2014	Red Rock 1	107	1	12	1	21.3	5.15
2014	Red Rock 1	107	1	12	2	12.1	5.59
2014	Red Rock 1	107	1	12	3	6.5	5.91
2014	Red Rock 1	107	1	12	4	4.2	6.59
2014	Red Rock 1	108	1	8	1	22.5	4.99
2014	Red Rock 1	108	1	8	2	12.8	5.11
2014	Red Rock 1	108	1	8	3	6.2	5.72

2014	Red Rock 1	108	1	8	4	3.8	6.40
2014	Red Rock 1	109	1	11	1	33.3	4.93
2014	Red Rock 1	109	1	11	2	13.8	5.46
2014	Red Rock 1	109	1	11	3	2.3	5.77
2014	Red Rock 1	109	1	11	4	8.2	6.63
2014	Red Rock 1	110	1	9	1	22.5	5.32
2014	Red Rock 1	110	1	9	2	15.1	5.72
2014	Red Rock 1	110	1	9	3	6.7	6.10
2014	Red Rock 1	110	1	9	4	2.2	6.77
2014	Red Rock 1	111	1	5	1	27.3	5.10
2014	Red Rock 1	111	1	5	2	13.4	5.61
2014	Red Rock 1	111	1	5	3	9.3	5.84
2014	Red Rock 1	111	1	5	4	5.0	6.54
2014	Red Rock 1	112	1	3	1	28.2	5.07
2014	Red Rock 1	112	1	3	2	10.3	5.38
2014	Red Rock 1	112	1	3	3	4.6	5.73
2014	Red Rock 1	112	1	3	4	3.2	6.33
2014	Red Rock 1	201	2	4	1	24.0	5.10
2014	Red Rock 1	201	2	4	2	12.4	5.37
2014	Red Rock 1	201	2	4	3	7.5	5.83
2014	Red Rock 1	201	2	4	4	3.1	6.53
2014	Red Rock 1	202	2	5	1	34.9	5.20
2014	Red Rock 1	202	2	5	2	9.7	5.61

2014	Red Rock 1	202	2	5	3	5.8	5.93
2014	Red Rock 1	202	2	5	4	2.4	6.56
2014	Red Rock 1	203	2	2	1	20.3	5.19
2014	Red Rock 1	203	2	2	2	11.0	5.45
2014	Red Rock 1	203	2	2	3	7.7	5.60
2014	Red Rock 1	203	2	2	4	2.7	6.31
2014	Red Rock 1	204	2	12	1	28.8	5.32
2014	Red Rock 1	204	2	12	2	10.9	5.51
2014	Red Rock 1	204	2	12	3	5.4	5.78
2014	Red Rock 1	204	2	12	4	1.7	6.32
2014	Red Rock 1	205	2	7	1	28.0	5.01
2014	Red Rock 1	205	2	7	2	13.3	5.58
2014	Red Rock 1	205	2	7	3	7.7	5.92
2014	Red Rock 1	205	2	7	4	2.0	6.68
2014	Red Rock 1	206	2	3	1	17.1	5.11
2014	Red Rock 1	206	2	3	2	10.7	5.46
2014	Red Rock 1	206	2	3	3	5.7	5.81
2014	Red Rock 1	206	2	3	4	3.2	6.49
2014	Red Rock 1	207	2	6	1	24.6	5.54
2014	Red Rock 1	207	2	6	2	16.9	5.90
2014	Red Rock 1	207	2	6	3	6.8	6.65
2014	Red Rock 1	207	2	6	4	3.1	5.15
2014	Red Rock 1	208	2	1	1	35.8	5.03

2014	Red Rock 1	208	2	1	2	16.6	5.47
2014	Red Rock 1	208	2	1	3	7.3	5.64
2014	Red Rock 1	208	2	1	4	4.4	6.58
2014	Red Rock 1	209	2	9	1	25.0	5.07
2014	Red Rock 1	209	2	9	2	12.0	5.48
2014	Red Rock 1	209	2	9	3	10.7	5.68
2014	Red Rock 1	209	2	9	4	6.5	6.28
2014	Red Rock 1	210	2	10	1	19.8	5.36
2014	Red Rock 1	210	2	10	2	9.2	5.69
2014	Red Rock 1	210	2	10	3	10.7	5.99
2014	Red Rock 1	210	2	10	4	4.1	6.40
2014	Red Rock 1	211	2	8	1	25.6	5.29
2014	Red Rock 1	211	2	8	2	13.5	5.77
2014	Red Rock 1	211	2	8	3	8.9	5.90
2014	Red Rock 1	211	2	8	4	3.0	6.32
2014	Red Rock 1	212	2	11	1	39.3	5.11
2014	Red Rock 1	212	2	11	2	16.8	5.55
2014	Red Rock 1	212	2	11	3	8.0	5.97
2014	Red Rock 1	212	2	11	4	7.2	6.35
2014	Red Rock 1	301	3	10	1	30.3	5.03
2014	Red Rock 1	301	3	10	2	13.1	5.47
2014	Red Rock 1	301	3	10	3	14.8	5.73
2014	Red Rock 1	301	3	10	4	3.1	6.59

2014	Red Rock 1	302	3	3	1	21.5	5.12
2014	Red Rock 1	302	3	3	2	9.2	5.49
2014	Red Rock 1	302	3	3	3	6.9	5.83
2014	Red Rock 1	302	3	3	4	2.0	6.79
2014	Red Rock 1	303	3	12	1	19.1	5.30
2014	Red Rock 1	303	3	12	2	15.1	5.65
2014	Red Rock 1	303	3	12	3	9.1	6.05
2014	Red Rock 1	303	3	12	4	2.6	6.67
2014	Red Rock 1	304	3	7	1	24.0	5.42
2014	Red Rock 1	304	3	7	2	11.2	5.71
2014	Red Rock 1	304	3	7	3	6.4	5.96
2014	Red Rock 1	304	3	7	4	2.2	6.57
2014	Red Rock 1	305	3	4	1	36.4	5.28
2014	Red Rock 1	305	3	4	2	10.7	5.62
2014	Red Rock 1	305	3	4	3	5.3	5.89
2014	Red Rock 1	305	3	4	4	3.6	6.57
2014	Red Rock 1	306	3	5	1	26.6	5.35
2014	Red Rock 1	306	3	5	2	11.5	5.69
2014	Red Rock 1	306	3	5	3	5.0	5.98
2014	Red Rock 1	306	3	5	4	2.3	6.89
2014	Red Rock 1	307	3	1	1	15.5	5.31
2014	Red Rock 1	307	3	1	2	10.2	5.56
2014	Red Rock 1	307	3	1	3	6.7	5.80

2014	Red Rock 1	307	3	1	4	2.9	6.47
2014	Red Rock 1	308	3	8	1	23.5	5.25
2014	Red Rock 1	308	3	8	2	9.3	5.62
2014	Red Rock 1	308	3	8	3	5.0	6.07
2014	Red Rock 1	308	3	8	4	4.2	6.82
2014	Red Rock 1	309	3	2	1	21.7	5.40
2014	Red Rock 1	309	3	2	2	14.4	5.60
2014	Red Rock 1	309	3	2	3	7.6	5.82
2014	Red Rock 1	309	3	2	4	2.7	6.56
2014	Red Rock 1	310	3	6	1	20.3	5.53
2014	Red Rock 1	310	3	6	2	10.7	5.78
2014	Red Rock 1	310	3	6	3	8.1	6.16
2014	Red Rock 1	310	3	6	4	3.1	6.67
2014	Red Rock 1	311	3	11	1	26.8	5.25
2014	Red Rock 1	311	3	11	2	12.0	5.73
2014	Red Rock 1	311	3	11	3	8.5	5.64
2014	Red Rock 1	311	3	11	4	3.9	6.50
2014	Red Rock 1	312	3	9	1	20.9	5.38
2014	Red Rock 1	312	3	9	2	12.9	5.44
2014	Red Rock 1	312	3	9	3	26.3	5.83
2014	Red Rock 1	312	3	9	4	11.6	6.30
2014	Red Rock 1	401	4	2	1	40.7	5.08
2014	Red Rock 1	401	4	2	2	19.5	5.59

2014	Red Rock 1	401	4	2	3	11.0	5.78
2014	Red Rock 1	401	4	2	4	3.7	6.79
2014	Red Rock 1	402	4	4	1	18.2	5.38
2014	Red Rock 1	402	4	4	2	8.7	5.65
2014	Red Rock 1	402	4	4	3	4.8	5.57
2014	Red Rock 1	402	4	4	4	1.9	6.77
2014	Red Rock 1	403	4	9	1	40.2	5.11
2014	Red Rock 1	403	4	9	2	10.9	5.54
2014	Red Rock 1	403	4	9	3	7.6	5.58
2014	Red Rock 1	403	4	9	4	2.8	6.33
2014	Red Rock 1	404	4	7	1	33.2	5.21
2014	Red Rock 1	404	4	7	2	20.2	5.54
2014	Red Rock 1	404	4	7	3	8.1	5.65
2014	Red Rock 1	404	4	7	4	2.9	6.33
2014	Red Rock 1	405	4	3	1	57.2	5.06
2014	Red Rock 1	405	4	3	2	12.9	5.41
2014	Red Rock 1	405	4	3	3	7.0	5.91
2014	Red Rock 1	405	4	3	4	2.5	6.45
2014	Red Rock 1	406	4	10	1	18.1	4.96
2014	Red Rock 1	406	4	10	2	9.2	5.59
2014	Red Rock 1	406	4	10	3	5.3	5.88
2014	Red Rock 1	406	4	10	4	5.5	6.59
2014	Red Rock 1	407	4	11	1	23.4	5.08

2014	Red Rock 1	407	4	11	2	11.1	5.21
2014	Red Rock 1	407	4	11	3	6.9	5.71
2014	Red Rock 1	407	4	11	4	3.6	6.08
2014	Red Rock 1	408	4	12	1	22.5	4.97
2014	Red Rock 1	408	4	12	2	14.4	5.34
2014	Red Rock 1	408	4	12	3	7.0	5.76
2014	Red Rock 1	408	4	12	4	3.9	6.59
2014	Red Rock 1	409	4	1	1	20.5	5.11
2014	Red Rock 1	409	4	1	2	13.7	5.20
2014	Red Rock 1	409	4	1	3	8.4	5.68
2014	Red Rock 1	409	4	1	4	3.5	6.06
2014	Red Rock 1	410	4	6	1	19.4	5.30
2014	Red Rock 1	410	4	6	2	17.1	5.69
2014	Red Rock 1	410	4	6	3	6.7	5.90
2014	Red Rock 1	410	4	6	4	2.3	6.74
2014	Red Rock 1	411	4	8	1	27.8	5.06
2014	Red Rock 1	411	4	8	2	14.1	5.49
2014	Red Rock 1	411	4	8	3	6.9	5.90
2014	Red Rock 1	411	4	8	4	3.1	6.50
2014	Red Rock 1	412	4	5	1	35.6	5.28
2014	Red Rock 1	412	4	5	2	14.9	5.46
2014	Red Rock 1	412	4	5	3	7.5	5.74
2014	Red Rock 1	412	4	5	4	5.7	6.19

2014	Red Rock 2	101	1	3	1	38.9	4.56
2014	Red Rock 2	101	1	3	2	25.2	4.74
2014	Red Rock 2	101	1	3	3	12.3	5.01
2014	Red Rock 2	101	1	3	4	3.2	5.64
2014	Red Rock 2	102	1	11	1	44.8	5.08
2014	Red Rock 2	102	1	11	2	16.2	5.33
2014	Red Rock 2	102	1	11	3	8.8	4.56
2014	Red Rock 2	102	1	11	4	2.9	5.92
2014	Red Rock 2	103	1	8	1	41.8	5.26
2014	Red Rock 2	103	1	8	2	18.2	5.01
2014	Red Rock 2	103	1	8	3	7.9	5.17
2014	Red Rock 2	103	1	8	4	2.5	6.10
2014	Red Rock 2	104	1	12	1	40.4	5.08
2014	Red Rock 2	104	1	12	2	18.9	5.11
2014	Red Rock 2	104	1	12	3	9.0	5.40
2014	Red Rock 2	104	1	12	4	2.9	6.20
2014	Red Rock 2	105	1	1	1	38.7	4.96
2014	Red Rock 2	105	1	1	2	17.3	5.18
2014	Red Rock 2	105	1	1	3	9.2	5.23
2014	Red Rock 2	105	1	1	4	2.9	6.70
2014	Red Rock 2	106	1	6	1	47.7	5.11
2014	Red Rock 2	106	1	6	2	17.7	5.00
2014	Red Rock 2	106	1	6	3	7.6	4.82

2014	Red Rock 2	106	1	6	4	2.5	6.22
2014	Red Rock 2	107	1	4	1	34.7	5.13
2014	Red Rock 2	107	1	4	2	16.8	4.70
2014	Red Rock 2	107	1	4	3	7.6	5.34
2014	Red Rock 2	107	1	4	4	2.8	5.76
2014	Red Rock 2	108	1	5	1	31.1	5.21
2014	Red Rock 2	108	1	5	2	15.1	5.37
2014	Red Rock 2	108	1	5	3	7.7	5.38
2014	Red Rock 2	108	1	5	4	2.9	5.99
2014	Red Rock 2	109	1	9	1	33.9	5.06
2014	Red Rock 2	109	1	9	2	18.2	5.00
2014	Red Rock 2	109	1	9	3	10.9	4.51
2014	Red Rock 2	109	1	9	4	3.1	6.27
2014	Red Rock 2	110	1	10	1	32.7	5.20
2014	Red Rock 2	110	1	10	2	13.8	4.73
2014	Red Rock 2	110	1	10	3	8.3	5.48
2014	Red Rock 2	110	1	10	4	3.7	5.94
2014	Red Rock 2	111	1	2	1	38.3	5.11
2014	Red Rock 2	111	1	2	2	19.0	4.51
2014	Red Rock 2	111	1	2	3	8.9	5.32
2014	Red Rock 2	111	1	2	4	3.0	5.58
2014	Red Rock 2	112	1	7	1	32.8	5.42
2014	Red Rock 2	112	1	7	2	21.0	5.39

2014	Red Rock 2	112	1	7	3	11.5	5.54
2014	Red Rock 2	112	1	7	4	2.7	5.76
2014	Red Rock 2	201	2	11	1	45.4	5.09
2014	Red Rock 2	201	2	11	2	22.5	5.20
2014	Red Rock 2	201	2	11	3	8.0	4.89
2014	Red Rock 2	201	2	11	4	3.0	6.07
2014	Red Rock 2	202	2	5	1	43.6	5.12
2014	Red Rock 2	202	2	5	2	14.9	5.26
2014	Red Rock 2	202	2	5	3	7.7	5.37
2014	Red Rock 2	202	2	5	4	2.4	6.39
2014	Red Rock 2	203	2	3	1	44.9	5.00
2014	Red Rock 2	203	2	3	2	20.6	5.14
2014	Red Rock 2	203	2	3	3	9.7	5.36
2014	Red Rock 2	203	2	3	4	3.1	6.81
2014	Red Rock 2	204	2	1	1	38.5	5.14
2014	Red Rock 2	204	2	1	2	21.2	5.16
2014	Red Rock 2	204	2	1	3	9.3	5.18
2014	Red Rock 2	204	2	1	4	2.8	5.23
2014	Red Rock 2	205	2	4	1	33.5	5.29
2014	Red Rock 2	205	2	4	2	20.2	5.14
2014	Red Rock 2	205	2	4	3	9.4	5.18
2014	Red Rock 2	205	2	4	4	2.9	5.99
2014	Red Rock 2	206	2	10	1	43.4	5.01

2014	Red Rock 2	206	2	10	2	22.6	5.10
2014	Red Rock 2	206	2	10	3	8.2	5.13
2014	Red Rock 2	206	2	10	4	2.0	6.24
2014	Red Rock 2	207	2	7	1	36.8	5.29
2014	Red Rock 2	207	2	7	2	15.8	5.02
2014	Red Rock 2	207	2	7	3	10.6	5.19
2014	Red Rock 2	207	2	7	4	2.3	5.92
2014	Red Rock 2	208	2	12	1	38.2	5.10
2014	Red Rock 2	208	2	12	2	19.0	5.25
2014	Red Rock 2	208	2	12	3	10.3	4.82
2014	Red Rock 2	208	2	12	4	4.9	6.37
2014	Red Rock 2	209	2	9	1	33.2	4.77
2014	Red Rock 2	209	2	9	2	16.2	5.12
2014	Red Rock 2	209	2	9	3	7.6	5.25
2014	Red Rock 2	209	2	9	4	2.3	6.23
2014	Red Rock 2	210	2	6	1	44.4	5.25
2014	Red Rock 2	210	2	6	2	16.8	5.30
2014	Red Rock 2	210	2	6	3	10.3	5.50
2014	Red Rock 2	210	2	6	4	2.3	6.00
2014	Red Rock 2	211	2	2	1	36.3	4.92
2014	Red Rock 2	211	2	2	2	18.6	4.50
2014	Red Rock 2	211	2	2	3	10.3	6.01
2014	Red Rock 2	211	2	2	4	2.7	5.02

2014	Red Rock 2	212	2	8	1	42.8	4.84
2014	Red Rock 2	212	2	8	2	23.7	4.40
2014	Red Rock 2	212	2	8	3	15.2	5.10
2014	Red Rock 2	212	2	8	4	4.8	5.76
2014	Red Rock 2	301	3	11	1	52.5	5.14
2014	Red Rock 2	301	3	11	2	32.4	5.20
2014	Red Rock 2	301	3	11	3	23.8	5.22
2014	Red Rock 2	301	3	11	4	6.5	6.61
2014	Red Rock 2	302	3	12	1	41.0	5.10
2014	Red Rock 2	302	3	12	2	18.8	5.02
2014	Red Rock 2	302	3	12	3	10.9	5.39
2014	Red Rock 2	302	3	12	4	2.6	6.23
2014	Red Rock 2	303	3	10	1	43.7	5.20
2014	Red Rock 2	303	3	10	2	9.6	5.77
2014	Red Rock 2	303	3	10	3	6.5	5.98
2014	Red Rock 2	303	3	10	4	2.6	7.08
2014	Red Rock 2	304	3	6	1	34.1	5.12
2014	Red Rock 2	304	3	6	2	18.4	5.33
2014	Red Rock 2	304	3	6	3	8.1	5.03
2014	Red Rock 2	304	3	6	4	2.2	6.27
2014	Red Rock 2	305	3	2	1	49.2	5.16
2014	Red Rock 2	305	3	2	2	15.6	5.19
2014	Red Rock 2	305	3	2	3	7.7	4.50

2014	Red Rock 2	305	3	2	4	2.3	5.82
2014	Red Rock 2	306	3	7	1	55.4	5.13
2014	Red Rock 2	306	3	7	2	22.9	5.10
2014	Red Rock 2	306	3	7	3	11.4	5.23
2014	Red Rock 2	306	3	7	4	3.4	6.09
2014	Red Rock 2	307	3	3	1	46.0	5.15
2014	Red Rock 2	307	3	3	2	16.5	5.34
2014	Red Rock 2	307	3	3	3	9.0	5.46
2014	Red Rock 2	307	3	3	4	2.9	5.88
2014	Red Rock 2	308	3	9	1	37.1	5.03
2014	Red Rock 2	308	3	9	2	18.9	5.11
2014	Red Rock 2	308	3	9	3	8.7	4.83
2014	Red Rock 2	308	3	9	4	2.4	6.56
2014	Red Rock 2	309	3	5	1	42.0	5.15
2014	Red Rock 2	309	3	5	2	23.5	5.22
2014	Red Rock 2	309	3	5	3	11.4	5.51
2014	Red Rock 2	309	3	5	4	2.9	6.17
2014	Red Rock 2	310	3	8	1	41.3	4.92
2014	Red Rock 2	310	3	8	2	19.7	4.89
2014	Red Rock 2	310	3	8	3	8.3	5.25
2014	Red Rock 2	310	3	8	4	2.3	5.82
2014	Red Rock 2	311	3	4	1	33.0	4.83
2014	Red Rock 2	311	3	4	2	19.0	5.13

2014	Red Rock 2	311	3	4	3	8.7	5.45
2014	Red Rock 2	311	3	4	4	2.5	5.87
2014	Red Rock 2	312	3	1	1	47.5	5.08
2014	Red Rock 2	312	3	1	2	26.1	5.16
2014	Red Rock 2	312	3	1	3	14.4	5.13
2014	Red Rock 2	312	3	1	4	3.0	5.70
2014	Red Rock 2	401	4	2	1	52.8	5.57
2014	Red Rock 2	401	4	2	2	23.4	5.22
2014	Red Rock 2	401	4	2	3	12.0	5.19
2014	Red Rock 2	401	4	2	4	3.9	6.39
2014	Red Rock 2	402	4	4	1	48.5	5.69
2014	Red Rock 2	402	4	4	2	19.1	5.26
2014	Red Rock 2	402	4	4	3	8.4	4.80
2014	Red Rock 2	402	4	4	4	2.6	5.28
2014	Red Rock 2	403	4	9	1	1.8	4.75
2014	Red Rock 2	403	4	9	2	4.9	6.98
2014	Red Rock 2	403	4	9	3	14.8	5.71
2014	Red Rock 2	403	4	9	4	38.6	5.30
2014	Red Rock 2	404	4	7	1	37.8	5.24
2014	Red Rock 2	404	4	7	2	17.4	6.14
2014	Red Rock 2	404	4	7	3	7.9	5.30
2014	Red Rock 2	404	4	7	4	2.2	5.24
2014	Red Rock 2	405	4	6	1	29.2	6.65

2014	Red Rock 2	405	4	6	2	19.1	5.52
2014	Red Rock 2	405	4	6	3	8.6	5.26
2014	Red Rock 2	405	4	6	4	2.8	5.04
2014	Red Rock 2	406	4	8	1	30.6	6.33
2014	Red Rock 2	406	4	8	2	17.7	6.19
2014	Red Rock 2	406	4	8	3	11.4	5.42
2014	Red Rock 2	406	4	8	4	2.8	5.31
2014	Red Rock 2	407	4	11	1	45.1	5.35
2014	Red Rock 2	407	4	11	2	19.5	5.40
2014	Red Rock 2	407	4	11	3	8.9	5.26
2014	Red Rock 2	407	4	11	4	2.1	5.52
2014	Red Rock 2	408	4	5	1	36.5	5.41
2014	Red Rock 2	408	4	5	2	13.3	5.48
2014	Red Rock 2	408	4	5	3	6.1	5.51
2014	Red Rock 2	408	4	5	4	1.9	6.56
2014	Red Rock 2	409	4	3	1	52.2	4.86
2014	Red Rock 2	409	4	3	2	15.7	5.07
2014	Red Rock 2	409	4	3	3	7.9	5.51
2014	Red Rock 2	409	4	3	4	2.7	5.96
2014	Red Rock 2	410	4	1	1	38.8	5.18
2014	Red Rock 2	410	4	1	2	20.8	5.14
2014	Red Rock 2	410	4	1	3	10.5	5.28
2014	Red Rock 2	410	4	1	4	2.2	5.90

2014	Red Rock 2	411	4	12	1	34.0	4.92
2014	Red Rock 2	411	4	12	2	15.6	4.87
2014	Red Rock 2	411	4	12	3	7.9	5.05
2014	Red Rock 2	411	4	12	4	2.1	6.17
2014	Red Rock 2	412	4	10	1	2.4	5.13
2014	Red Rock 2	412	4	10	2	43.9	4.83
2014	Red Rock 2	412	4	10	3	9.3	5.32
2014	Red Rock 2	412	4	10	4	17.5	5.56
2014	Red Rock 3	101	1	3	1	38.4	5.21
2014	Red Rock 3	101	1	3	2	21.4	5.43
2014	Red Rock 3	101	1	3	3	10.0	5.81
2014	Red Rock 3	101	1	3	4	4.1	7.22
2014	Red Rock 3	102	1	11	1	40.0	5.62
2014	Red Rock 3	102	1	11	2	24.1	5.79
2014	Red Rock 3	102	1	11	3	10.3	5.81
2014	Red Rock 3	102	1	11	4	3.4	7.40
2014	Red Rock 3	103	1	8	1	37.4	5.81
2014	Red Rock 3	103	1	8	2	30.8	5.74
2014	Red Rock 3	103	1	8	3	15.1	5.97
2014	Red Rock 3	103	1	8	4	4.2	7.30
2014	Red Rock 3	104	1	12	1	44.1	5.94
2014	Red Rock 3	104	1	12	2	22.2	5.69
2014	Red Rock 3	104	1	12	3	7.0	5.88

2014	Red Rock 3	104	1	12	4	3.7	7.40
2014	Red Rock 3	105	1	1	1	45.8	5.91
2014	Red Rock 3	105	1	1	2	30.9	5.71
2014	Red Rock 3	105	1	1	3	18.5	6.00
2014	Red Rock 3	105	1	1	4	5.1	7.24
2014	Red Rock 3	106	1	6	1	41.1	5.59
2014	Red Rock 3	106	1	6	2	25.6	5.70
2014	Red Rock 3	106	1	6	3	12.5	5.91
2014	Red Rock 3	106	1	6	4	3.3	5.95
2014	Red Rock 3	107	1	4	1	37.6	5.88
2014	Red Rock 3	107	1	4	2	28.4	5.75
2014	Red Rock 3	107	1	4	3	14.7	6.02
2014	Red Rock 3	107	1	4	4	3.9	7.66
2014	Red Rock 3	108	1	5	1	49.8	6.11
2014	Red Rock 3	108	1	5	2	27.7	5.92
2014	Red Rock 3	108	1	5	3	7.7	6.30
2014	Red Rock 3	108	1	5	4	3.2	6.88
2014	Red Rock 3	109	1	9	1	53.2	5.95
2014	Red Rock 3	109	1	9	2	26.5	5.60
2014	Red Rock 3	109	1	9	3	8.7	5.64
2014	Red Rock 3	109	1	9	4	3.4	7.21
2014	Red Rock 3	110	1	10	1	54.5	5.82
2014	Red Rock 3	110	1	10	2	26.5	5.89

2014	Red Rock 3	110	1	10	3	12.9	6.18
2014	Red Rock 3	110	1	10	4	4.0	7.08
2014	Red Rock 3	111	1	2	1	50.5	5.96
2014	Red Rock 3	111	1	2	2	26.0	5.86
2014	Red Rock 3	111	1	2	3	7.2	6.32
2014	Red Rock 3	111	1	2	4	3.2	7.27
2014	Red Rock 3	112	1	7	1	47.4	5.95
2014	Red Rock 3	112	1	7	2	36.4	5.62
2014	Red Rock 3	112	1	7	3	12.5	5.96
2014	Red Rock 3	112	1	7	4	4.1	7.02
2014	Red Rock 3	201	2	11	1	41.2	6.21
2014	Red Rock 3	201	2	11	2	21.3	5.95
2014	Red Rock 3	201	2	11	3	9.7	6.08
2014	Red Rock 3	201	2	11	4	5.2	7.07
2014	Red Rock 3	202	2	5	1	38.1	5.52
2014	Red Rock 3	202	2	5	2	25.3	5.80
2014	Red Rock 3	202	2	5	3	12.6	6.44
2014	Red Rock 3	202	2	5	4	5.5	7.26
2014	Red Rock 3	203	2	3	1	40.8	5.87
2014	Red Rock 3	203	2	3	2	27.3	5.56
2014	Red Rock 3	203	2	3	3	16.7	6.19
2014	Red Rock 3	203	2	3	4	5.6	7.38
2014	Red Rock 3	204	2	1	1	45.4	5.87

2014	Red Rock 3	204	2	1	2	25.9	5.99
2014	Red Rock 3	204	2	1	3	13.1	6.41
2014	Red Rock 3	204	2	1	4	5.2	7.24
2014	Red Rock 3	205	2	4	1	51.1	5.86
2014	Red Rock 3	205	2	4	2	36.5	5.79
2014	Red Rock 3	205	2	4	3	19.4	5.84
2014	Red Rock 3	205	2	4	4	5.5	6.17
2014	Red Rock 3	206	2	10	1	47.6	5.86
2014	Red Rock 3	206	2	10	2	32.9	5.93
2014	Red Rock 3	206	2	10	3	16.7	6.10
2014	Red Rock 3	206	2	10	4	4.5	6.94
2014	Red Rock 3	207	2	7	1	42.6	5.92
2014	Red Rock 3	207	2	7	2	29.9	5.90
2014	Red Rock 3	207	2	7	3	15.2	6.00
2014	Red Rock 3	207	2	7	4	4.7	6.75
2014	Red Rock 3	208	2	12	1	58.5	6.16
2014	Red Rock 3	208	2	12	2	31.9	6.02
2014	Red Rock 3	208	2	12	3	12.0	6.13
2014	Red Rock 3	208	2	12	4	4.0	7.05
2014	Red Rock 3	209	2	9	1	52.7	6.06
2014	Red Rock 3	209	2	9	2	26.7	5.97
2014	Red Rock 3	209	2	9	3	10.7	5.95
2014	Red Rock 3	209	2	9	4	3.8	7.03

2014	Red Rock 3	210	2	6	1	59.1	5.74
2014	Red Rock 3	210	2	6	2	32.0	6.25
2014	Red Rock 3	210	2	6	3	11.1	6.50
2014	Red Rock 3	210	2	6	4	3.6	7.76
2014	Red Rock 3	211	2	2	1	48.3	6.07
2014	Red Rock 3	211	2	2	2	23.0	6.03
2014	Red Rock 3	211	2	2	3	10.7	6.11
2014	Red Rock 3	211	2	2	4	3.5	6.97
2014	Red Rock 3	212	2	8	1	47.9	6.12
2014	Red Rock 3	212	2	8	2	27.0	6.17
2014	Red Rock 3	212	2	8	3	9.4	6.55
2014	Red Rock 3	212	2	8	4	3.9	7.15
2014	Red Rock 3	301	3	11	1	39.9	5.65
2014	Red Rock 3	301	3	11	2	27.9	5.97
2014	Red Rock 3	301	3	11	3	17.0	5.95
2014	Red Rock 3	301	3	11	4	3.9	6.77
2014	Red Rock 3	302	3	12	1	39.9	5.90
2014	Red Rock 3	302	3	12	2	27.8	6.09
2014	Red Rock 3	302	3	12	3	14.4	6.37
2014	Red Rock 3	302	3	12	4	6.3	6.93
2014	Red Rock 3	303	3	10	1	42.8	6.05
2014	Red Rock 3	303	3	10	2	26.9	5.86
2014	Red Rock 3	303	3	10	3	14.0	6.04

2014	Red Rock 3	303	3	10	4	5.0	6.79
2014	Red Rock 3	304	3	6	1	54.1	5.84
2014	Red Rock 3	304	3	6	2	34.0	5.63
2014	Red Rock 3	304	3	6	3	20.0	5.98
2014	Red Rock 3	304	3	6	4	6.6	6.53
2014	Red Rock 3	305	3	2	1	52.0	5.73
2014	Red Rock 3	305	3	2	2	39.2	5.79
2014	Red Rock 3	305	3	2	3	20.5	5.75
2014	Red Rock 3	305	3	2	4	9.3	6.73
2014	Red Rock 3	306	3	7	1	51.2	5.60
2014	Red Rock 3	306	3	7	2	39.5	5.71
2014	Red Rock 3	306	3	7	3	12.8	5.80
2014	Red Rock 3	306	3	7	4	4.0	7.33
2014	Red Rock 3	307	3	3	1	45.9	5.71
2014	Red Rock 3	307	3	3	2	35.2	5.77
2014	Red Rock 3	307	3	3	3	17.9	5.74
2014	Red Rock 3	307	3	3	4	4.2	6.81
2014	Red Rock 3	308	3	9	1	53.1	5.82
2014	Red Rock 3	308	3	9	2	30.9	5.87
2014	Red Rock 3	308	3	9	3	7.4	6.29
2014	Red Rock 3	308	3	9	4	3.3	5.65
2014	Red Rock 3	309	3	5	1	57.1	5.96
2014	Red Rock 3	309	3	5	2	33.5	7.55

2014	Red Rock 3	309	3	5	3	10.5	6.07
2014	Red Rock 3	309	3	5	4	3.6	5.83
2014	Red Rock 3	310	3	8	1	47.7	6.06
2014	Red Rock 3	310	3	8	2	25.1	6.01
2014	Red Rock 3	310	3	8	3	11.1	6.08
2014	Red Rock 3	310	3	8	4	4.0	7.34
2014	Red Rock 3	311	3	4	1	44.8	6.05
2014	Red Rock 3	311	3	4	2	24.3	6.07
2014	Red Rock 3	311	3	4	3	8.6	6.34
2014	Red Rock 3	311	3	4	4	4.7	7.55
2014	Red Rock 3	312	3	1	1	42.9	5.94
2014	Red Rock 3	312	3	1	2	27.1	6.05
2014	Red Rock 3	312	3	1	3	10.3	6.16
2014	Red Rock 3	312	3	1	4	4.2	7.26
2014	Red Rock 3	401	4	2	1	40.7	5.84
2014	Red Rock 3	401	4	2	2	21.7	5.98
2014	Red Rock 3	401	4	2	3	9.6	6.02
2014	Red Rock 3	401	4	2	4	3.7	6.53
2014	Red Rock 3	402	4	4	1	50.0	5.75
2014	Red Rock 3	402	4	4	2	27.8	5.70
2014	Red Rock 3	402	4	4	3	14.9	6.03
2014	Red Rock 3	402	4	4	4	3.3	6.90
2014	Red Rock 3	403	4	9	1	46.0	5.76

2014	Red Rock 3	403	4	9	2	29.2	5.88
2014	Red Rock 3	403	4	9	3	15.6	5.94
2014	Red Rock 3	403	4	9	4	5.6	6.87
2014	Red Rock 3	404	4	7	1	52.2	5.68
2014	Red Rock 3	404	4	7	2	39.2	5.65
2014	Red Rock 3	404	4	7	3	19.7	6.19
2014	Red Rock 3	404	4	7	4	8.1	7.17
2014	Red Rock 3	405	4	6	1	54.3	5.82
2014	Red Rock 3	405	4	6	2	33.4	5.60
2014	Red Rock 3	405	4	6	3	17.0	5.83
2014	Red Rock 3	405	4	6	4	4.4	7.20
2014	Red Rock 3	406	4	8	1	50.1	5.77
2014	Red Rock 3	406	4	8	2	35.3	6.24
2014	Red Rock 3	406	4	8	3	16.8	6.04
2014	Red Rock 3	406	4	8	4	4.8	6.76
2014	Red Rock 3	407	4	11	1	49.0	5.97
2014	Red Rock 3	407	4	11	2	34.1	5.95
2014	Red Rock 3	407	4	11	3	14.4	6.04
2014	Red Rock 3	407	4	11	4	4.6	7.28
2014	Red Rock 3	408	4	5	1	42.5	5.90
2014	Red Rock 3	408	4	5	2	28.8	6.22
2014	Red Rock 3	408	4	5	3	11.4	6.41
2014	Red Rock 3	408	4	5	4	3.6	7.07

2014	Red Rock 3	409	4	3	1	45.8	5.92
2014	Red Rock 3	409	4	3	2	33.3	5.98
2014	Red Rock 3	409	4	3	3	16.3	6.24
2014	Red Rock 3	409	4	3	4	4.0	7.27
2014	Red Rock 3	410	4	1	1	45.5	5.89
2014	Red Rock 3	410	4	1	2	25.2	5.97
2014	Red Rock 3	410	4	1	3	11.5	6.13
2014	Red Rock 3	410	4	1	4	4.0	7.15
2014	Red Rock 3	411	4	12	1	45.2	6.07
2014	Red Rock 3	411	4	12	2	22.8	6.06
2014	Red Rock 3	411	4	12	3	10.2	6.18
2014	Red Rock 3	411	4	12	4	4.0	6.97
2014	Red Rock 3	412	4	10	1	48.4	5.81
2014	Red Rock 3	412	4	10	2	33.6	6.02
2014	Red Rock 3	412	4	10	3	15.5	6.32
2014	Red Rock 3	412	4	10	4	4.6	7.05
2014	Waukomis 1	101	1	7	1	51.7	4.85
2014	Waukomis 1	101	1	7	2	43.9	4.87
2014	Waukomis 1	101	1	7	3	35.8	5.19
2014	Waukomis 1	101	1	7	4	8.5	6.98
2014	Waukomis 1	102	1	1	1	75.8	4.74
2014	Waukomis 1	102	1	1	2	39.3	4.63
2014	Waukomis 1	102	1	1	3	26.5	4.81

2014	Waukomis 1	102	1	1	4	9.2	5.85
2014	Waukomis 1	103	1	6	1	60.4	4.59
2014	Waukomis 1	103	1	6	2	37.6	4.80
2014	Waukomis 1	103	1	6	3	32.6	4.96
2014	Waukomis 1	103	1	6	4	8.6	7.20
2014	Waukomis 1	104	1	12	1	54.8	4.79
2014	Waukomis 1	104	1	12	2	40.3	4.72
2014	Waukomis 1	104	1	12	3	36.8	5.02
2014	Waukomis 1	104	1	12	4	6.9	6.41
2014	Waukomis 1	105	1	8	1	95.5	4.82
2014	Waukomis 1	105	1	8	2	52.7	4.83
2014	Waukomis 1	105	1	8	3	33.4	5.09
2014	Waukomis 1	105	1	8	4	5.0	7.27
2014	Waukomis 1	106	1	2	1	45.6	4.82
2014	Waukomis 1	106	1	2	2	41.9	5.04
2014	Waukomis 1	106	1	2	3	24.4	5.07
2014	Waukomis 1	106	1	2	4	4.0	7.00
2014	Waukomis 1	107	1	9	1	58.4	4.73
2014	Waukomis 1	107	1	9	2	41.2	4.67
2014	Waukomis 1	107	1	9	3	24.9	5.23
2014	Waukomis 1	107	1	9	4	5.0	7.05
2014	Waukomis 1	108	1	5	1	53.8	4.84
2014	Waukomis 1	108	1	5	2	42.0	4.99

2014	Waukomis 1	108	1	5	3	28.1	5.39
2014	Waukomis 1	108	1	5	4	5.2	7.64
2014	Waukomis 1	109	1	10	1	58.0	4.93
2014	Waukomis 1	109	1	10	2	42.4	4.90
2014	Waukomis 1	109	1	10	3	24.2	5.72
2014	Waukomis 1	109	1	10	4	4.4	7.49
2014	Waukomis 1	110	1	4	1	53.0	5.25
2014	Waukomis 1	110	1	4	2	38.2	4.99
2014	Waukomis 1	110	1	4	3	27.2	5.49
2014	Waukomis 1	110	1	4	4	5.9	7.56
2014	Waukomis 1	111	1	3	1	67.9	4.88
2014	Waukomis 1	111	1	3	2	34.4	5.40
2014	Waukomis 1	111	1	3	3	27.5	5.48
2014	Waukomis 1	111	1	3	4	6.6	7.57
2014	Waukomis 1	112	1	11	1	56.1	5.20
2014	Waukomis 1	112	1	11	2	38.4	5.20
2014	Waukomis 1	112	1	11	3	17.8	6.08
2014	Waukomis 1	112	1	11	4	4.4	7.99
2014	Waukomis 1	201	2	4	1	57.4	4.72
2014	Waukomis 1	201	2	4	2	47.5	4.60
2014	Waukomis 1	201	2	4	3	31.5	4.92
2014	Waukomis 1	201	2	4	4	8.9	5.59
2014	Waukomis 1	202	2	5	1	78.1	5.02

2014	Waukomis 1	202	2	5	2	50.0	4.96
2014	Waukomis 1	202	2	5	3	37.1	4.99
2014	Waukomis 1	202	2	5	4	13.9	6.31
2014	Waukomis 1	203	2	6	1	88.1	4.80
2014	Waukomis 1	203	2	6	2	51.3	4.77
2014	Waukomis 1	203	2	6	3	35.1	5.14
2014	Waukomis 1	203	2	6	4	7.3	6.73
2014	Waukomis 1	204	2	2	1	59.2	4.61
2014	Waukomis 1	204	2	2	2	38.4	4.96
2014	Waukomis 1	204	2	2	3	28.1	5.26
2014	Waukomis 1	204	2	2	4	7.1	7.00
2014	Waukomis 1	205	2	1	1	60.0	4.84
2014	Waukomis 1	205	2	1	2	40.0	4.96
2014	Waukomis 1	205	2	1	3	23.7	5.17
2014	Waukomis 1	205	2	1	4	4.9	7.36
2014	Waukomis 1	206	2	11	1	79.8	4.88
2014	Waukomis 1	206	2	11	2	45.8	4.87
2014	Waukomis 1	206	2	11	3	29.7	5.40
2014	Waukomis 1	206	2	11	4	4.6	7.42
2014	Waukomis 1	207	2	7	1	93.8	4.86
2014	Waukomis 1	207	2	7	2	41.7	4.96
2014	Waukomis 1	207	2	7	3	28.7	5.51
2014	Waukomis 1	207	2	7	4	5.0	7.35

2014	Waukomis 1	208	2	10	1	69.7	4.85
2014	Waukomis 1	208	2	10	2	35.4	5.00
2014	Waukomis 1	208	2	10	3	20.9	5.39
2014	Waukomis 1	208	2	10	4	4.1	7.39
2014	Waukomis 1	209	2	3	1	56.6	4.83
2014	Waukomis 1	209	2	3	2	36.4	4.81
2014	Waukomis 1	209	2	3	3	23.8	5.40
2014	Waukomis 1	209	2	3	4	6.5	7.27
2014	Waukomis 1	210	2	12	1	66.4	4.98
2014	Waukomis 1	210	2	12	2	36.6	4.88
2014	Waukomis 1	210	2	12	3	22.3	5.63
2014	Waukomis 1	210	2	12	4	3.7	7.48
2014	Waukomis 1	211	2	9	1	62.8	5.01
2014	Waukomis 1	211	2	9	2	39.7	4.74
2014	Waukomis 1	211	2	9	3	26.1	5.30
2014	Waukomis 1	211	2	9	4	4.0	7.31
2014	Waukomis 1	212	2	8	1	54.1	4.75
2014	Waukomis 1	212	2	8	2	32.5	5.08
2014	Waukomis 1	212	2	8	3	23.7	5.26
2014	Waukomis 1	212	2	8	4	4.3	7.76
2014	Waukomis 1	301	3	8	1	71.2	4.43
2014	Waukomis 1	301	3	8	2	55.1	4.58
2014	Waukomis 1	301	3	8	3	26.1	4.73

2014	Waukomis 1	301	3	8	4	6.1	5.88
2014	Waukomis 1	302	3	9	1	82.6	4.67
2014	Waukomis 1	302	3	9	2	57.3	4.89
2014	Waukomis 1	302	3	9	3	28.2	5.20
2014	Waukomis 1	302	3	9	4	6.0	6.68
2014	Waukomis 1	303	3	7	1	52.3	4.65
2014	Waukomis 1	303	3	7	2	52.2	4.84
2014	Waukomis 1	303	3	7	3	38.8	5.03
2014	Waukomis 1	303	3	7	4	8.9	6.79
2014	Waukomis 1	304	3	2	1	63.7	5.12
2014	Waukomis 1	304	3	2	2	51.2	4.90
2014	Waukomis 1	304	3	2	3	29.1	5.27
2014	Waukomis 1	304	3	2	4	5.4	7.15
2014	Waukomis 1	305	3	4	1	82.7	4.95
2014	Waukomis 1	305	3	4	2	35.6	4.93
2014	Waukomis 1	305	3	4	3	21.9	5.22
2014	Waukomis 1	305	3	4	4	5.8	6.64
2014	Waukomis 1	306	3	10	1	50.9	4.89
2014	Waukomis 1	306	3	10	2	39.7	4.94
2014	Waukomis 1	306	3	10	3	27.4	5.21
2014	Waukomis 1	306	3	10	4	4.9	7.21
2014	Waukomis 1	307	3	12	1	56.1	4.94
2014	Waukomis 1	307	3	12	2	41.5	4.93

2014	Waukomis 1	307	3	12	3	28.6	5.30
2014	Waukomis 1	307	3	12	4	5.6	7.03
2014	Waukomis 1	308	3	6	1	50.1	5.08
2014	Waukomis 1	308	3	6	2	38.3	4.79
2014	Waukomis 1	308	3	6	3	23.4	5.76
2014	Waukomis 1	308	3	6	4	5.6	7.13
2014	Waukomis 1	309	3	11	1	88.6	4.83
2014	Waukomis 1	309	3	11	2	40.2	4.99
2014	Waukomis 1	309	3	11	3	28.3	5.43
2014	Waukomis 1	309	3	11	4	5.5	7.16
2014	Waukomis 1	310	3	5	1	57.5	5.09
2014	Waukomis 1	310	3	5	2	28.4	5.27
2014	Waukomis 1	310	3	5	3	21.6	7.01
2014	Waukomis 1	310	3	5	4	5.7	4.69
2014	Waukomis 1	311	3	1	1	60.1	5.06
2014	Waukomis 1	311	3	1	2	32.8	5.45
2014	Waukomis 1	311	3	1	3	21.8	5.51
2014	Waukomis 1	311	3	1	4	3.5	7.47
2014	Waukomis 1	312	3	3	1	68.3	4.91
2014	Waukomis 1	312	3	3	2	36.5	5.04
2014	Waukomis 1	312	3	3	3	20.4	5.43
2014	Waukomis 1	312	3	3	4	4.0	7.14
2014	Waukomis 1	401	4	6	1	79.5	4.70

2014	Waukomis 1	401	4	6	2	63.1	4.76
2014	Waukomis 1	401	4	6	3	33.7	5.21
2014	Waukomis 1	401	4	6	4	8.3	6.88
2014	Waukomis 1	402	4	4	1	71.1	4.88
2014	Waukomis 1	402	4	4	2	51.8	4.90
2014	Waukomis 1	402	4	4	3	36.8	5.02
2014	Waukomis 1	402	4	4	4	10.4	6.71
2014	Waukomis 1	403	4	2	1	46.1	5.02
2014	Waukomis 1	403	4	2	2	49.6	4.84
2014	Waukomis 1	403	4	2	3	26.0	5.02
2014	Waukomis 1	403	4	2	4	6.3	6.90
2014	Waukomis 1	404	4	11	1	45.1	4.87
2014	Waukomis 1	404	4	11	2	36.2	4.62
2014	Waukomis 1	404	4	11	3	22.2	6.65
2014	Waukomis 1	404	4	11	4	5.4	6.52
2014	Waukomis 1	405	4	3	1	61.6	4.83
2014	Waukomis 1	405	4	3	2	44.6	4.60
2014	Waukomis 1	405	4	3	3	21.7	4.86
2014	Waukomis 1	405	4	3	4	5.0	6.48
2014	Waukomis 1	406	4	7	1	49.7	4.86
2014	Waukomis 1	406	4	7	2	30.9	4.90
2014	Waukomis 1	406	4	7	3	19.9	5.20
2014	Waukomis 1	406	4	7	4	5.2	7.02

2014	Waukomis 1	407	4	8	1	59.9	5.26
2014	Waukomis 1	407	4	8	2	34.7	5.01
2014	Waukomis 1	407	4	8	3	27.7	5.40
2014	Waukomis 1	407	4	8	4	8.9	7.11
2014	Waukomis 1	408	4	9	1	42.9	4.99
2014	Waukomis 1	408	4	9	2	29.7	5.01
2014	Waukomis 1	408	4	9	3	21.2	5.32
2014	Waukomis 1	408	4	9	4	5.5	7.38
2014	Waukomis 1	409	4	5	1	69.2	5.12
2014	Waukomis 1	409	4	5	2	37.2	5.03
2014	Waukomis 1	409	4	5	3	21.7	5.32
2014	Waukomis 1	409	4	5	4	7.1	6.54
2014	Waukomis 1	410	4	10	1	44.0	5.39
2014	Waukomis 1	410	4	10	2	33.2	5.18
2014	Waukomis 1	410	4	10	3	20.3	5.31
2014	Waukomis 1	410	4	10	4	5.3	7.28
2014	Waukomis 1	411	4	1	1	68.5	5.21
2014	Waukomis 1	411	4	1	2	30.8	4.88
2014	Waukomis 1	411	4	1	3	25.1	5.47
2014	Waukomis 1	411	4	1	4	6.3	7.47
2014	Waukomis 1	412	4	12	1	50.1	5.34
2014	Waukomis 1	412	4	12	2	30.8	7.68
2014	Waukomis 1	412	4	12	3	23.7	5.22

2014	Waukomis 1	412	4	12	4	4.6	5.54
2014	Waukomis 2	101	1	11	1	37.1	6.08
2014	Waukomis 2	101	1	11	2	30.6	5.55
2014	Waukomis 2	101	1	11	3	22.4	5.65
2014	Waukomis 2	101	1	11	4	14.9	6.61
2014	Waukomis 2	102	1	7	1	26.5	5.95
2014	Waukomis 2	102	1	7	2	22.0	5.80
2014	Waukomis 2	102	1	7	3	18.6	5.75
2014	Waukomis 2	102	1	7	4	10.3	6.96
2014	Waukomis 2	103	1	10	1	26.4	6.07
2014	Waukomis 2	103	1	10	2	21.8	5.88
2014	Waukomis 2	103	1	10	3	17.3	5.91
2014	Waukomis 2	103	1	10	4	9.4	7.27
2014	Waukomis 2	104	1	5	1	22.3	6.35
2014	Waukomis 2	104	1	5	2	23.8	6.19
2014	Waukomis 2	104	1	5	3	23.0	6.65
2014	Waukomis 2	104	1	5	4	7.9	7.81
2014	Waukomis 2	105	1	4	1	23.4	6.73
2014	Waukomis 2	105	1	4	2	19.2	6.33
2014	Waukomis 2	105	1	4	3	21.9	6.43
2014	Waukomis 2	105	1	4	4	9.3	7.36
2014	Waukomis 2	106	1	6	1	22.6	7.05
2014	Waukomis 2	106	1	6	2	21.3	6.29

2014	Waukomis 2	106	1	6	3	19.2	6.74
2014	Waukomis 2	106	1	6	4	8.3	7.49
2014	Waukomis 2	107	1	12	1	25.0	6.57
2014	Waukomis 2	107	1	12	2	24.8	6.61
2014	Waukomis 2	107	1	12	3	19.9	6.63
2014	Waukomis 2	107	1	12	4	8.0	7.57
2014	Waukomis 2	108	1	2	1	24.2	6.58
2014	Waukomis 2	108	1	2	2	26.8	6.02
2014	Waukomis 2	108	1	2	3	20.3	6.47
2014	Waukomis 2	108	1	2	4	12.3	7.48
2014	Waukomis 2	109	1	3	1	23.7	6.15
2014	Waukomis 2	109	1	3	2	24.4	5.33
2014	Waukomis 2	109	1	3	3	18.5	5.58
2014	Waukomis 2	109	1	3	4	7.7	6.63
2014	Waukomis 2	110	1	9	1	24.8	5.95
2014	Waukomis 2	110	1	9	2	22.2	5.73
2014	Waukomis 2	110	1	9	3	19.4	6.06
2014	Waukomis 2	110	1	9	4	8.1	6.72
2014	Waukomis 2	111	1	8	1	23.0	6.08
2014	Waukomis 2	111	1	8	2	18.3	5.52
2014	Waukomis 2	111	1	8	3	17.4	6.02
2014	Waukomis 2	111	1	8	4	8.7	6.83
2014	Waukomis 2	112	1	1	1	25.2	5.96

2014	Waukomis 2	112	1	1	2	24.2	5.45
2014	Waukomis 2	112	1	1	3	21.0	5.50
2014	Waukomis 2	112	1	1	4	8.4	6.85
2014	Waukomis 2	201	2	7	1	26.9	5.55
2014	Waukomis 2	201	2	7	2	18.7	5.36
2014	Waukomis 2	201	2	7	3	13.3	5.72
2014	Waukomis 2	201	2	7	4	7.0	7.00
2014	Waukomis 2	202	2	9	1	13.9	5.65
2014	Waukomis 2	202	2	9	2	14.4	5.56
2014	Waukomis 2	202	2	9	3	10.4	5.78
2014	Waukomis 2	202	2	9	4	4.2	6.79
2014	Waukomis 2	203	2	5	1	18.1	5.62
2014	Waukomis 2	203	2	5	2	16.0	5.43
2014	Waukomis 2	203	2	5	3	13.3	5.65
2014	Waukomis 2	203	2	5	4	6.7	6.83
2014	Waukomis 2	204	2	12	1	21.8	5.56
2014	Waukomis 2	204	2	12	2	19.8	5.33
2014	Waukomis 2	204	2	12	3	15.4	5.94
2014	Waukomis 2	204	2	12	4	6.8	7.16
2014	Waukomis 2	205	2	10	1	17.7	5.47
2014	Waukomis 2	205	2	10	2	16.0	5.60
2014	Waukomis 2	205	2	10	3	21.6	5.81
2014	Waukomis 2	205	2	10	4	6.0	6.96

2014	Waukomis 2	206	2	1	1	22.7	5.51
2014	Waukomis 2	206	2	1	2	19.4	5.60
2014	Waukomis 2	206	2	1	3	14.2	6.19
2014	Waukomis 2	206	2	1	4	28.3	7.04
2014	Waukomis 2	207	2	4	1	26.8	5.80
2014	Waukomis 2	207	2	4	2	19.1	5.61
2014	Waukomis 2	207	2	4	3	27.1	5.86
2014	Waukomis 2	207	2	4	4	7.0	6.82
2014	Waukomis 2	208	2	6	1	40.0	5.44
2014	Waukomis 2	208	2	6	2	20.5	5.37
2014	Waukomis 2	208	2	6	3	13.3	5.81
2014	Waukomis 2	208	2	6	4	6.6	7.05
2014	Waukomis 2	209	2	8	1	27.9	5.83
2014	Waukomis 2	209	2	8	2	17.7	5.50
2014	Waukomis 2	209	2	8	3	12.2	5.64
2014	Waukomis 2	209	2	8	4	6.7	6.67
2014	Waukomis 2	210	2	11	1	20.8	5.80
2014	Waukomis 2	210	2	11	2	18.7	5.73
2014	Waukomis 2	210	2	11	3	13.4	6.18
2014	Waukomis 2	210	2	11	4	6.0	7.11
2014	Waukomis 2	211	2	3	1	35.5	5.64
2014	Waukomis 2	211	2	3	2	21.8	5.64
2014	Waukomis 2	211	2	3	3	14.6	5.95

2014	Waukomis 2	211	2	3	4	6.6	6.82
2014	Waukomis 2	212	2	2	1	34.4	5.51
2014	Waukomis 2	212	2	2	2	17.1	5.66
2014	Waukomis 2	212	2	2	3	11.0	6.16
2014	Waukomis 2	212	2	2	4	5.6	7.17
2014	Waukomis 2	301	3	12	1	25.6	6.13
2014	Waukomis 2	301	3	12	2	16.0	5.77
2014	Waukomis 2	301	3	12	3	12.6	6.22
2014	Waukomis 2	301	3	12	4	7.1	7.29
2014	Waukomis 2	302	3	5	1	18.6	6.01
2014	Waukomis 2	302	3	5	2	15.0	5.71
2014	Waukomis 2	302	3	5	3	10.0	6.08
2014	Waukomis 2	302	3	5	4	5.1	7.14
2014	Waukomis 2	303	3	7	1	21.3	6.05
2014	Waukomis 2	303	3	7	2	14.4	5.50
2014	Waukomis 2	303	3	7	3	9.4	5.78
2014	Waukomis 2	303	3	7	4	4.0	7.21
2014	Waukomis 2	304	3	9	1	22.0	5.90
2014	Waukomis 2	304	3	9	2	16.1	6.00
2014	Waukomis 2	304	3	9	3	14.9	6.58
2014	Waukomis 2	304	3	9	4	4.9	7.66
2014	Waukomis 2	305	3	6	1	20.5	5.83
2014	Waukomis 2	305	3	6	2	16.3	5.45

2014	Waukomis 2	305	3	6	3	8.3	6.11
2014	Waukomis 2	305	3	6	4	4.3	7.29
2014	Waukomis 2	306	3	2	1	18.7	6.00
2014	Waukomis 2	306	3	2	2	12.4	5.80
2014	Waukomis 2	306	3	2	3	8.8	6.45
2014	Waukomis 2	306	3	2	4	5.1	7.30
2014	Waukomis 2	307	3	8	1	20.6	6.06
2014	Waukomis 2	307	3	8	2	13.5	5.36
2014	Waukomis 2	307	3	8	3	8.2	6.18
2014	Waukomis 2	307	3	8	4	4.3	7.24
2014	Waukomis 2	308	3	3	1	19.6	5.64
2014	Waukomis 2	308	3	3	2	11.5	5.86
2014	Waukomis 2	308	3	3	3	7.7	6.62
2014	Waukomis 2	308	3	3	4	4.5	7.33
2014	Waukomis 2	309	3	4	1	16.9	5.89
2014	Waukomis 2	309	3	4	2	13.6	5.52
2014	Waukomis 2	309	3	4	3	9.1	5.88
2014	Waukomis 2	309	3	4	4	4.1	6.93
2014	Waukomis 2	310	3	11	1	60.0	6.46
2014	Waukomis 2	310	3	11	2	15.4	5.80
2014	Waukomis 2	310	3	11	3	8.7	6.38
2014	Waukomis 2	310	3	11	4	4.3	7.02
2014	Waukomis 2	311	3	1	1	15.2	5.82

2014	Waukomis 2	311	3	1	2	12.4	5.82
2014	Waukomis 2	311	3	1	3	8.9	6.42
2014	Waukomis 2	311	3	1	4	4.2	7.20
2014	Waukomis 2	312	3	10	1	16.4	5.83
2014	Waukomis 2	312	3	10	2	13.8	5.80
2014	Waukomis 2	312	3	10	3	9.6	6.16
2014	Waukomis 2	312	3	10	4	4.8	6.97
2014	Waukomis 2	401	4	5	1	19.3	6.69
2014	Waukomis 2	401	4	5	2	15.0	5.76
2014	Waukomis 2	401	4	5	3	13.1	6.22
2014	Waukomis 2	401	4	5	4	4.9	7.43
2014	Waukomis 2	402	4	2	1	20.8	6.40
2014	Waukomis 2	402	4	2	2	13.7	5.91
2014	Waukomis 2	402	4	2	3	9.0	6.55
2014	Waukomis 2	402	4	2	4	7.8	7.89
2014	Waukomis 2	403	4	6	1	36.5	6.72
2014	Waukomis 2	403	4	6	2	13.9	6.33
2014	Waukomis 2	403	4	6	3	10.7	6.83
2014	Waukomis 2	403	4	6	4	5.2	8.45
2014	Waukomis 2	404	4	9	1	17.9	6.68
2014	Waukomis 2	404	4	9	2	11.0	6.35
2014	Waukomis 2	404	4	9	3	7.1	6.85
2014	Waukomis 2	404	4	9	4	5.1	7.98

2014	Waukomis 2	405	4	8	1	18.3	6.57
2014	Waukomis 2	405	4	8	2	10.5	5.99
2014	Waukomis 2	405	4	8	3	6.4	6.54
2014	Waukomis 2	405	4	8	4	3.7	7.92
2014	Waukomis 2	406	4	7	1	15.5	6.53
2014	Waukomis 2	406	4	7	2	9.6	6.26
2014	Waukomis 2	406	4	7	3	7.7	6.67
2014	Waukomis 2	406	4	7	4	4.4	8.39
2014	Waukomis 2	407	4	11	1	15.5	6.82
2014	Waukomis 2	407	4	11	2	10.3	6.61
2014	Waukomis 2	407	4	11	3	7.7	6.85
2014	Waukomis 2	407	4	11	4	4.5	7.48
2014	Waukomis 2	408	4	10	1	16.1	6.72
2014	Waukomis 2	408	4	10	2	11.0	6.28
2014	Waukomis 2	408	4	10	3	7.6	6.69
2014	Waukomis 2	408	4	10	4	4.3	7.56
2014	Waukomis 2	409	4	1	1	20.6	6.99
2014	Waukomis 2	409	4	1	2	12.3	6.47
2014	Waukomis 2	409	4	1	3	9.4	6.77
2014	Waukomis 2	409	4	1	4	4.1	7.70
2014	Waukomis 2	410	4	3	1	23.0	6.71
2014	Waukomis 2	410	4	3	2	13.9	6.10
2014	Waukomis 2	410	4	3	3	9.2	5.99

2014	Waukomis 2	410	4	3	4	4.7	7.27
2014	Waukomis 2	411	4	4	1	38.4	6.88
2014	Waukomis 2	411	4	4	2	13.2	5.89
2014	Waukomis 2	411	4	4	3	8.9	6.37
2014	Waukomis 2	411	4	4	4	5.2	7.34
2014	Waukomis 2	412	4	12	1	16.4	6.39
2014	Waukomis 2	412	4	12	2	14.7	5.92
2014	Waukomis 2	412	4	12	3	8.3	6.19
2014	Waukomis 2	412	4	12	4	4.4	7.35
2015	North 40 2	101	1	2	1	13.9	6.46
2015	North 40 2	101	1	2	2	4.6	7.51
2015	North 40 2	101	1	2	3	4.3	7.66
2015	North 40 2	101	1	2	4	2.9	8.04
2015	North 40 2	102	1	9	1	12.6	7.25
2015	North 40 2	102	1	9	2	4.6	7.37
2015	North 40 2	102	1	9	3	4.2	7.31
2015	North 40 2	102	1	9	4	2.6	8.1
2015	North 40 2	103	1	3	1	12.0	6.77
2015	North 40 2	103	1	3	2	3.3	7.61
2015	North 40 2	103	1	3	3	3.0	7.88
2015	North 40 2	103	1	3	4	2.3	7.97
2015	North 40 2	104	1	11	1	18.9	7.24
2015	North 40 2	104	1	11	2	23.2	7.87

2015	North 40 2	104	1	11	3	5.4	7.24
2015	North 40 2	104	1	11	4	2.8	7.85
2015	North 40 2	105	1	12	1	39.5	7.74
2015	North 40 2	105	1	12	2	47.1	7.94
2015	North 40 2	105	1	12	3	14.4	7.86
2015	North 40 2	105	1	12	4	3.8	8.31
2015	North 40 2	106	1	4	1	56.3	7.17
2015	North 40 2	106	1	4	2	28.2	7.96
2015	North 40 2	106	1	4	3	5.2	7.52
2015	North 40 2	106	1	4	4	4.1	8.03
2015	North 40 2	107	1	6	1	48.9	7.25
2015	North 40 2	107	1	6	2	20.1	8.11
2015	North 40 2	107	1	6	3	5.4	7.99
2015	North 40 2	107	1	6	4	4.3	8.33
2015	North 40 2	108	1	7	1	42.9	6.65
2015	North 40 2	108	1	7	2	10.4	7.81
2015	North 40 2	108	1	7	3	6.8	7.46
2015	North 40 2	108	1	7	4	3.1	8.18
2015	North 40 2	109	1	1	1	20.7	7.65
2015	North 40 2	109	1	1	2	7.1	8.08
2015	North 40 2	109	1	1	3	4.5	7.76
2015	North 40 2	109	1	1	4	2.9	8.16
2015	North 40 2	110	1	10	1	10.4	7.35

2015	North 40 2	110	1	10	2	5.2	7.97
2015	North 40 2	110	1	10	3	3.5	8.36
2015	North 40 2	110	1	10	4	2.7	8.17
2015	North 40 2	111	1	5	1	36.5	7.29
2015	North 40 2	111	1	5	2	20.8	8.02
2015	North 40 2	111	1	5	3	4.9	7.67
2015	North 40 2	111	1	5	4	2.5	8.5
2015	North 40 2	112	1	8	1	11.7	7.27
2015	North 40 2	112	1	8	2	3.9	7.73
2015	North 40 2	112	1	8	3	2.7	7.31
2015	North 40 2	112	1	8	4	2.1	7.95
2015	North 40 2	201	2	10	1	19.8	6.22
2015	North 40 2	201	2	10	2	5.4	7.27
2015	North 40 2	201	2	10	3	4.2	7.18
2015	North 40 2	201	2	10	4	3.9	7.45
2015	North 40 2	202	2	8	1	13.3	6.51
2015	North 40 2	202	2	8	2	5.6	7.3
2015	North 40 2	202	2	8	3	5.6	7.07
2015	North 40 2	202	2	8	4	2.4	7.86
2015	North 40 2	203	2	5	1	23.4	6.82
2015	North 40 2	203	2	5	2	4.6	7.06
2015	North 40 2	203	2	5	3	3.9	7.14
2015	North 40 2	203	2	5	4	3.1	7.91

2015	North 40 2	204	2	3	1	15.0	6.56
2015	North 40 2	204	2	3	2	5.1	7.52
2015	North 40 2	204	2	3	3	4.5	7.91
2015	North 40 2	204	2	3	4	3.3	8.56
2015	North 40 2	205	2	9	1	18.8	6.72
2015	North 40 2	205	2	9	2	5.0	7.95
2015	North 40 2	205	2	9	3	4.8	7.99
2015	North 40 2	205	2	9	4	4.2	8.29
2015	North 40 2	206	2	1	1	18.3	7.42
2015	North 40 2	206	2	1	2	4.0	8.11
2015	North 40 2	206	2	1	3	4.1	7.71
2015	North 40 2	206	2	1	4	4.9	8.19
2015	North 40 2	207	2	12	1	11.8	7.21
2015	North 40 2	207	2	12	2	4.7	7.62
2015	North 40 2	207	2	12	3	3.6	7.89
2015	North 40 2	207	2	12	4	3.1	8.45
2015	North 40 2	208	2	7	1	21.1	6.8
2015	North 40 2	208	2	7	2	5.5	7.85
2015	North 40 2	208	2	7	3	5.2	8.42
2015	North 40 2	208	2	7	4	2.1	8.43
2015	North 40 2	209	2	2	1	13.6	7.31
2015	North 40 2	209	2	2	2	4.0	7.7
2015	North 40 2	209	2	2	3	4.2	7.84

2015	North 40 2	209	2	2	4	2.7	8.83
2015	North 40 2	210	2	6	1	13.7	7.17
2015	North 40 2	210	2	6	2	4.4	8.04
2015	North 40 2	210	2	6	3	3.4	7.99
2015	North 40 2	210	2	6	4	2.9	8.52
2015	North 40 2	211	2	11	1	12.1	7.14
2015	North 40 2	211	2	11	2	4.4	7.49
2015	North 40 2	211	2	11	3	3.3	7.79
2015	North 40 2	211	2	11	4	2.6	8.27
2015	North 40 2	212	2	4	1	7.9	7.28
2015	North 40 2	212	2	4	2	2.7	7.92
2015	North 40 2	212	2	4	3	2.4	8.01
2015	North 40 2	212	2	4	4	2.0	8.22
2015	North 40 2	301	3	12	1	23.4	5.99
2015	North 40 2	301	3	12	2	7.7	6.75
2015	North 40 2	301	3	12	3	6.8	7.11
2015	North 40 2	301	3	12	4	4.5	7.52
2015	North 40 2	302	3	7	1	18.0	6.49
2015	North 40 2	302	3	7	2	4.9	7.27
2015	North 40 2	302	3	7	3	3.1	7.35
2015	North 40 2	302	3	7	4	3.4	7.76
2015	North 40 2	303	3	5	1	23.3	7.51
2015	North 40 2	303	3	5	2	6.6	6.74

2015	North 40 2	303	3	5	3	5.0	7.07
2015	North 40 2	303	3	5	4	5.5	7.23
2015	North 40 2	304	3	11	1	13.6	6.8
2015	North 40 2	304	3	11	2	6.1	7.18
2015	North 40 2	304	3	11	3	5.4	6.79
2015	North 40 2	304	3	11	4	3.4	7.51
2015	North 40 2	305	3	3	1	16.7	6.19
2015	North 40 2	305	3	3	2	5.8	7.44
2015	North 40 2	305	3	3	3	4.5	7.34
2015	North 40 2	305	3	3	4	2.3	8.01
2015	North 40 2	306	3	4	1	21.0	6.58
2015	North 40 2	306	3	4	2	5.6	7.26
2015	North 40 2	306	3	4	3	4.0	7.55
2015	North 40 2	306	3	4	4	4.3	8.24
2015	North 40 2	307	3	1	1	22.4	7.01
2015	North 40 2	307	3	1	2	4.6	7.73
2015	North 40 2	307	3	1	3	3.7	7
2015	North 40 2	307	3	1	4	4.7	8.02
2015	North 40 2	308	3	9	1	24.2	6.85
2015	North 40 2	308	3	9	2	13.5	7.56
2015	North 40 2	308	3	9	3	26.6	7.18
2015	North 40 2	308	3	9	4	3.2	8.15
2015	North 40 2	309	3	8	1	15.4	6.65

2015	North 40 2	309	3	8	2	4.8	7.63
2015	North 40 2	309	3	8	3	4.3	7.21
2015	North 40 2	309	3	8	4	2.4	7.82
2015	North 40 2	310	3	10	1	19.8	6.65
2015	North 40 2	310	3	10	2	5.2	7.18
2015	North 40 2	310	3	10	3	4.7	7.24
2015	North 40 2	310	3	10	4	3.0	8.03
2015	North 40 2	311	3	2	1	12.8	6.77
2015	North 40 2	311	3	2	2	4.3	7.27
2015	North 40 2	311	3	2	3	3.7	7.22
2015	North 40 2	311	3	2	4	3.0	8.11
2015	North 40 2	312	3	6	1	23.0	6.81
2015	North 40 2	312	3	6	2	5.1	7.14
2015	North 40 2	312	3	6	3	3.5	7.09
2015	North 40 2	312	3	6	4	3.3	8.06
2015	Garber	101	1	2	1	62.0	5.56
2015	Garber	101	1	2	2	47.5	5.54
2015	Garber	101	1	2	3	23.9	5.47
2015	Garber	101	1	2	4	12.9	5.84
2015	Garber	102	1	1	1	50.9	5.48
2015	Garber	102	1	1	2	21.6	5.23
2015	Garber	102	1	1	3	17.7	5.09
2015	Garber	102	1	1	4	7.4	5.57

2015	Garber	103	1	7	1	69.7	6.11
2015	Garber	103	1	7	2	35.0	5.29
2015	Garber	103	1	7	3	25.2	5.34
2015	Garber	103	1	7	4	11.8	6.09
2015	Garber	104	1	6	1	67.5	5.61
2015	Garber	104	1	6	2	35.8	5.23
2015	Garber	104	1	6	3	22.2	5.44
2015	Garber	104	1	6	4	7.8	6.11
2015	Garber	105	1	4	1	87.2	5.99
2015	Garber	105	1	4	2	35.4	5.26
2015	Garber	105	1	4	3	26.6	5.5
2015	Garber	105	1	4	4	15.3	6.37
2015	Garber	106	1	10	1	64.8	6.38
2015	Garber	106	1	10	2	39.7	5.45
2015	Garber	106	1	10	3	26.8	5.31
2015	Garber	106	1	10	4	10.4	6.44
2015	Garber	107	1	12	1	81.7	6.29
2015	Garber	107	1	12	2	45.3	5.59
2015	Garber	107	1	12	3	26.1	5.68
2015	Garber	107	1	12	4	7.0	6.72
2015	Garber	108	1	8	1	88.4	5.85
2015	Garber	108	1	8	2	52.6	5.58
2015	Garber	108	1	8	3	26.9	5.66

2015	Garber	108	1	8	4	6.3	6.16
2015	Garber	109	1	11	1	57.3	6.15
2015	Garber	109	1	11	2	50.7	5.48
2015	Garber	109	1	11	3	43.5	5.64
2015	Garber	109	1	11	4	13.3	6.12
2015	Garber	110	1	9	1	81.3	5.8
2015	Garber	110	1	9	2	53.5	5.45
2015	Garber	110	1	9	3	33.6	5.72
2015	Garber	110	1	9	4	8.9	6.75
2015	Garber	111	1	5	1	97.9	5.76
2015	Garber	111	1	5	2	112.2	5.57
2015	Garber	111	1	5	3	32.9	6.16
2015	Garber	111	1	5	4	7.9	7.03
2015	Garber	112	1	3	1	67.6	6.14
2015	Garber	112	1	3	2	39.9	5.68
2015	Garber	112	1	3	3	31.4	6.06
2015	Garber	112	1	3	4	7.4	6.86
2015	Garber	201	2	4	1	70.3	5.89
2015	Garber	201	2	4	2	66.5	5.18
2015	Garber	201	2	4	3	23.0	5.51
2015	Garber	201	2	4	4	12.1	5.95
2015	Garber	202	2	5	1	50.2	6.08
2015	Garber	202	2	5	2	27.7	5.38

2015	Garber	202	2	5	3	20.0	5.46
2015	Garber	202	2	5	4	6.1	6.2
2015	Garber	203	2	2	1	68.7	5.64
2015	Garber	203	2	2	2	35.9	5.09
2015	Garber	203	2	2	3	23.8	5.2
2015	Garber	203	2	2	4	6.5	6.09
2015	Garber	204	2	12	1	88.3	6.01
2015	Garber	204	2	12	2	42.7	5.29
2015	Garber	204	2	12	3	30.4	5.32
2015	Garber	204	2	12	4	7.4	6.19
2015	Garber	205	2	7	1	77.2	5.92
2015	Garber	205	2	7	2	34.9	5.34
2015	Garber	205	2	7	3	28.9	5.77
2015	Garber	205	2	7	4	5.4	6.51
2015	Garber	206	2	3	1	91.5	6.37
2015	Garber	206	2	3	2	66.3	5.44
2015	Garber	206	2	3	3	34.9	5.47
2015	Garber	206	2	3	4	7.0	5.9
2015	Garber	207	2	6	1	71.0	6.59
2015	Garber	207	2	6	2	70.6	5.36
2015	Garber	207	2	6	3	43.1	5.26
2015	Garber	207	2	6	4	14.5	6.25
2015	Garber	208	2	1	1	89.1	6.14

2015	Garber	208	2	1	2	72.9	5.35
2015	Garber	208	2	1	3	35.9	5.6
2015	Garber	208	2	1	4	11.2	6.27
2015	Garber	209	2	9	1	88.2	5.84
2015	Garber	209	2	9	2	67.0	5.4
2015	Garber	209	2	9	3	46.1	5.58
2015	Garber	209	2	9	4	14.5	6.12
2015	Garber	210	2	10	1	83.8	6.48
2015	Garber	210	2	10	2	67.3	5.69
2015	Garber	210	2	10	3	46.1	5.62
2015	Garber	210	2	10	4	9.3	6.04
2015	Garber	211	2	8	1	94.5	6.31
2015	Garber	211	2	8	2	68.2	5.56
2015	Garber	211	2	8	3	32.4	5.8
2015	Garber	211	2	8	4	10.6	6.57
2015	Garber	212	2	11	1	91.6	5.88
2015	Garber	212	2	11	2	72.9	5.55
2015	Garber	212	2	11	3	38.3	5.85
2015	Garber	212	2	11	4	14.7	6.41
2015	Garber	301	3	10	1	66.2	6.58
2015	Garber	301	3	10	2	30.6	5.51
2015	Garber	301	3	10	3	24.0	5.57
2015	Garber	301	3	10	4	9.5	5.96

2015	Garber	302	3	3	1	60.0	6.51
2015	Garber	302	3	3	2	29.0	5.73
2015	Garber	302	3	3	3	16.5	5.76
2015	Garber	302	3	3	4	3.7	6.26
2015	Garber	303	3	12	1	60.5	6.79
2015	Garber	303	3	12	2	37.9	5.79
2015	Garber	303	3	12	3	14.1	5.68
2015	Garber	303	3	12	4	5.1	6.14
2015	Garber	304	3	7	1	51.9	5.99
2015	Garber	304	3	7	2	24.3	5.65
2015	Garber	304	3	7	3	18.2	5.56
2015	Garber	304	3	7	4	4.6	6.26
2015	Garber	305	3	4	1	63.5	6.63
2015	Garber	305	3	4	2	33.3	5.43
2015	Garber	305	3	4	3	25.5	5.57
2015	Garber	305	3	4	4	6.8	6.11
2015	Garber	306	3	5	1	59.3	6.16
2015	Garber	306	3	5	2	57.7	5.59
2015	Garber	306	3	5	3	37.0	5.63
2015	Garber	306	3	5	4	5.9	6.23
2015	Garber	307	3	1	1	74.2	6.4
2015	Garber	307	3	1	2	35.6	5.49
2015	Garber	307	3	1	3	28.2	5.47

2015	Garber	307	3	1	4	9.4	6.56
2015	Garber	308	3	8	1	62.1	6.18
2015	Garber	308	3	8	2	33.0	5.66
2015	Garber	308	3	8	3	25.1	5.91
2015	Garber	308	3	8	4	8.7	6.63
2015	Garber	309	3	2	1	56.5	6.54
2015	Garber	309	3	2	2	31.6	5.43
2015	Garber	309	3	2	3	22.8	5.84
2015	Garber	309	3	2	4	10.2	6.42
2015	Garber	310	3	6	1	59.8	6.45
2015	Garber	310	3	6	2	32.3	5.44
2015	Garber	310	3	6	3	20.0	5.58
2015	Garber	310	3	6	4	5.5	6.51
2015	Garber	311	3	11	1	99.4	6.59
2015	Garber	311	3	11	2	77.1	5.56
2015	Garber	311	3	11	3	22.5	5.54
2015	Garber	311	3	11	4	5.0	6.49
2015	Garber	312	3	9	1	60.2	5.95
2015	Garber	312	3	9	2	36.1	5.44
2015	Garber	312	3	9	3	26.3	5.85
2015	Garber	312	3	9	4	11.1	6.8
2015	Garber	401	4	2	1	37.6	6.13
2015	Garber	401	4	2	2	21.8	5.36

2015	Garber	401	4	2	3	18.3	5.45
2015	Garber	401	4	2	4	11.6	5.89
2015	Garber	402	4	4	1	46.0	6.52
2015	Garber	402	4	4	2	18.1	5.38
2015	Garber	402	4	4	3	15.0	5.32
2015	Garber	402	4	4	4	7.2	5.9
2015	Garber	403	4	9	1	40.3	6.21
2015	Garber	403	4	9	2	31.2	5.52
2015	Garber	403	4	9	3	14.8	5.36
2015	Garber	403	4	9	4	6.2	5.89
2015	Garber	404	4	7	1	48.9	5.99
2015	Garber	404	4	7	2	20.8	5.4
2015	Garber	404	4	7	3	18.5	5.31
2015	Garber	404	4	7	4	6.6	5.92
2015	Garber	405	4	3	1	59.4	6.47
2015	Garber	405	4	3	2	53.3	5.83
2015	Garber	405	4	3	3	25.1	5.51
2015	Garber	405	4	3	4	11.1	6.23
2015	Garber	406	4	10	1	57.2	5.97
2015	Garber	406	4	10	2	32.8	5.41
2015	Garber	406	4	10	3	21.9	5.5
2015	Garber	406	4	10	4	6.9	5.88
2015	Garber	407	4	11	1	74.9	6.08

2015	Garber	407	4	11	2	37.2	5.42
2015	Garber	407	4	11	3	19.0	5.49
2015	Garber	407	4	11	4	3.9	6.25
2015	Garber	408	4	12	1	62.6	5.89
2015	Garber	408	4	12	2	23.8	5.47
2015	Garber	408	4	12	3	14.2	5.6
2015	Garber	408	4	12	4	4.8	6.25
2015	Garber	409	4	1	1	63.1	6.15
2015	Garber	409	4	1	2	29.2	5.55
2015	Garber	409	4	1	3	23.7	5.68
2015	Garber	409	4	1	4	6.7	6.27
2015	Garber	410	4	6	1	58.5	5.86
2015	Garber	410	4	6	2	29.0	5.48
2015	Garber	410	4	6	3	19.1	5.71
2015	Garber	410	4	6	4	5.7	6.32
2015	Garber	411	4	8	1	70.7	6.17
2015	Garber	411	4	8	2	49.3	5.42
2015	Garber	411	4	8	3	17.6	5.8
2015	Garber	411	4	8	4	4.7	6.48
2015	Garber	412	4	5	1	61.5	5.67
2015	Garber	412	4	5	2	26.0	5.48
2015	Garber	412	4	5	3	21.6	5.72
2015	Garber	412	4	5	4	6.1	6.6

2015	Waukomis 3	101	1	7	1	32.8	5.38
2015	Waukomis 3	101	1	7	2	34.2	5.06
2015	Waukomis 3	101	1	7	3	22.3	5.32
2015	Waukomis 3	101	1	7	4	10.3	6.48
2015	Waukomis 3	102	1	1	1	39.6	5.06
2015	Waukomis 3	102	1	1	2	34.8	5
2015	Waukomis 3	102	1	1	3	23.3	5.27
2015	Waukomis 3	102	1	1	4	10.6	6.44
2015	Waukomis 3	103	1	6	1	42.4	5.52
2015	Waukomis 3	103	1	6	2	37.7	5.07
2015	Waukomis 3	103	1	6	3	21.3	5.3
2015	Waukomis 3	103	1	6	4	7.6	6.48
2015	Waukomis 3	104	1	12	1	41.9	5.34
2015	Waukomis 3	104	1	12	2	32.4	5.17
2015	Waukomis 3	104	1	12	3	20.9	5.44
2015	Waukomis 3	104	1	12	4	9.2	6.31
2015	Waukomis 3	105	1	8	1	34.0	5.38
2015	Waukomis 3	105	1	8	2	28.6	5.21
2015	Waukomis 3	105	1	8	3	19.4	5.34
2015	Waukomis 3	105	1	8	4	9.8	6.18
2015	Waukomis 3	106	1	2	1	44.7	5.74
2015	Waukomis 3	106	1	2	2	31.6	5.19
2015	Waukomis 3	106	1	2	3	17.6	5.46

2015	Waukomis 3	106	1	2	4	8.3	6.3
2015	Waukomis 3	107	1	9	1	33.2	5.66
2015	Waukomis 3	107	1	9	2	29.1	5.15
2015	Waukomis 3	107	1	9	3	13.0	5.35
2015	Waukomis 3	107	1	9	4	8.4	6.25
2015	Waukomis 3	108	1	5	1	31.2	5.67
2015	Waukomis 3	108	1	5	2	31.6	5.21
2015	Waukomis 3	108	1	5	3	14.5	5.48
2015	Waukomis 3	108	1	5	4	8.0	6.37
2015	Waukomis 3	109	1	10	1	38.0	5.67
2015	Waukomis 3	109	1	10	2	25.8	5.08
2015	Waukomis 3	109	1	10	3	14.2	5.32
2015	Waukomis 3	109	1	10	4	7.7	6.22
2015	Waukomis 3	110	1	4	1	37.2	5.72
2015	Waukomis 3	110	1	4	2	24.6	5.12
2015	Waukomis 3	110	1	4	3	15.6	5.44
2015	Waukomis 3	110	1	4	4	8.4	6.54
2015	Waukomis 3	111	1	3	1	33.3	5.56
2015	Waukomis 3	111	1	3	2	30.8	5.36
2015	Waukomis 3	111	1	3	3	17.6	5.44
2015	Waukomis 3	111	1	3	4	8.7	6.46
2015	Waukomis 3	112	1	11	1	35.1	5.32
2015	Waukomis 3	112	1	11	2	29.9	5.13

2015	Waukomis 3	112	1	11	3	17.0	5.88
2015	Waukomis 3	112	1	11	4	8.1	6.65
2015	Waukomis 3	201	2	4	1	36.7	5.82
2015	Waukomis 3	201	2	4	2	33.6	5.43
2015	Waukomis 3	201	2	4	3	14.2	5.75
2015	Waukomis 3	201	2	4	4	24.1	6.77
2015	Waukomis 3	202	2	5	1	43.1	5.86
2015	Waukomis 3	202	2	5	2	31.4	5.38
2015	Waukomis 3	202	2	5	3	20.4	5.69
2015	Waukomis 3	202	2	5	4	12.7	6.55
2015	Waukomis 3	203	2	6	1	31.7	5.57
2015	Waukomis 3	203	2	6	2	33.8	5.06
2015	Waukomis 3	203	2	6	3	18.6	5.52
2015	Waukomis 3	203	2	6	4	10.4	6.6
2015	Waukomis 3	204	2	2	1	50.3	5.63
2015	Waukomis 3	204	2	2	2	30.8	5.08
2015	Waukomis 3	204	2	2	3	15.9	5.42
2015	Waukomis 3	204	2	2	4	8.8	6.18
2015	Waukomis 3	205	2	1	1	38.6	5.57
2015	Waukomis 3	205	2	1	2	26.7	5.24
2015	Waukomis 3	205	2	1	3	17.7	5.55
2015	Waukomis 3	205	2	1	4	8.9	6.25
2015	Waukomis 3	206	2	11	1	26.1	5.48

2015	Waukomis 3	206	2	11	2	20.3	5.31
2015	Waukomis 3	206	2	11	3	14.8	6.45
2015	Waukomis 3	206	2	11	4	9.7	5.45
2015	Waukomis 3	207	2	7	1	43.8	5.27
2015	Waukomis 3	207	2	7	2	23.0	5.58
2015	Waukomis 3	207	2	7	3	14.2	6.17
2015	Waukomis 3	207	2	7	4	9.0	5.47
2015	Waukomis 3	208	2	10	1	24.4	5.4
2015	Waukomis 3	208	2	10	2	23.7	5.72
2015	Waukomis 3	208	2	10	3	15.9	5.46
2015	Waukomis 3	208	2	10	4	8.3	5.25
2015	Waukomis 3	209	2	3	1	25.1	5.78
2015	Waukomis 3	209	2	3	2	20.3	6.08
2015	Waukomis 3	209	2	3	3	15.2	5.45
2015	Waukomis 3	209	2	3	4	7.7	5.13
2015	Waukomis 3	210	2	12	1	40.8	5.71
2015	Waukomis 3	210	2	12	2	26.6	6.19
2015	Waukomis 3	210	2	12	3	20.6	5.39
2015	Waukomis 3	210	2	12	4	11.3	6.11
2015	Waukomis 3	211	2	9	1	27.6	5.42
2015	Waukomis 3	211	2	9	2	23.9	5
2015	Waukomis 3	211	2	9	3	11.6	5.41
2015	Waukomis 3	211	2	9	4	7.1	6.44

2015	Waukomis 3	212	2	8	1	39.1	5.51
2015	Waukomis 3	212	2	8	2	29.8	5.15
2015	Waukomis 3	212	2	8	3	15.7	5.33
2015	Waukomis 3	212	2	8	4	7.6	6.33
2015	Waukomis 3	301	3	8	1	36.0	5.98
2015	Waukomis 3	301	3	8	2	31.6	5.46
2015	Waukomis 3	301	3	8	3	24.5	5.67
2015	Waukomis 3	301	3	8	4	13.5	6.83
2015	Waukomis 3	302	3	9	1	39.4	5.83
2015	Waukomis 3	302	3	9	2	31.3	5.36
2015	Waukomis 3	302	3	9	3	18.9	5.48
2015	Waukomis 3	302	3	9	4	11.5	6.5
2015	Waukomis 3	303	3	7	1	36.1	5.74
2015	Waukomis 3	303	3	7	2	29.5	5.25
2015	Waukomis 3	303	3	7	3	19.6	5.84
2015	Waukomis 3	303	3	7	4	8.6	7.31
2015	Waukomis 3	304	3	2	1	42.4	5.68
2015	Waukomis 3	304	3	2	2	29.3	5.15
2015	Waukomis 3	304	3	2	3	17.2	5.75
2015	Waukomis 3	304	3	2	4	8.5	6.66
2015	Waukomis 3	305	3	4	1	39.9	6.27
2015	Waukomis 3	305	3	4	2	26.1	5.44
2015	Waukomis 3	305	3	4	3	17.0	5.6

2015	Waukomis 3	305	3	4	4	7.8	6.49
2015	Waukomis 3	306	3	10	1	49.8	5.93
2015	Waukomis 3	306	3	10	2	27.9	5.22
2015	Waukomis 3	306	3	10	3	18.9	5.34
2015	Waukomis 3	306	3	10	4	7.7	6.38
2015	Waukomis 3	307	3	12	1	30.6	5.56
2015	Waukomis 3	307	3	12	2	27.7	5.21
2015	Waukomis 3	307	3	12	3	16.8	5.35
2015	Waukomis 3	307	3	12	4	7.5	6.4
2015	Waukomis 3	308	3	6	1	44.8	5.65
2015	Waukomis 3	308	3	6	2	30.4	5.16
2015	Waukomis 3	308	3	6	3	19.4	5.2
2015	Waukomis 3	308	3	6	4	9.0	6.43
2015	Waukomis 3	309	3	11	1	47.1	5.51
2015	Waukomis 3	309	3	11	2	29.1	5.01
2015	Waukomis 3	309	3	11	3	16.0	5.33
2015	Waukomis 3	309	3	11	4	6.6	6.16
2015	Waukomis 3	310	3	5	1	47.2	5.27
2015	Waukomis 3	310	3	5	2	28.9	5.06
2015	Waukomis 3	310	3	5	3	15.6	5.24
2015	Waukomis 3	310	3	5	4	6.9	6.3
2015	Waukomis 3	311	3	1	1	41.8	5.19
2015	Waukomis 3	311	3	1	2	26.7	5.1

2015	Waukomis 3	311	3	1	3	20.4	5.16
2015	Waukomis 3	311	3	1	4	7.9	6.11
2015	Waukomis 3	312	3	3	1	49.9	5.36
2015	Waukomis 3	312	3	3	2	30.7	5.02
2015	Waukomis 3	312	3	3	3	19.3	5.25
2015	Waukomis 3	312	3	3	4	8.8	6.3
2015	Waukomis 3	401	4	6	1	42.0	5.47
2015	Waukomis 3	401	4	6	2	23.5	5.04
2015	Waukomis 3	401	4	6	3	15.4	5.52
2015	Waukomis 3	401	4	6	4	8.3	6.75
2015	Waukomis 3	402	4	4	1	32.2	6.89
2015	Waukomis 3	402	4	4	2	26.4	5.31
2015	Waukomis 3	402	4	4	3	21.3	5.53
2015	Waukomis 3	402	4	4	4	8.5	6.63
2015	Waukomis 3	403	4	2	1	32.9	5.49
2015	Waukomis 3	403	4	2	2	23.6	5.05
2015	Waukomis 3	403	4	2	3	14.2	5.44
2015	Waukomis 3	403	4	2	4	7.2	6.74
2015	Waukomis 3	404	4	11	1	36.7	5.45
2015	Waukomis 3	404	4	11	2	34.5	5.11
2015	Waukomis 3	404	4	11	3	17.5	5.49
2015	Waukomis 3	404	4	11	4	8.3	6.61
2015	Waukomis 3	405	4	3	1	37.3	5.45

2015	Waukomis 3	405	4	3	2	28.2	5.07
2015	Waukomis 3	405	4	3	3	16.3	5.32
2015	Waukomis 3	405	4	3	4	6.8	6.43
2015	Waukomis 3	406	4	7	1	40.6	5.25
2015	Waukomis 3	406	4	7	2	27.6	5.14
2015	Waukomis 3	406	4	7	3	17.5	5.21
2015	Waukomis 3	406	4	7	4	8.2	6.35
2015	Waukomis 3	407	4	8	1	51.5	5.4
2015	Waukomis 3	407	4	8	2	28.2	5.19
2015	Waukomis 3	407	4	8	3	18.8	5.35
2015	Waukomis 3	407	4	8	4	6.1	6.56
2015	Waukomis 3	408	4	9	1	39.1	5.77
2015	Waukomis 3	408	4	9	2	28.8	5.34
2015	Waukomis 3	408	4	9	3	14.6	5.49
2015	Waukomis 3	408	4	9	4	5.6	6.72
2015	Waukomis 3	409	4	5	1	31.6	5.7
2015	Waukomis 3	409	4	5	2	27.4	5.42
2015	Waukomis 3	409	4	5	3	12.9	5.71
2015	Waukomis 3	409	4	5	4	6.0	7.14
2015	Waukomis 3	410	4	10	1	32.2	5.81
2015	Waukomis 3	410	4	10	2	24.3	5.33
2015	Waukomis 3	410	4	10	3	14.7	5.55
2015	Waukomis 3	410	4	10	4	5.9	6.9

2015	Waukomis 3	411	4	1	1	26.1	5.57
2015	Waukomis 3	411	4	1	2	17.2	5.11
2015	Waukomis 3	411	4	1	3	9.5	5.49
2015	Waukomis 3	411	4	1	4	4.2	6.63
2015	Waukomis 3	412	4	12	1	24.9	5.67
2015	Waukomis 3	412	4	12	2	21.4	5.29
2015	Waukomis 3	412	4	12	3	11.8	5.57
2015	Waukomis 3	412	4	12	4	5.1	6.78

C: Chang and Jackson fractionation phosphorus concentrations.

year	location	plot	depth_id	soluble	Al_P	Fe_P	Reductant	Ca_P	Total
2014	North 40	107	1	0.390	4.733	10.800	7.536	7.650	31.109
2014	North 40	107	2	0.390	3.577	28.976	14.986	9.150	57.079
2014	North 40	107	3	0.390	2.035	22.106	14.986	10.050	49.567
2014	North 40	201	1	0.390	10.259	43.001	14.159	14.550	82.358
2014	North 40	201	2	0.390	0.750	20.818	12.503	8.250	42.710
2014	North 40	201	3	0.390	0.364	16.382	10.019	10.650	37.805
2014	North 40	301	1	0.390	4.476	25.398	12.503	8.100	50.867
2014	North 40	301	2	0.390	1.906	20.675	6.708	5.250	34.929
2014	North 40	301	3	0.390	4.348	15.809	6.708	6.150	33.405
2014	North 40	405	1	0.390	1.906	22.535	10.847	5.700	41.379
2014	North 40	405	2	0.390	0.878	19.959	10.019	7.050	38.297
2014	North 40	405	3	0.390	0.236	19.530	12.503	6.750	39.408
2014	Red Rock 1	107	1	0.390	10.002	49.870	14.986	9.900	85.149
2014	Red Rock 1	107	2	0.390	4.091	34.557	10.847	8.400	58.285
2014	Red Rock 1	107	3	0.390	1.135	20.102	10.847	3.750	36.225
2014	Red Rock 1	204	1	0.390	7.946	45.291	44.789	13.200	111.615
2014	Red Rock 1	204	2	0.390	4.348	32.124	44.789	10.350	92.000

2014	Red Rock 1	204	3	0.390	1.906	27.544	39.822	12.450	82.112
2014	Red Rock 1	303	1	0.390	6.918	46.006	56.378	21.450	131.142
2014	Red Rock 1	303	2	0.390	2.677	30.550	44.789	14.550	92.956
2014	Red Rock 1	303	3	0.390	2.163	24.253	47.272	9.300	83.378
2014	Red Rock 1	408	1	0.390	24.009	80.783	49.756	19.950	174.888
2014	Red Rock 1	408	2	0.390	3.705	40.139	46.444	14.700	105.378
2014	Red Rock 1	408	3	0.390	1.778	24.110	41.477	12.600	80.355
2014	Red Rock 2	105	1	0.390	12.701	47.867	24.093	12.600	97.650
2014	Red Rock 2	105	2	0.390	3.962	34.986	37.338	12.000	88.677
2014	Red Rock 2	105	3	0.390	1.264	43.287	35.682	11.700	92.323
2014	Red Rock 2	209	1	0.390	9.102	23.251	38.166	12.150	83.059
2014	Red Rock 2	209	2	0.390	3.705	31.838	38.994	10.200	85.127
2014	Red Rock 2	209	3	0.390	1.392	18.958	34.855	10.800	66.394
2014	Red Rock 2	311	1	0.390	9.616	41.427	36.510	11.550	99.493
2014	Red Rock 2	311	2	0.390	4.476	33.698	34.855	11.700	85.119
2014	Red Rock 2	311	3	0.390	2.549	18.814	29.060	11.400	62.213
2014	Red Rock 2	409	1	0.390	12.829	46.436	38.994	12.300	110.948
2014	Red Rock 2	409	2	0.390	3.705	28.403	38.994	11.250	82.742
2014	Red Rock 2	409	3	0.390	1.392	17.097	35.682	11.400	65.962
2014	Red Rock 3	104	1	0.529	15.656	50.729	36.510	15.150	118.574
2014	Red Rock 3	104	2	0.390	6.275	37.133	31.543	13.650	88.992
2014	Red Rock 3	104	3	0.390	1.778	17.240	29.888	13.050	62.345
2014	Red Rock 3	208	1	0.668	20.796	60.318	42.305	18.450	142.537

2014	Red Rock 3	208	2	0.390	10.259	47.008	32.371	16.500	106.528
2014	Red Rock 3	208	3	0.390	3.577	23.680	23.265	12.750	63.662
2014	Red Rock 3	302	1	0.390	12.443	53.162	30.715	21.000	117.711
2014	Red Rock 3	302	2	0.390	8.074	44.289	34.027	14.550	101.330
2014	Red Rock 3	302	3	0.390	3.191	31.122	30.715	21.000	86.419
2014	Red Rock 3	411	1	0.390	14.885	51.731	33.199	17.100	117.305
2014	Red Rock 3	411	2	0.390	5.247	38.851	30.715	15.750	90.953
2014	Red Rock 3	411	3	0.390	2.292	20.246	27.404	11.250	61.581
2014	Waukomis 1	104	1	0.390	4.862	24.825	29.888	25.350	85.315
2014	Waukomis 1	104	2	0.390	-0.150	21.104	28.232	20.850	70.426
2014	Waukomis 1	104	3	0.390	7.432	18.099	34.855	17.400	78.175
2014	Waukomis 1	210	1	1.502	21.310	36.704	31.543	22.650	113.709
2014	Waukomis 1	210	2	0.390	10.644	30.407	34.855	16.650	92.946
2014	Waukomis 1	210	3	0.390	6.532	22.679	28.232	13.950	71.783
2014	Waukomis 1	307	1	1.224	16.556	31.552	30.715	24.600	104.647
2014	Waukomis 1	307	2	0.529	11.672	35.130	35.682	24.000	107.013
2014	Waukomis 1	307	3	0.390	8.074	27.401	36.510	20.550	92.926
2014	Waukomis 1	412	1	1.154	18.355	40.568	44.789	27.600	132.466
2014	Waukomis 1	412	2	0.390	10.130	35.273	41.477	23.700	110.970
2014	Waukomis 1	412	3	0.390	9.745	28.976	39.822	21.450	100.382
2014	Waukomis 2	107	1	0.390	5.761	20.532	34.027	30.750	91.460
2014	Waukomis 2	107	2	0.390	6.275	19.816	30.715	24.600	81.797
2014	Waukomis 2	107	3	0.390	5.247	16.668	34.027	21.150	77.482

2014	Waukomis 2	204	1	0.390	5.504	19.673	39.822	28.650	94.039
2014	Waukomis 2	204	2	0.390	4.605	18.385	36.510	25.500	85.390
2014	Waukomis 2	204	3	0.390	3.962	15.093	28.232	23.550	71.227
2014	Waukomis 2	301	1	0.390	10.002	20.532	33.199	41.550	105.673
2014	Waukomis 2	301	2	0.390	4.605	16.382	33.199	37.350	91.925
2014	Waukomis 2	301	3	0.390	2.806	14.807	33.199	31.800	83.002
2014	Waukomis 2	412	1	0.390	4.091	15.666	26.576	36.900	83.623
2014	Waukomis 2	412	2	0.390	3.834	14.235	19.953	31.350	69.762
2014	Waukomis 2	412	3	0.390	1.521	10.657	27.404	27.300	67.271
2015	Garber	107	1	2.892	7.817	75.917	34.855	19.200	140.681
2015	Garber	107	2	0.390	12.572	63.037	33.199	21.300	130.498
2015	Garber	107	3	0.390	9.231	42.858	33.199	19.800	105.478
2015	Garber	204	1	1.363	30.306	104.540	19.126	18.750	174.085
2015	Garber	204	2	0.390	12.829	61.892	14.159	17.400	106.670
2015	Garber	204	3	0.390	11.030	51.302	18.298	14.400	95.419
2015	Garber	303	1	0.390	19.254	70.479	22.437	18.150	130.710
2015	Garber	303	2	0.529	10.901	50.872	16.642	12.900	91.845
2015	Garber	303	3	0.390	3.705	25.684	15.814	8.100	53.693
2015	Garber	408	1	0.598	19.254	76.347	24.920	16.650	137.770
2015	Garber	408	2	0.390	5.761	42.285	14.986	14.250	77.673
2015	Garber	408	3	0.390	4.091	27.544	13.331	9.900	55.256
2015	North 40	105	1	1.363	12.293	49.727	33.199	14.250	110.833
2015	North 40	105	2	2.892	28.507	43.287	24.093	31.800	130.578

2015	North 40	105	3	0.390	14.243	28.546	29.060	18.450	90.689
2015	North 40	207	1	0.390	4.990	25.827	13.331	9.600	54.138
2015	North 40	207	2	0.390	0.621	16.525	10.847	9.150	37.533
2015	North 40	207	3	0.390	0.364	13.805	10.847	6.150	31.557
2015	North 40	301	1	0.390	6.661	35.702	14.986	7.800	65.539
2015	North 40	301	2	0.390	2.677	20.389	15.814	7.050	46.320
2015	North 40	301	3	0.390	1.521	18.099	13.331	6.600	39.940
2015	Waukomis 3	104	1	0.390	12.829	23.823	13.331	21.450	71.823
2015	Waukomis 3	104	2	0.390	9.616	20.818	14.159	13.500	58.483
2015	Waukomis 3	104	3	0.390	4.605	17.097	10.847	10.200	43.139
2015	Waukomis 3	210	1	0.390	11.415	22.965	12.503	19.650	66.923
2015	Waukomis 3	210	2	0.390	6.147	18.814	8.364	14.100	47.815
2015	Waukomis 3	210	3	0.390	4.476	15.809	10.847	10.800	42.322
2015	Waukomis 3	307	1	0.390	7.946	19.244	9.192	14.700	51.471
2015	Waukomis 3	307	2	0.390	6.661	19.530	10.019	12.000	48.600
2015	Waukomis 3	307	3	0.390	3.191	14.521	9.192	8.700	35.994
2015	Waukomis 3	412	1	0.390	7.432	18.385	10.847	31.350	68.404
2015	Waukomis 3	412	2	0.390	6.789	17.956	10.019	21.450	56.604
2015	Waukomis 3	412	3	0.390	3.834	13.519	10.019	34.650	62.412

D: EPA 3050b preplant soil phosphorus.

Year	Location	Plot	Depth	weight	Total P mg/kg
2014	N40 1	107	1	1.9994	137.87
2014	N40 1	107	2	2.0039	201.51
2014	N40 1	107	3	1.9904	186.09
2014	RedRock 1	107	1	1.9918	311.83
2014	RedRock 1	107	2	1.9941	250.41
2014	RedRock 1	107	3	2.003	192.16
2014	Waukomis 1	104	1	2.0094	298.07
2014	Waukomis 1	104	2	2.0013	257.56
2014	Waukomis 1	104	3	1.9976	239.44
2015	Garber	107	1	2.0013	352.12
2015	Garber	107	2	2.0036	269.42
2015	Garber	107	3	2.0007	226.67
2015	N40 2	105	1	2.0001	344.26
2015	N40 2	105	2	2.0037	273.94
2015	N40 2	105	3	2.0007	194.21
2015	Waukomis 3	104	1	1.9982	248.92
2015	Waukomis 3	104	2	1.9919	230.66
2015	Waukomis 3	104	3	2.0084	194.16

Vita

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