INTERPRETING AND MANAGING SOYBEAN IRON CHLOROSIS IN WESTERN KANSAS

by

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Abstract

Soybeans have expanded into Western Kansas during the last 50 years, increasing in area by 14,500% . There are several limitations that come with trying to grow soybeans in this region, including fertility constraints, moisture stress, and improper use of fertilizers. However, the largest constraint at this time seems to be the presence of micronutrient deficiencies, specifically iron. This thesis has an introduction, and three major chapters.The objective of the first study on agronomics was the evaluation of the effect of Fe fertilizer application using foliar and seed-applied methods in combination with variety selection for Fe deficiency management of soybean grown under irrigated conditions in Western Kansas. The second study uses multivariate analysis as an exploratory tool useful in determining simultaneous observation and analysis of more than one variable in a multidimensional space. Factor analysis is used to find underlying factors that one variable alone cannot measure. The objective of this study was to determine the underlying factors and the multi-linear models that are associated with soil parameters that can create Fe chlorosis in the Great Plains. The third study looked at different application rates of seed-applied Fe fertilizer to try and determine the optimum application rate for application of chelated Fe in Western Kansas.

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Dedication

There are many people and things that I would like to dedicate my thesis to, including Clark, my always amusing fuzzy child who thinks that he is a cat, for sprawling out on top of the couch to watch over my shoulders as I was typing my thesis. This thesis is also dedicated to the environmental damage that I caused after accidentally throwing a dodge-ball over the side of a Royal Caribbean Cruise Ship, Care-bears that possess flamethrowers and projectile weaponry, the velociraptor riding cyborgs bent on world domination, supervolvanoes, icebergs and Dick Cheney.

CHAPTER 1- GENERAL INTRODUCTION

One of the largest nutrient constraints in growing soybeans in a semi-arid region like Western Kansas is the prevalence of iron deficiency chlorosis. Soybeans have expanded into Western Kansas during the last 50 years, increasing in area by 14,500% (NASS, 2010). Iron chlorosis in the North Central region of the United States causes over $120 million in potential yield losses annually (Hansen et al., 2004). This region does not include Kansas, even though substantial yield losses also occur. There are several limitations that come with trying to grow soybeans in this region, including fertility constraints, moisture stress, and improper use of fertilizers. However, the largest constraint at this time seems to be the presence of micronutrient deficiencies, specifically iron, which has traditionally been costly to fix.

Plant response to iron is difficult to predict, because it can be toxic in excess, and plants fervently regulate uptake (Guerinot and Yi, 1994). Under adverse conditions, this very uptake mechanism that saves the plants can be a liability (Lucena, 2000). Iron chlorosis can be due to several factors: soil, plant, and microbial. Soil factors can make iron unavailable in many ways. Low iron availability in the soil is highly dependent on soil pH. Solubility of Fe^{3+} decreases 1000 times for every unit increase in pH, and Fe^{2+} solubility decreases 100 times (Lindsey and Norvell, 1978). Carbonates (Inskeep and Bloom, 1984) and calcareous parent material (Miller et al., 1984), also contribute to a lack of available iron. Low organic matter or a lack of natural chelates can prevent iron movement in the soil to the roots (Lindsay, 1991).

Several management practices are recommended to remediate effects of iron deficiency. The selection of a tolerant variety is one of the most widely recommended methods in chlorosis prevention (Goos and Johnson, 2000; Wiersma 2005). However Helms et al., (2010) suggested that the tolerant variety is not necessarily the best selection, and it would be better to plant a variety with high yield potential outside of severely chlorotic zones. Mordvedt, (1991) found that adding $FeSO_4$ to the furrow increased yields and reduce chlorosis, however inorganic Fe sources quickly become unavailable, and may not be economical .

Foliar iron application, especially of chelated forms, has been inconsistent, being successful at some locations in reducing signs of chlorosis in soybeans (Goos and Johnson, 2000) and increasing yield in some cases (Penas et al., 1990). However it has been unsuccessful at other locations in soybeans (Ligenfelser et al., 2005) as well as corn (Godsey et al., 2003). Another suggested method is to apply chelated iron sources to the soil, which has been successful (Rehm, Personal Communication, 2009) or seed applied, which has been successful in some cases (Karkosh et al., 1988) and unsuccessful in other cases (Goos and Johnson, 2001) for soybean management. Traditionally, chelated iron sources were only economically practical for high-value crops. Technology has heralded a change in chlorosis management. New chelated fertilizers are more effective, more available, and economical for agronomic systems. In addition, good soybean grain prices now allow the use of some of these fertilizer sources.

Iron deficiency also can be induced by various interactions in the soil. Soil nitrate can impact pH and the redox state, which can negatively influence the uptake of Fe (Lucena, 2000). High levels of NO_3-N results in the plants exuding more OH^-, increasing the pH of the rhizosphere, and making iron less available (Atkas and Egmond, 1979). The presence of high levels of phosphorus can decrease soil available iron (Elliot and Lauchli, 1985), and deactivate iron in the plant leaves (Chaney and Coulumbe, 1982). Calcium (Ca) and magnesium (Mg) also play important roles in photosynthesis. High levels of Ca and low levels of Mg can increase chlorosis.

Plants play a critical role in the chlorosis equation as well. Tolerant cultivars, are able to utilize and mobilize Fe under deficient conditions, but non-tolerant cultivars have a harder time mobilizing Fe. There are several mechanisms of tolerance to iron deficiency chlorosis. Some plants possess a greater ability to exude H^+ ions to acidify the rhizosphere, resulting in greater available iron concentrations (Brown et al., 1961). Also, different plants can better metabolize high levels of NO_3-N, P, and bicarbonates. The second chapter looks at the complex soil relationships in an intensely sampled grid, as well as how each of the different varieties processes different soil conditions. The objective of this chapter was to determine the underlying factors that impact chlorosis across seven irrigated sites. Regression analysis was also used to determine those soil factors that impacted iron chlorosis.

THESIS ORGANIZATION

This thesis is divided into four chapters. The first chapter is a general introduction. The second chapter "Foliar and Seed-Applied Iron Fertilizer for Tolerant And Susceptible Soybean Varieties Under Irrigation" looks at different management strategies, including foliar iron application, seed applied iron, and varietal selection, and aims to determine the effectiveness of these treatments at seven different irrigated locations across a transact of Western Kansas. The third chapter "Interpreting Iron Chlorosis Using Factor Analysis and Multiple Regression" uses multiple regression techniques to determine the underlying factors in soils controlling or impacting chlorosis in Western Kansas, and describes how these underlying factors impact plant agronomic parameters. The fourth chapter "Optimum Application Rate of Chelated Iron Fertilizer For Iron Chlorosis in Soybeans" looks at different application rates, and focuses on finding the optimum application rate of a chelated FeEDDHA seed treatment.

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CHAPTER 2-FOLIAR AND SEED-APPLIED IRON FERTILIZER FOR TOLERANT AND SUSCEPTIBLE SOYBEAN VARIETIES UNDER IRRIGATION

ABSTRACT

Soybean [*Glycine max* (L.) Merr.] production has increased by more than 55,000 hectares in the last 25 years in the Western third of Kansas. This region is dominated by alkaline soils, prone to reducing iron (Fe) availability. The objective of this study was to evaluate the relative effectiveness of varietal selection and foliar and seed applied Fe fertilizers to reduce the incidence of Fe chlorosis under irrigated soybean production. Seven locations in Western Kansas with a history of Fe deficiency in soybeans were selected. Plots were laid out in a randomized complete block with a factorial treatment structure with three foliar treatments (FeEDDHA 6%, FeHEDTA 4.5%, and no foliar), two seed coatings (with FeEDDHA seed coating and without), and two different varieties (a non-tolerant and tolerant commercial variety). Plant population, chlorophyll meter (CM) readings (V3 and V6 growth stage), plant height at R7 and grain yield were measured at seven irrigated locations. Foliar Fe application did not impact any of the agronomic parameters measured. However, the use of FeEDDHA seed coating significantly increased CM readings at the V3 and V6 growth stages, plant height at maturity, and grain yield. Chlorosis evaluated at V3-V6 growth stage may not be correlated to the yield potential of a variety in a certain environment. Given soil conditions that are conducive to the development of severe iron chlorosis, the seed-applied chelated Fe fertilizer increased yields by approximately 60% for both tolerant and susceptible varieties. This suggests that producers should choose the best varieties primarily based on yield potential for a certain environment, regardless of iron chlorosis tolerance, if supplemental seed-applied Fe fertilizer will be applied.

Abbreviations: CM, SPAD Chlorophyll Meter; EDDHA, Ethylene Diamine-N,N'-bis (hydroxy phenyl) Acetic Acid; HEDTA, Hydroxyethylethylenediaminetriacetic Acid.

INTRODUCTION

Due to advances in breeding, irrigation technology, and weed control, the corn (*Zea Mays* L.) soybean rotation has extended westward into regions traditionally dominated by winter wheat (*Triticum aestivum* L.) production in the U.S. Great Plains. In the Western region of Kansas between 1980 and 2005, soybean production has increased from 15,000 hectares to approximately 71,000 hectares annually in Northwest, Southwest, and West Central Kansas (NASS, 2010). Production of soybeans in these alkaline, often calcareous soils is frequently impacted by Fe deficiency. Iron chlorosis is thought to impact 30% of the world's semi-arid crop production areas (Yousfi et al., 2007). In the Northern Central United States (an area including North Dakota, South Dakota, Minnesota, and Iowa, and not including Kansas), Fe chlorosis is estimated to cause $120 million dollar's worth of yield loss annually (Hansen et al., 2004). Low Fe availability decreases the synthesis of chlorophyll (Taylor et al., 1982). Symptoms of plants experiencing chlorosis can vary, from interveinal yellowing in the uppermost leaves of the plant, to necrosis and plant death in severe cases (Lingenfelser et al., 2005).

Iron chlorosis is a complex nutrient deficiency. Iron is the fourth most abundant element in the earth's crust (Rodgers et al., 2009); and Fe has the potential for wreaking cellular havoc when in excess (Guernot and Yi, 1994), so plants evolved natural mechanisms to limit Fe uptake. Modern agricultural crop development occurs in naturally fertile areas, with high application of mineral fertilizers (Dakora and Phillips, 2002) to obtain high yields and biomass. This type of crop development passes down the traits that limit Fe uptake to the next generation, which is contrary to most growing conditions that have less than ideal nutrient availabilities (Marschner, 1995). Under calcareous conditions, however, these plant uptake mechanisms become prohibitory to proper Fe nutrition, and a large portion of Fe is in forms unavailable to the plant because of physiological evolution (Miller et al., 1984).

One of the mechanisms that plants use to avoid Fe deficiency is the exudance of H^+ or organic acid ions into the root membrane (Römheld, 1987). This process is controlled by cation-anion regulations, and acidifies the rhizosphere, making Fe more available for plant uptake (Dakora and Phillips, 2002). This process is dependent on nitrogen source, as well as availability and presence of other cations and anions in the soil.

There is often high spatial variability of Fe chlorosis in areas within a field. Different weather patterns can make Fe chlorosis more or less prevalent each year (Godsey et al., 2003). Iron chlorosis and differs under different soil conditions. In general, high soil pH impacts$CaCO_3$ and HCO_3^- availability, especially in wetter springs. Bicarbonates can reduce plant ion absorption (including Fe^{2+}) in absorbing cells (Wadleigh et al., 1952). High bicarbonates in soils also increase P availability in soil solution (Greenwald, 1945), which can result in the deactivation of Fe in the plant leaves due to bonding with P and bicarbonates (Chaney and Coulumbe, 1982; Inskeep and Bloom, 1984), as well as deactivation of P (Brown et al., 1959).

Several management strategies have been suggested for management of Fe chlorosis in soybean systems. These management strategies involve varietal selection (Goos and Johnson, 2000; Helms et al., 2010), fertilizer soil Fe applied in furrow (Godsey et al., 2003; Hergert et al., 1996), seed coating with Fe fertilizer (Karkosh et al., 1988; Goos and Johnson 2001; Wiersma 2005), and foliar application of Fe fertilizer (Godsey et al., 2003; Modaihsh, 1997). However, the benefits gained from application of Fe fertilizer to the agricultural system often is mixed, because results can vary from year to year, and can show little or no improvement in yield or increased plant greenness (Cihacek, 1984). One of the methods with the most consistent the positive results, as well as the lowest cost in dealing with Fe chlorosis is the use of a tolerant variety. Goos and Johnson (2000), and Wiersma (2007) found that growing Fe chlorosis-tolerant varieties resulted in greater yields and chlorophyll meter readings compared to a non-tolerant variety.

Using a foliar application of chelated Fe fertilizer sources has been inconsistent, being successful at some locations in reducing signs of chlorosis in soybeans (Goos and Johnson, 2000), increasing yield in some cases (Penas et al., 1990), and having no effect at other locations in soybeans (Ligenfelser et al., 2005) as well as corn (Godsey et al., 2003). Chelated Fe fertilizer forms are often best as they are soluble and readily available to plants, and can be translocated to the leaves better than inorganic forms (Wittwer et al., 1965). However, they are rarely economical in field scale production of row crops, especially when applied as foliar applications that often need to be repeated. Modaihsh (1997) found that the chelated forms of micronutrients applied to a chlorotic wheat crop in Saudi Arabia as a foliar application had lower yield than the application of Fe sulfate forms, illustrating the difficulties in using micronutrient Fe foliar application.

Applying a Fe source to the soil in furrow has proven to be successful in corn using a Fe sulfate fertilizer (Hergert et al., 1996; Godsey et al., 2003); however, the sulfate forms of fertilizer become insoluble quickly at high soil pH levels. In Kansas, Fe sulfate fertilizer did not reduce the prevalence of chlorosis in soybeans (Ligenfelser et al., 2005). However, the application of FeEDDHA [6% Fe ethylene diamine-N,N'-bis (hydroxy phenyl) acetic acid] to the soil has reduced chlorosis in calcareous soils for peanut in India (Clemens and Singer, 1992).

The use of a FeEDDHA chelated Fe seed coating has been successful in the North Central Region of the United States in some cases (Karkosh et al., 1988; Wiersma, 2005), and unsuccessful in other cases (Goos and Johnson, 2001). Even though Ligenfelser et al., (2005) and Godsey et al., (2003) studied the impact of adding Fe to the soil in Kansas in soybean and corn respectively, they did not use chelated Fe sources. Furthermore, research on soybean Fe deficiency in the U.S. has been focused on rain-fed production systems, with limited research for irrigated conditions in the Great Plains region. The objective of this study was to evaluate the effect of Fe fertilizer application using foliar and seed-applied methods in combination with variety selection for Fe deficiency management of soybean grown under irrigated conditions.

MATERIALS AND METHODS

During 2009 and 2010 seven trials were conducted at producers' fields and research experiment fields with a history of Fe deficiency under irrigated conditions. Descriptions for each location can be found in Table 2-1. Soybean was planted at 0.76 m row spacing with a seeding density of 370,000-420,000 plants ha^{-1}. Post emergence weed control was completed as needed using glyphosate [N-(phosphonomethyl) glycine]. Weather variables were recorded by automated weather station located within 10 km ofthe field locations.

Four varieties of maturity group II or III Roundup Ready® soybean were selected with varying Fe chlorosis ratings. Two varieties were selected to represent very good tolerance (Asgrow 2906 in 2009 and Asgrow 3039 in 2010), and low tolerance (Asgrow 3205 in 2009 and Asgrow 3005 in 2010). Treatments included two different varieties (tolerant and susceptible to Fe deficiency); three foliar Fe treatments (FeEDDHA 6%, FeHEDTA 4.5% [4.5% Fe Hydroxyethylethylenediaminetriacetic acid], and no foliar application), and two seed coatings (coated with 6% FeEDDHA and non-coated) in a three way factorial combination. Plots were 4 rows wide and 7.6 m long.

A mixture of Fe-EDDHA (6% Fe) product, water and a protective seed coating adhesive polymer (2.46 g ha^{-1}) were mixed into a slurry and was applied at a rate totaling 0.22 kg ha^{-1} of actual Fe. The adhesive seed coating polymer was applied to prevent dust off of the applied fertilizer. Seeds were dropped into the mix and coated using a cement mixer, treated seeds were air dried before planting. Two different Fe chelates (Fe-EDDHA or Fe-HEDTA) were applied as foliar treatment at 0.11 kg Fe ha^{-1} approximately at the V3 to V5 growth stage (Pedersen, 2004) and a second application repeated approximately 2-4 weeks later if chlorosis persisted (only in location 2 in 2009). The adjuvant used with foliar applied fertilizer was 7.72 kg of ammonium sulfate additive per 380 L water spray solution.

Soil Sampling and Chemical Analysis

Soil samples were collected at the 0-15 cm depth, and analyzed for pH using a 1:1 soil: water ratio (Waterson and Brown, 1998). Soil organic matter (OM) was measured using the Walkley-Black method (Combs and Nathan, 1998). Iron DTPA (diethylene-triamine-penta-acetate) extraction used the method of Whitney (1998) on an ICP Spectrometer. Extractable potassium was determined by the ammonium acetate extraction and analyzed on an ICP Spectrometer. Nitrate-N was measured with a 1 M KCl extraction (Gelderman and Beegle, 1998) and using a Rapid Flow Analyzer (Alpkem, College Station, TX). Calcium carbonate equivalent (CCE) was measured by adding dilute HCl to the soil and measuring CO_2 gas displacement. This displacement percentage is compared to the total displacement of pure $CaCO_2$, a method adapted from that of Huang et al., (2007).

Plant Parameters

Plant population was counted after emergence at the V3 growth stage. In each location, chlorophyll meter (CM) readings were recorded with a SPAD 502 (Minolta, Ramsey, NJ) using 20 uppermost fully developed leaflets per plot, and averaged into one value per plot. A second set of CM readings were collected to monitor the effectiveness of foliar applied Fe at the V6 growth stage, within two weeks after foliar Fe application. Plant height was recorded at maturity (R7 growth stage). Grain yield was determined by harvesting the two center rows using a plot combine or cutting plants from the two center rows and threshing with a stationary thresher. Grain moisture was measured by weighing approximately 500 g of field-moist grain and weighing the grain again after drying it at 65°C for 6 d. Moisture content was recorded and used to adjust grain yields to a moisture content of 130 g kg^{-1}.

Statistical Analyses

The treatment structure was a complete factorial arranged in the field in a randomized complete block experimental design with four replications. Data were analyzed using PROC GLIMMIX in SAS 9.2 (SAS Institute, 2010). Separate analyses were completed for each location, considering block as a random factor. To determine the effectiveness of treatments across locations, data was also analyzed across locations, using location and block as random factors. Plant population was used as a covariate in the analysis because of the high variability in seeding rates. Values were deemed to be significant at the 0.05 probability level.

RESULTS AND DISCUSSION

The average precipitation and temperature for the growing season at all of the locations are presented in Table 2-2. At every location except location 7, the April precipitation levels were above average, followed by a cooler than average May, creating conditions conducive to Fe chlorosis development. Temperatures in June 2010 were higher than average.becausehigh temperatures can induce Fe deficiency by stimulating rapid relative growth rates in the plant (Inskeep and Bloom, 1986), further exacerbating chlorosis and possibly affecting yields.\

Many studies have attempted to link chlorosis to different soil parameters. However environmental factors, such as the amount of precipitation at different times of the year can be important. For instance, in cool and wet springs in calcareous soils, more HCO3 in the soil becomes available, which is a causative agent of chlorosis (Chaney, 1984). In this study chlorosis developed shortly after emergence at all locations, likely affected by environmental conditions in addition to the typical soil factors conducive to Fe deficiency found at these locations.

Plant Population

Interactions between seed coating and variety selection were present at location 1 and 7 (Table 2-3). The seed coating treatment significantly decreased germination rates in the tolerant variety at location 1, likely the effect of wildlife that severely impacted plant population of the treated seed plots at this location. The non-tolerant variety with seed coating at location 7 was also significantly lower than all of the other treatments. In locations without interactions, location 4 and 5 had fewer plants per hectare in response to the addition of seed coating (Table 2-4). At location 3, 4, and 5, the tolerant variety experienced a decline in population compared to the non-tolerant variety (Table 2-4); the tolerant variety did not show higher population at any location when compared to the non-tolerant variety. However, the results at all locations were variable.Across all locations, the non-tolerant variety without seed coating was 7% higher than the non-tolerant variety with seed coating, and both the tolerant variety, with and without seed coating (Figure 2-1).

Early Chlorophyll Meter Readings

Iron chlorosis developed early at all locations. Location 7 was the only location showing a significant interaction between seed coating and variety type (Table 2-5). At this location, both varieties with seed coating had an equal CM reading; however, in the non-tolerant variety, CM readings were significantly lower than the non-seed coated plants in the tolerant variety. At locations 1, 5, and 6, the tolerant variety had greater CM readings than the non-tolerant variety (Table 2-6). At locations 2, 3, 4, and 7 varietal selection did not affect CM readings. Seed coating caused a higher CM reading at all locations except location 2, and was more influential than varietal selection (Table 2-6) in increasing CM readings.

In the non-seed coated plants, the tolerant variety CM readings were significantly greater than the non-tolerant variety. The application of seed coating generated a significant response in both varieties; however, the non-tolerant variety had a response of 10.80 SPAD units, which was larger in magnitude than the tolerant variety of 8.19 units. Karkosh et al., (1988) and Wiersma (2005) also found that applying Fe seed coating significantly reduced visual chlorosis scores at V3 more for the non-tolerant variety, than for the tolerant variety. These rates of improvement were greater than the comparisons between chlorotic and non-chlorotic locations that Helms et al., (2010) observed. They found that CM readings at the V2 to V4 growth stage was 30 for the chlorotic locations and 35 for the non-chlorotic locations.

Late Chlorophyll Meter Readings

Plants may have the ability to outgrow Fe chlorosis, but at some locations, the V6 CM reading was relatively lower than the V3 reading. This may be because the reserve gained by seed-applied Fe became exhausted later in the season. Foliar application and associated interactions were not significant at any location (Table 2-7). However, there was a significant variety by seed interaction at location 1 (Table 2-8). At location 1, CM values increased from the first sampling. The tolerant variety with seed coating was impaired by the overshadowing weeds, remaining the same as all of the other values. Location 1 was the only location that demonstrated a net decline in CM readings due to seed coating.

At the V6 growth stage, varietal selection showed more effect than seed-applied Fe fertilizer. At location 4, 5, 6, and 7 the tolerant variety had higher CM reading than the non-tolerant variety (Table 2-9). CM readings of seed coated plants were significantly higher at locations 4, 5, and 7; probably associated with soil parameters like higher CCE levels reducing CM values without seed treatment (Table 2-1). Locations 4 and 5 experienced a sharp decline in chlorophyll scores compering to the V3 growth stage, suggesting that the benefit from seed-applied fertilizer started to disappear at this stage. The tolerant variety experienced 10 unit decline from the V3 measurement, where the non-tolerant variety dropped approximately 14 units, with the decline being most severe at location 4. This exhaustion of the seed reservoir was also found at later stages by others (Karkosh, et al., 1988). Goos and Johnson (2001) also noted a potential exhaustion of the Fe reservoir around the seed at this stage, but their rates were only 0.07 and 0.03 kg Fe ha^{-1} of chelated Fe fertilizer, which was much lower than our 0.22 kg Fe ha^{-1} rate.

At location 7, the CM values were slightly lower (between 2-3 unit decline), but the non-tolerant variety with the seed coating dropped more, and became equal to both the tolerant variety with and without seed coating (Table 2-9). At location 1 and 2, there were no differences between the seed coating or varieties, indicating equal CM readings, and that the systems have grown out of chlorosis. Soybeans can grow out of more mild cases of chlorosis as the season progresses, diminishing over time until eventually CM reading indices no longer significantly differ be tween the seed and non seed coated varieties (Schenkeveld et al., 2008). Like our results, Wiersma (2005) found that Fe applied a level of 0.27 kg Fe ha^{-1}, and found that the non-tolerant varieties continued to show responses to seed coating at the V6 growth stage compared to lower application rates. In the second CM reading, the tolerant variety showed higher CM readings across all locations, with 10% increase over the non-tolerant variety (Figure 2-3). However, using seed coating resulted in 15% increase for both varieties. The application of foliar Fe fertilizer did not increase CM readings, like others have found (Goos and Johnson, 2000). In the hot and windy conditions in Western Kansas, the addition of a foliar treatment may not be very effective, because successful foliar applications require sufficient humidity and low wind conditions (Fernandez and Eichert, 2009).

Plant Height

At all locations, seed coating significantly increased plant height. Overall, the non-tolerant variety was taller than the tolerant variety (Figure 2-4) but this can be attributed to genotypic differences and a higher growth potential of the non-tolerant variety planted in 2009. In 2010, both varieties were of equal height under good growing conditions. Soybean plant height was the most variable of all of the agronomic parameters due to confounding effects of environment and varieties. Foliar Fe application showed no significant interaction with any other main effects (Table 2-7). However, the variety by seed interaction was significant at locations 1, 4, and 7 (Table 2-10). At location 4, both of the seed coated varieties were the same height. At location 7, the height did not match the CM level tendencies. The non-tolerant plants were taller, but the tolerant plants were severely stunted. The tolerant plants with seed coating averaged a height of 19 cm, and the non-treated averaged 7 cm. So seed coating did influence the final height.

Even though variety selection and seed coating was not necessarily important in CM readings, variety was important for plant height at all locations but location 6 (Table 2-11). At location 1, 2, and 3, the tolerant variety was significantly shorter than the non-tolerant variety, and the non-tolerant variety was shorter at location 5. Even though the seed treated plots are taller in 6 out of 7 locations, the magnitude of the response differed. Soybeans that exhibit chlorosis symptoms are often shorter than non-chlorotic counterparts (Wiersma, 2005, Penas et al., 1990, Hansen et al., 2003), and adding the chelated Fe source drastically increased the height of mature soybeans. For all combined data, in both varieties, the non-treated soybean plants were about 33 cm shorter than seed coating (Figure 2-4). The non-tolerant variety responded better to seed coating, growing 19 cm, versus the 12.5 cm increase in the tolerant variety.

Grain Yield

There were no treatment interactions between foliar application and other treatments (Table 2-7). However, the variety by seed interaction was significant at location 1, 2, and 5 (Table 2-12). Overall, varietal selection did not impact grain yield in our study (Figure 2-5) like in other locations (Goos and Johnson, 2000; Wiersma 2007). Without seed coating, both varieties yielded approximately the same. With the seed coating, the non-tolerant variety tended to yield more and had a higher overall response to Fe fertilizer. Even though this wasn't a significant difference, it may have the potential to be economically important to the farmer. This is contrary to the results of Karkosh et al. (1988), who found that the re-greening of plants and the improvement to Fe tolerant varieties resulted in significantly higher yields; however, in susceptible varieties, there was no increase in plant yield in response to the seed coating. Yield in the tolerant variety increased 57%, compared to the 63% increase experienced by the non-tolerant variety due to the seed-applied fertilizer. Wiersma (2007) found that applying

FeEDDHA at planting resulted in the reduction of early season chlorosis, but only resulted in a 15% increase in grain yield. This is much lower than the 60% increase we observed in our study. Not all additions of Fe to the soil near the seed was significant. Heitholt et al., (2003) found that Fe treatments applied to soil (DTPA, EDDHA, and Sulfate) yield increased by 13%, but wasn't significant in a Vertisol prairie experiment from Texas. However, these Fe sources were applied to the soil, and were likely immobilized and made inactive more quickly compared to fertilizer applied in direct seed contact.

Grain yield increased in response to the tolerant variety of location 1 and 7 with seed coating increasing yield to equal levels; however, in this case, the tolerant variety yielded higher, increasing 27% versus the 11% of the non-tolerant variety (Table 2-12). At location 2 and 4, both varieties with seed coating yielded the same. Except, in location 2, the non-tolerant variety yielded higher without seed coating, and in location 4, the tolerant variety yielded more without seed coating and the non-tolerant variety did not yield at all. At location 5, both varieties without seed coating did not yield, and the non-tolerant variety yielded half of the tolerant variety with seed coating. So, at some locations, variety was extremely important (Table 2-13)

At location 6, seed coating was still important in increasing grain yield, but unlike all other agronomic parameters and locations measured, foliar treatment was significant (Table 2-13). The FeHEDTA 4.5% had a higher yield overall in comparison to the FeEDDHA 6% treatment and the non foliar application.. Foliar applications are most successful when applied without wind, under higher relative humidity, and sprayed early in the morning (Fernandez and Eichert, 2009). In locations where this study was completed, the air during the growing season is generally hot and dry, and it was nearly always windy, not facilitative to foliar application. However, location 6 was surrounded by a corn field. The corn was nearly 2 m high, and generated a higher level of humidity with evapotranspiration, and also blocked the wind. All of these factors could have contributed to potential better uptakeof foliar applied Fe at this location (Fernandez and Eichert, 2009). In similar locations in Western Kansas under corn, Godsey et al., (2003) found that foliar FeHEDTA 4.5% chelate was not effective in increasing yield, indicating that this region is not conducive to responses from foliar Fe application.

There are locations that may explain the high overall yield in the non-tolerant variety. At location 1, the non treated seeds in the tolerant variety were the same as the treated seeds. The non-tolerant variety out-yielded the tolerant by 21%. Varietal selection has been proven to be successful management strategy in relieving the pressures of Fe deficiency chlorosis (Goos and Johnson, 2000; Wiersma, 2007). However, in systems under irrigation in Western Kansas over a two year period, both tolerant and susceptible varieties, th, yielded equally well under good growing conditions, except at location 7 (Table 2-12), which had a very high amount of total P in the soil (Table 2-1). Under conditions of Fe deficiency, plants exude phenolic molecules and organic acids that increase P mobility from traditionally unavailable sources (Römheld, 1987). In the soybean cultivar 'Forest' several studies indicated that a good indicator for Fe chlorosis development is high P concentration and P/Fe ratio in plant leaves (Chaney and Coulumbe, 1982; Inskeep and Bloom, 1984). For example, Fe oxides can chelate with P so that the availability of each element could be decreased. This happens in plants, as well as in the soil solution. So, in our high P condition, the very trait that makes a tolerant variety successful may be responsible for worse chlorosis conditions.

Equal yields in the tolerant and non-tolerant variety occurred even though the early season CM readings reflected a lower CM in the susceptible variety. Significant yield increases were observed with the application of the seed coating, but not with foliar treatment. Even though plants can outgrow chlorosis in the youngest leaves, the consequences seem to remain in terms of reduced yield (Schenkeveld, 2008; Naeve and Rehm, 2006). However, the influence of the composition and effectiveness of the FeEDDHA treatment on the degree of chlorosis is illustrated best when chlorosis in the control treatment is most severe (Schenkeveld et al., 2008).

Another possible explaination of these yield trends is in the screening methods that seed companies use for determining chlorosis tolerance. Greenness is usually measured visually at the V3-V6 growth stage, and the green plants are considered to have a greater tolerance to Fe chlorosis. There is no yield component to these evaluations under chlorotic and non-chlorotic conditions (Naeve and Rehm, 2006). Therefore, yields may be similar, even though one variety was yellower than the other early in the season. This suggests that, although areas prone to chlorosis are planted to tolerant varieties, it may not always be adventitious at the whole field scale. In a study done with Fe efficient cultivars spread over the Great Plains, Helms et al., (2010) reported that planting a chlorosis tolerant cultivar leads to increased cosmetic effects (greenness), but this does not necessarily maximize the yield in the entire field. In fact, selection for chlorosis tolerance often selected lower-yielding or mediocre cultivars in the absence of chlorosis. Similar results were found by Froehlich and Fehr (1981). With the advancements in precision technology, it may be possible for farmers to plant different varieties within a field to maximize yield potential.

CONCLUSION

Soybean response to seed-applied chelated Fe fertilizer was significant, with increase in grain yield, plant height, and CM readings at the V3 and V6 growth stage in both the tolerant and non-tolerant varieties. Chlorophyll meter readings at the V5-V7 growth stage (after foliar Fe application) was significantly increased by seed-applied Fe fertilizer and variety selection, however, foliar Fe application did not increase in CM readings for any variety. The tolerant variety showed consistently higher CM readings, particularly at the V5-V7 growth stage. However, grain yield level and yield response to seed-applied Fe fertilizer application was the same for both varieties.   This suggest that early season greenness is not always correlated to potential yield response, and chlorosis evaluation at the V3-V6 growth stage may not be correlated to the yield potential of a variety in a certain environment. Foliar application of both Fe sources (EDDHA and HEDTA) showed no significant effect on CM reading, plant height and grain yield overall.

Given soil conditions that are conducive to the development of severe iron chlorosis, the seed-applied chelated Fe fertilizer increased yields by approximately 60% for both tolerant and susceptible varieties. This suggests that producers should consider choosing varieties primarily based on yield potential if supplemental seed-applied Fe fertilizer will be applied.

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TABLES AND FIGURES

Table 2-1. Soil classification and initial soil test information for each location, samples were collected at the 0- to 15-cm depth before planting, and NO_3-N at the 0- to 60 cm depth.

Location	County	Predominant Soil: Series	Subgroup	Soil Chemical Analysis†: pH	CCE‡	OM§	Fe¶	NO_3-N	STP††	STK††
					---- $g\ kg^{-1}$ ----		------------ $mg\ kg^{-1}$ ------------			
			2009							
1	Finney	Ulysses	Aridic Haplustolls	8.1	93	22	2.5	17.4	27	822
2	Lane West	Richfield	Aridic Argiustolls	8.3	61	19	2.8	6.9	19	1050
3	Lane East	Richfield	Aridic Argiustolls	8.2	45	18	3.3	8.8	20	1018
			2010							
4	Thomas North	Ulysses	Aridic Haplustolls	8.3	97	21	1.7	7.0	53	923
5	Thomas South	Ulysses	Aridic Haplustolls	8.5	138	17	2.3	5.1	60	958
6	Finney	Ulysses	Aridic Haplustolls	8.2	114	20	2.3	14.5	24	657
7	Lane	Richfield	Aridic Argiustolls	8.1	140	27	2.5	11.5	117	898

†Mean values of the initial samples collected from each block.
‡CCE, Effective Calcium Carbonates
§ OM, soil organic matter.
¶ Fe, Soil extractable Fe determined by DTPA extraction.
†† STP, Soil test P determined by Mehlich-3; STK, soil test K determined by ammonium acetate extraction.

Table 2-2. Average monthly temperature and precipitation. Values in parentheses indicate deviation from 50 year average historical climate.

		April		May		June		July		August	
Location	Year	Air Temp	Rainfall	Air Temp	Rainfall	Air Temp	Rainfall	Air Temp	Rainfall	Air Temp	Rainfall
		°C	Mm	°C	Mm	°C	Mm	°C	Mm	°C	mm
						Finney County					
1	2009	10.5 (-0.8)	106 (67)	16.9 (-0.2)	41 (-38)	22.4 (-0.2)	80 (-1)	24.7 (-0.8)	66 (-4)	23.5 (-0.9)	46 (-18)
6	2010	12.2 (0.9)	48 (8)	16.4 (-0.7)	91 (11)	25.0 (2.4)	30 (-51)	26.4 (0.9)	61 (-9)	25.6 (1.2)	60 (-4)
						Lane County†					
2 3	2009	9.9 (-1.4)	99 (53)	16.5 (-0.3)	63 (-12)	23.2 (0.8)	62 (-13)	24.6 (-1.2)	37 (-35)	23.0 (-1.9)	56 (-13)
7	2010	12.2 (2.3)	44 (-2)	18.1 (1.3)	8 (-67)	24.8 (2.3)	7 (-69)	26.4 (1.0)	39 (-33)	26.0 (1.1)	39 (-34)
						Thomas County					
4 5	2010	10.8 (1.4)	58 (15)	14.2 (-1.1)	58 (-22)	23.2 (2.1)	62 (-16)	24.9 (0.4)	77 (-13)	24.2 (0.9)	55 (-8)

†Lane Co. historic data is a 100 year historic data set

Table 2-3. Seed coating and variety interactions on plant population

Location	Tolerant		Non Tolerant		P value
	Yes†	No†	Yes	No	V × S
	- - -- - - - - - - plants ha^{-1} (x1000)			- - - - - - - -	P < F
1	203.8 b‡	292.7 a	307.0 a	288.5 a	<0.001
2	331.9 a	327.5 a	333.7 a	337.8 a	0.508
3	339.6 a	313.4 a	348.9 a	326.7 a	0.565
4	226.8 a	243.8 a	248.0 a	294.4 a	0.100
5	263.7 a	270.6 a	280.9 a	313.4 a	0.071
6	119.3 a	126.7 a	123.8 a	153.2 a	0.548
7	408.9 a	406.4 a	349.6 b	424.3 a	<0.001

†Seed coating treatment with FeEDDHA.

‡Means within each row followed by different letters are statistically different at the 0.05 probability level.

Table 2-4. Main effects of seed coating and variety selection on plant population

	Variety		Seed Coating†		Main Effects	
Location	Tolerant	Non Tolerant	Yes	No	Variety	Seed
	plants ha^{-1} (x1000)				P > F	
1	248.0 b	297.6 a	255.2 b	290.4 a	0.0003	0.0073
2	329.7 a	335.7 a	332.8 a	332.7 a	0.3468	0.9887
3	326.5 b	337.8 a	334.2 a	320.0 b	0.0019	<0.001
4	235.4 b	271.2 a	237.4 b	269.1 a	0.0002	0.0008
5	267.1 b	297.2 a	272.3 b	292.0 a	<0.001	0.0069
6	123.1 a	138.5 a	121.6 a	140.0 a	0.3981	0.3125
7	407.6 a	386.9 b	379.2 b	415.3 a	0.012	<0.001

†Seed coating treatment with FeEDDHA.

‡ Means within each variety and seed coating are statistically different at the 0.05 probability level.

Table 2-5. Interactions between seed coating and varietal selection on SPAD Chlorophyll Meter Readings at the V3 growth stage, before foliar Fe application.

	Variety (V)				
	Tolerant		Non Tolerant		P Value
Location	Yes†	No†	Yes	No	V × S
					P > F
1	36.61 a	36.47 a	36.22 a	32.83 a	0.109
2	30.63 a	30.65 a	30.80 a	30.96 a	0.871
3	32.20 a	28.75 a	32.45 a	29.44 a	0.612
4	35.53 a	26.68 a	34.31 a	25.66 a	0.887
5	34.63 a	23.37 a	32.67 a	21.89 a	0.736
6	36.13 a	29.23 a	33.21 a	24.48 a	0.159
7	36.44 a‡	27.13 b	38.42 a	24.68 c	0.008

†Seed coating treatment with FeEDDHA.

‡ Means within each row are statistically different at the 0.05 probability level.

Table 2-6. Main effects of the V3 CM readings on variety and seed coating

	Variety		Seed Coating†		Main Effects	
Location	Tolerant	Non Tolerant	Yes	No	Variety	Seed
					P > F	
1	36.54 a‡	34.53 b	36.42 a	34.65 a	0.0439	0.0556
2	30.58 a	30.89 a	30.71 a	30.75 a	0.5069	0.9326
3	30.47 a	30.94 a	32.32 a	29.09 b	0.3243	<0.001
4	31.10 a	29.98 a	34.92 a	26.17 b	0.1726	<0.001
5	28.99 a	27.28 b	33.65 a	22.63 b	0.0421	<0.001
6	32.68 a	28.84 b	34.67 a	26.86 b	<0.001	<0.001
7	31.79 a	31.55 a	37.43 a	25.91 b	0.7310	<0.001

†Seed coating treatment with FeEDDHA.

‡ Means within each row of variety and seed coating are statistically different at the 0.05 probability level.

Table 2-7 Average SPAD Chlorophyll Meter Readings after foliar Fe application at the V6 growth stage as affected by seed coating and foliar Fe fertilizer applications for a tolerant and susceptible variety.

	Variety				P Value			
	Tolerant		Non Tolerant					
Location	Yes†	No†	Yes	No	V × S	S × F	V × F	V×S×F
					- - - - - - - - - *P* > *F* - - - - - - - - -			
1	38.6 b	40.5 a	40.5 a	38.5 b	0.01	0.76	0.70	0.51
2	35.9 a	35.5 a	35.6 a	35.2 a	0.92	0.81	0.39	0.57
3	39.4 a	38.3 a	38.9 a	38.4 a	0.57	0.25	0.18	0.72
4	25.8 a	15.4 a	20.8 a	10.5 a	0.94	0.88	0.70	0.68
5	25.1 a	13.3 a	20.3 a	9.3 a	0.80	0.92	0.97	0.71
6	42.3 a	40.4 a	34.6 a	34.6 a	0.35	0.28	0.24	0.28
7	34.6 a	29.5 a	33.2 a	24.7 a	0.19	0.66	0.65	0.79

†Seed coating treatment with FeEDDHA.

‡ Means within each row are statistically different at the 0.05 probability level.

Table 2-8 Statistical main effects of the CM readings at V6 as a result of variety, seed coating, and foliar application.

	Variety		Seed Coating		Foliar			P-Values		
Location	Tolerant	Non Tolerant	Yes	No	ED†	HE†	NF†	Variety	Seed	Foliar
								- - - - - - - - - - -*P > F* - - - - - - - - -		
1	39.56 a	39.51 a	39.49 a	39.58 a	39.54 a	39.32 a	39.75 a	0.95	0.90	0.83
2	35.69 a	35.43 a	35.77 a	35.35 a	35.60 a	35.44 a	35.81 a	0.68	0.51	0.76
3	38.85 a	38.67 a	39.16 a	38.85 a	38.73 a	38.69 a	38.85 a	0.70	0.22	0.94
4	20.61 a	15.57 b	23.35 a	12.93 b	17.86 a	18.25 a	18.31 a	<0.001	<0.001	0.90
5	19.09 a	14.77 b	22.58 a	11.29 b	17.56 a	16.75 a	16.49 a	<0.001	<0.001	0.50
6	41.68 a	34.59 b	38.45 a	37.82 a	38.30 a	38.07 a	38.03 a	<0.001	0.34	0.94
7	32.06 a	28.92 b	33.88 a	27.09 b	30.38 a	30.96 a	30.12 a	0.005	<0.001	0.76

†ED, foliar applied FeEDDHA ; HE, foliar applied HEDTA; NF, no foliar control.

‡ Means within each variety, seed coating, and foliar treatment are statistically different at the 0.05 probability level.

Table 2-9 Plant height at maturity (R7 growth stage) as affected by seed coating and foliar Fe fertilizer applications for a tolerant and susceptible variety.

	Variety				P Value			
	Tolerant		Non Tolerant					
Location	Yes†	No†	Yes	No	V × S	S × F	V × F	V×S×F
	- - - - - - cm - - - - - -				- - - - - - - - - -*P > F*- - - - - - - - - -			
1	30.8 c	35.3 b	40.8 a	34.1 b	<0.01	0.75	0.87	0.70
2	66.6 a	51.0 a	75.9 a	64.2 a	0.08	0.54	0.83	0.66
3	63.8 a	53.1 a	74.6 a	60.5 a	0.28	0.89	0.31	0.88
4	46.3 a	25.2 b	42.0 a	4.5 c	0.01	0.86	0.58	0.72
5	41.6 a	15.5 a	33.6 a	6.8 a	0.90	0.88	0.70	0.18
6	50.1 a	44.2 a	48.3 a	41.5 a	0.75	0.46	0.39	0.35
7	18.5 b	6.8 c	51.6 a	16.7 b	0.01	0.58	0.57	0.88

†Seed coating treatment with FeEDDHA.

‡ Means within each row are statistically different at the 0.05 probability level.

Table 2-10. Plant height at maturity (R7 growth stage) as a result of the interaction between variety, seed coating, and foliar application

Location	Variety		Seed Coating‡		Foliar			Source of Variation		
	Tolerant	Non Tolerant	Yes	No	ED†	HE†	NF†	Variety (V)	Seed (S)	Foliar (F)
	cm							*P* > *F*		
1	33.01 b§	37.50 a	35.82 a	34.69 a	35.41 a	34.54 a	35.83 a	0.002	0.358	0.607
2	58.76 b	70.08 a	71.24 a	57.60 b	63.56 a	64.43 a	65.28 a	<0.001	<0.001	0.493
3	58.48 b	67.52 a	69.16 a	56.84 b	63.94 a	63.64 a	61.42 a	<0.001	<0.001	0.353
4	35.74 a	23.09 b	44.16 a	14.67 b	28.86 a	28.17 a	30.22 a	0.002	<0.001	0.850
5	28.53 a	20.20 b	37.58 a	11.14 b	26.13 a	24.72 a	22.24 a	0.006	<0.001	0.403
6	47.14 a	44.91 a	49.22 a	42.83 b	45.38 a	46.85 a	45.84 a	0.108	<0.001	0.656
7	12.68 b	34.11 a	35.04 a	11.75 b	24.10 a	22.55 a	23.55 a	<0.001	<0.001	0.917

†ED, foliar applied FeEDDHA; HE, foliar applied HEDTA; NF, no foliar control.
‡Seed coating treatment with FeEDDHA
§ Means within each variety, seed coating, and foliar are statistically different at the 0.05 probability level.

Table 2-11 Plant yield interactions as affected by seed coating and foliar Fe fertilizer applications for a tolerant and susceptible variety.

	Variety							
	Tolerant		Non Tolerant		P Value			
Location	Yes†	No†	Yes	No	V × S	S × F	V × F	V×S×F
	- - - - - - - - - - - - - - Mg ha^{-1} - - - - - - - - - - - -				- - - - - - - - - *P > F* - - - - - - - - -			
1	2.07 c	2.42 b	2.68 a	2.21 b	0.02	0.67	0.49	0.47
2	3.96 a	2.24 c	4.00 a	3.03 b	<0.01	0.92	0.48	0.87
3	4.23 a	3.25 a	3.77 a	3.37 a	0.08	0.60	0.09	0.13
4	1.77 a	0.71 a	1.17 a	0.00 a	0.56	0.71	0.50	0.59
5	0.97 a	0.08 c	0.84 b	0.00 c	0.02	0.34	0.48	0.53
6	0.98 a	0.70 a	1.13 a	0.87 a	0.82	0.22	0.45	0.81
7	0.31 a	0.06 a	1.25 a	0.29 a	0.07	0.76	0.42	0.20

†Seed coating treatment with FeEDDHA.

‡ Means within each row are statistically different at the 0.05 probability level.

Table 2-12. The impacts of variety, seed coating, and foliar spray main effects on grain yield

Location	Variety		Seed Coating		Foliar			Source of Variation		
	Tolerant	Non Tolerant	Yes	No	ED 6%	HE 4.5%	None	Variety (V)	Seed (S)	Foliar (F)
	- Mg ha^{-1} -								*P* > *F*	
1	2.25 a§	2.44a	2.34 a	2.32 a	2.28 a	2.51 a	2.25 a	0.263	0.718	0.260
2	3.10 b	3.52 a	3.98 a	2.64 b	3.23 a	3.33 a	3.37 a	< 0.001	< 0.001	0.608
3	3.74 a	3.57 a	4.00 a	3.31 b	3.60 a	3.83 a	3.54 a	0.378	0.011	0.349
4	1.24 a	0.51 b	1.48 a	0.28 b	0.64 a	0.86 a	1.13 a	0.011	< 0.001	0.225
5	0.83 a	0.35 b	1.21 a	0.00 b	0.78 a	0.51 a	0.49 a	0.001	< 0.001	0.074
6	0.85 b	1.00 a	1.06 a	0.79 b	0.78 b	1.10 a	0.89 b	0.018	< 0.001	< 0.001
7	0.17 b	0.77 a	0.78 a	0.16 b	0.61 b	0.35 a	0.46 a	< 0.001	< 0.001	0.272

†ED, foliar applied FeEDDHA ; HE, foliar applied HEDTA; NF, no foliar control.

‡Seed coating treatment.

§ Means within each variety, seed coating, and foliar are statistically different at the 0.05 probability level.

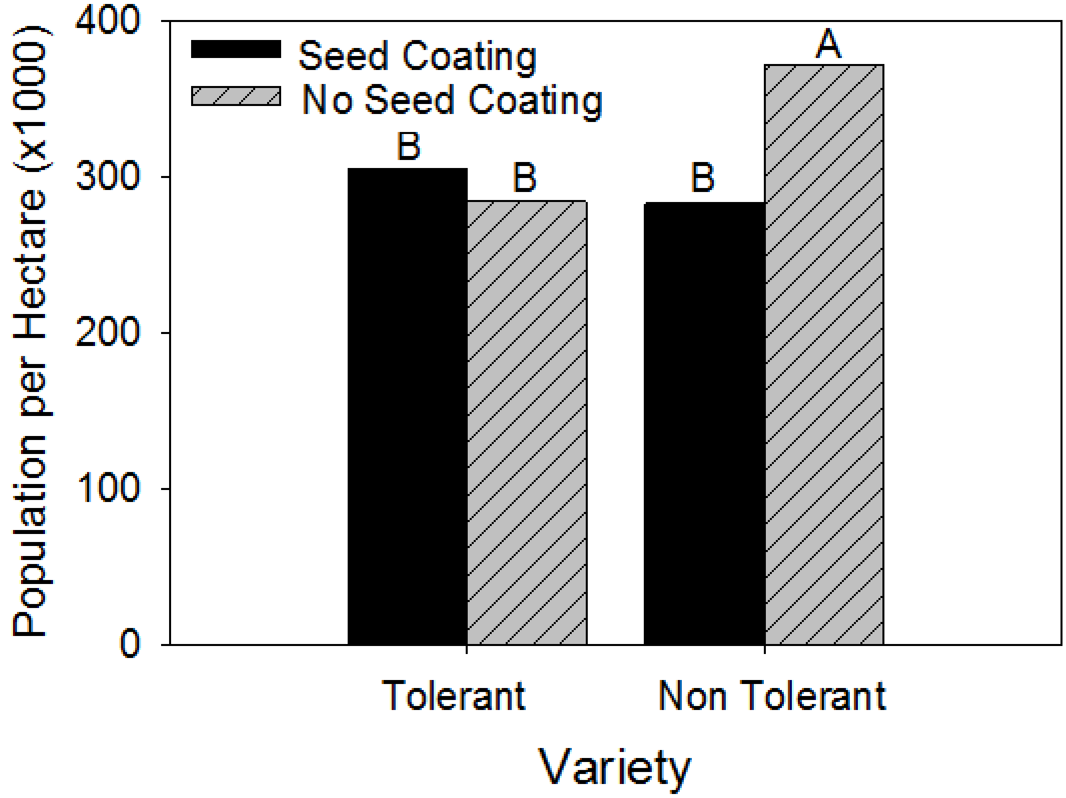

Figure 2-1. Overall Population Per Hectare (x1000) at the V3 stage across all locations, counted before foliar application. Means with different letters are statistically different at the 0.05 probability level.

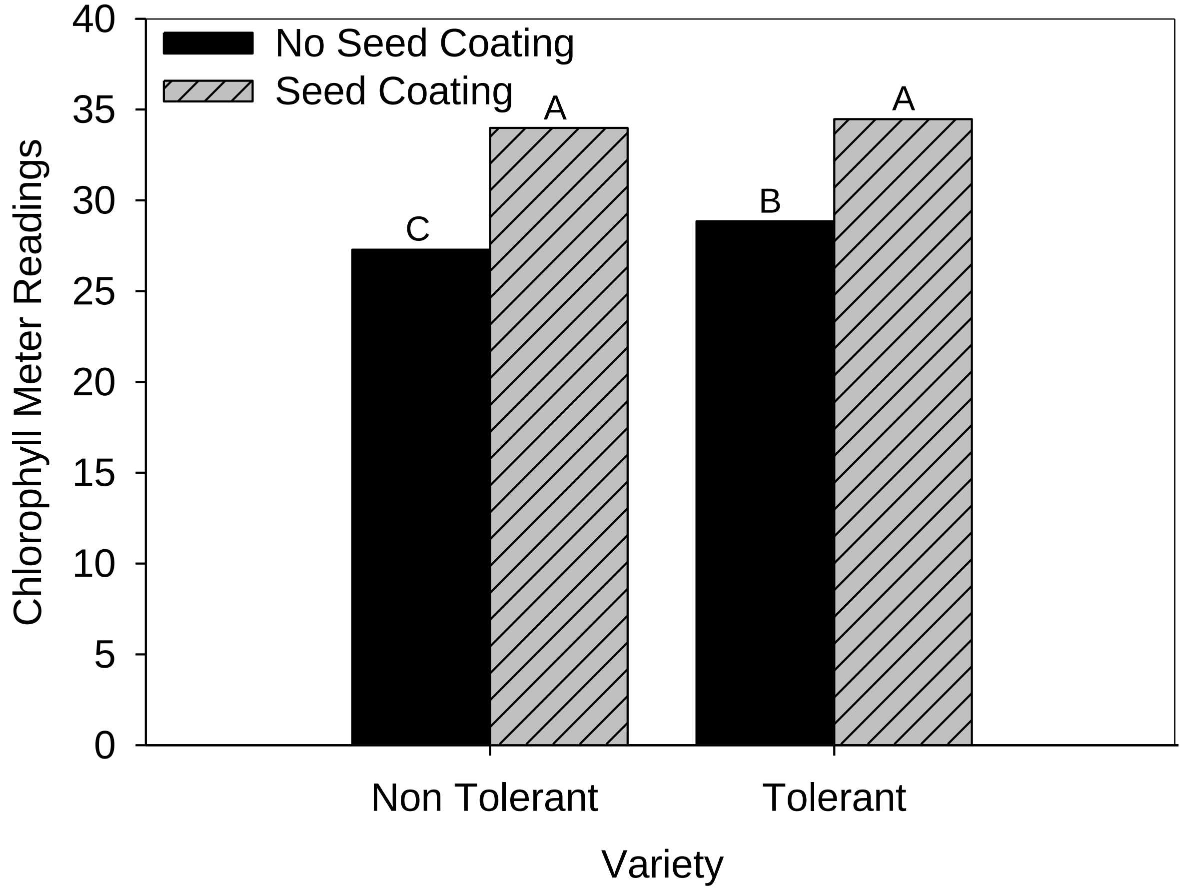

Figure 2-2. SPAD chlorophyll meter readings at the V2-V4 growth stage before foliar Fe application, average across all locations. Means with different letters are statistically different at the 0.05 probability level.

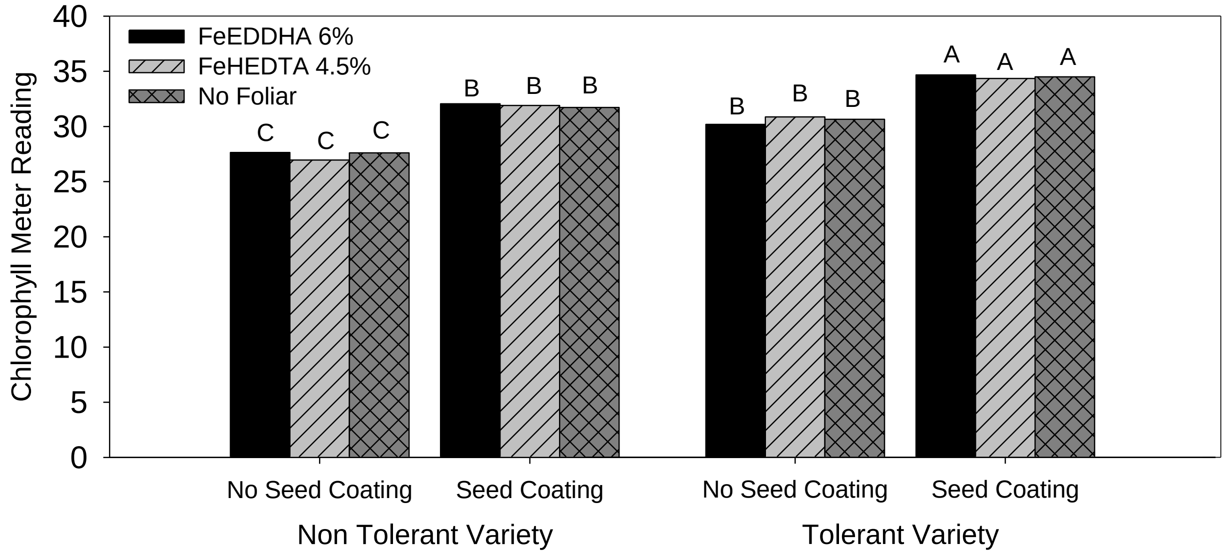

Figure 2-3. SPAD chlorophyll meter readings at the V5-V7 growth stage within 2 weeks after foliar Fe application, average across all locations. Means with different letters are statistically different at the 0.05 probability level.

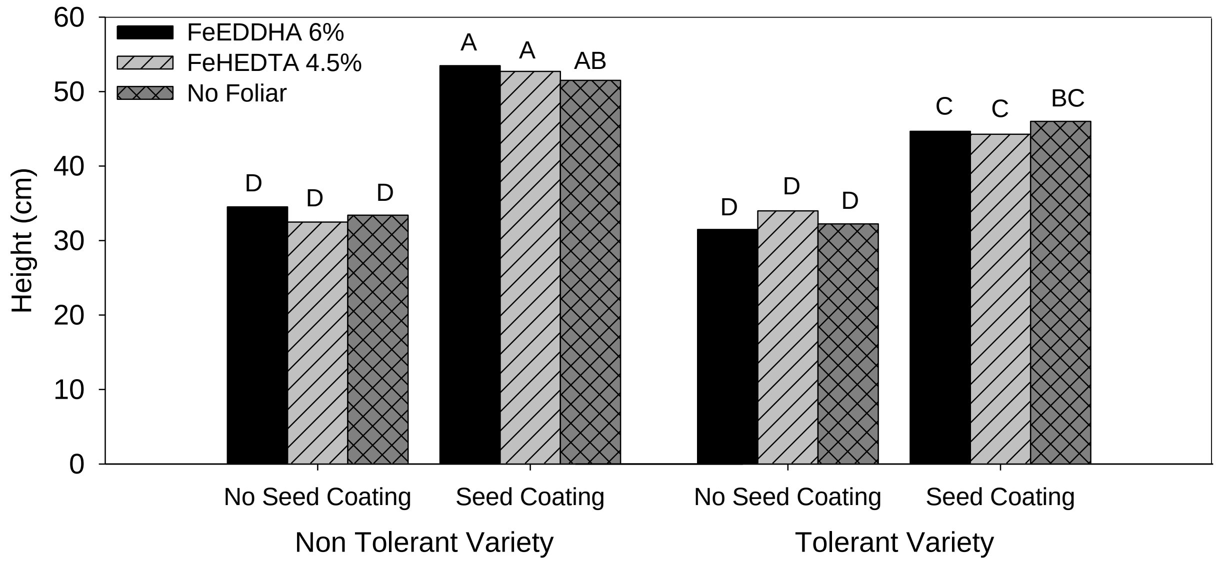

Figure 2-4. Soybean plant height at maturity average across all locations. Means with different letters are statistically different at the 0.05 probability level.

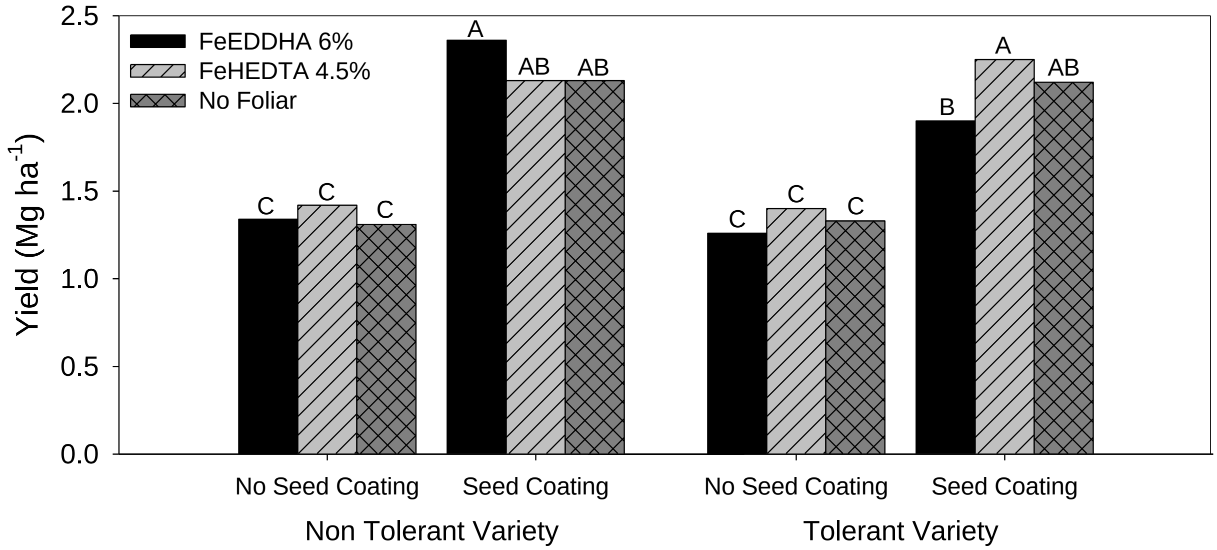

Figure 2-5. Soybean grain yield average across all locations. Means with different letters are statistically different at the 0.05 probability level.

CHAPTER 3- INTERPRETING SOYBEAN IRON CHLOROSIS USING FACTOR ANALYSIS AND MULTIPLE REGRESSION

ABSTRACT

Iron chlorosis in soybeans [*Glycine max* (L.) Merr.] is difficult to predict and can be reliant on several soil factors. The objectives of this study were to (1) determine the underlying factors conducive to iron chlorosis using exploratory factor analysis and (2) determine how individual soil variables impact iron chlorosis using a stepwise regression. This study evaluated seven locations in western Kansas, determining how the underlying soil factors influenced varietal performance, and with and without seed applied Fe fertilizer. Factor analysis was performed using the Varimax rotation and the Heywood convergence to get the best possible relationships. Factors were deemed significant if the Eigenvalues were greater than 1, and then removed if only one variable was present, making the factor trivial. Multiple regression analysis was performed using stepwise variable selection. Two significant underlying factors were related to iron chlorosis. Factor 1 was dubbed "Plant Chlorosis", and soil NO_3-N and Electrical Conductivity contributed to high levels of plant greenness, and P and Ca had an antagonistic effect on plant greenness. Factor 2 was the soil iron availability factor, which was made up of soil DTPA-Fe and Mg levels that positively influenced soil available iron, and the Alkalinity Stress Index (ASI) (made up of pH and carbonates), which negatively impacted soil iron availability. These underlying factors occurred in all varieties and seed-applied Fe fertilizer treatments. These underlying factors were indicative of soil chlorophyll meter readings (CM) at the V3 and V6 growth stage, as well as in grain yield.

Abbreviations: ASI- Alkalinity Stress Index CM- chlorophyll meter, EC- Electrical Conductivity EDDHA- 6% iron ethylene diamine-N,N'-bis (hydroxy phenyl) acetic acid OM- Soil Organic Matter

INTRODUCTION

Iron (Fe) is a critical nutrient for photosynthesis in higher plants (Longnecker, 1988); however, various interactions take place in the soil that can make Fe unavailable for uptake and plant use. Nutrient interactions can occur at the root surface or within the plant and are often considered to be in two major categories. In the first category are interactions that occur between ions that are able to form a chemical bond in the plant. In this case, ionic bonds create precipitate forms (Fageria, 2001). In the case of Fe, high levels of Fe and P can be present in leaves, but the plant may be presenting iron deficiency symptoms, because the P causes Fe to precipitate out of solution in the leaf (Decock et al., 1960). The second form of interaction is between ions whose chemical properties are similar enough that they compete for sites of adsorption, absorption, transport, and function on plant root surfaces or within plant tissues (Fageria, 2001). Cation-cation and anion-anion interactions occur at the membrane level and are primarily competitive (Hiatt and Leggett, 1974).

Interaction between nutrients in crop plants occurs when the supply of one nutrient affects the absorption and utilization of other nutrients in the soil and in the leaf (Fageria, 2001). Iron has antagonistic relationships with many other cations, and iron deficiency may inhibit adsorption of some elements (Madero et al., 1993). Iron is an essential component for a number of critical enzymes including those involved in photosynthesis and nitrogen fixation (Rotaru and Sinclair, 2009). However, the interactions that create iron chlorosis can be complex. The amount of iron in the soil affects uptake and use efficiency of other macronutrients (Fagaria, 2001; Malakouti, 2008). In a series of studies in western Minnesota, chlorosis was associated with higher soil Mg levels, higher Mg/Ca ratios, plant P levels, high soil moisture, low soil temperature, and higher bicarbonate levels (Inskeep and Bloom, 1984; Bloom and Inskeep, 1986; Inskeep and Bloom, 1986). Terman et al., (1977) reported a positive interaction between N and P, which leads to higher yields from increasing the ability of roots to adsorb and transport P. Legumes appear to be especially vulnerable to phosphorus (P) and iron (Fe) deficiencies because of their role insupporting symbiotic nitrogen fixation (Rotaru and Sinclair, 2009; O'Hara et al., 1988).

In high pH and calcareous soils, soybean yield is often limited by Fe deficiency, especially if nitrogen supply is reliant on symbiosis for biological N fixation (Caliskan et al., 2008). Iron is a vital part of microbe health, rhizobia bacteria nodulation, plant photosynthetic processes and physiological growth. Applying iron fertilizers and lowering the soil pH can increase iron uptake, which can remediate chlorosis (Rai, 1988). Large amounts of cations need to be exuded from the plant in order to maintain electron balance, to make P, Mn, Fe, Cu and Zn readily available in high pH soils (Aguilar and Van Diest, 1981; Gahoonia et al., 1992; and Gardner et al., 1983).

There has been significant work done on Fe chlorosis in the calcareous glacial lobes originating from calcareous shale bedrock under the Keewatin ice dome (Leverett, 1932), including the Des Moines lobe (Rosgovska et al., 2006) and the Red River Dome (Inskeep and Bloom, 1986; Franzen and Richardson, 2000). In these regions, Fe chlorosis occurs usually in areas of depressions in the landscape, or the potholes, left behind by massive chunks of melting ice. These depression areas usually have water in them temporarily, and the carbonates in the surrounding landscape leach into these areas (Rogovska et al., 2006). Water movement is very important in determining chlorosis risk. Therefore there is often high spatial variability of Fe chlorosis within a field. In addition, different weather patterns can make chlorosis more or less prevalent each year (Godsey et al., 2003; Naeve and Rehm, 2006), with significantly different effects under different soil conditions.

In the Great Plains region, including western Kansas, such potholes and depressions are less common. The loess in Western Kansas is also calcareous in nature, but because the soils are more uniformly wind deposited, these potholes do not exist.Even though there are spots in the field that can be more severely affected, Fe chlorosis can impact entire fields. In comparison to other regions, soils in Western Kansas are fairly uniform, so the properties that create Fe chlorosis are likely different. Research on iron chlorosis has been conducted for several decades, and studies suggested various soil factors associated with Fe chlorosis. Individual studies found key factors determining chlorosis, including soil pH, calcium carbonate concentration, organic matter and the interaction of iron with other nutrients, especially nitrogen and phosphorus. However, few studies have evaluated iron chlorosis with a multivariate approach including the expected interaction of soil and potential production management factors under production conditions. Multivariate analysis is an exploratory tool useful in determining simultaneous observation and analysis of more than one variable in a multidimensional space. Factor analysis is used to find underlying factors that one variable alone cannot measure. The objective of this study was to determine the underlying factors and the multi-linear models that are associated with Fechlorosis in the Great Plains region of western Kansas.

MATERIALS AND METHODS

Trials were conducted at producers' fields and research experiment fields with a history of iron deficiency. In 2009 studies were conducted at three locations, and four locations in 2010, for a total of seven site-years under irrigated conditions. Description for each location can be found in Table 3-1, and soil chemical factors can be found in Table 3-2. Soybeans were planted at 0.76 m row spacing. Four varieties of maturity group II or III Roundup Ready® soybeans were selected with varying iron chlorosis rating. Two varieties were selected to represent very good tolerance to Fe chlorosis: Asgrow 2906 in 2009 and Asgrow 3039 in 2010, and low tolerance: Asgrow 3205 in 2009 and Asgrow 3005 in 2010. Treatments in a factorial arrangement included two different varieties (tolerant and susceptible to Fe deficiency and two seed coatings (coated with 6% FeEDDHA and non coated). A mixture of Fe-EDDHA (6% Fe) product, water and a protective seed coating adhesive polymer (2.46 g ha^{-1}) were mixed into a slurry and was applied at a rate totaling 0.22 kg ha^{-1} of actual iron. Treated seed was air dried before planting.

Agronomic Parameters

In each location, chlorophyll meter (CM) readings were recorded with a SPAD 502 (Minolta, Ramsey, NJ) for 20 uppermost fully developed leaflets per plot, and averaged into one value to ascertain the effectiveness of seed treatment at the V3 growth stage (Pedersen, 2004). A second set of CM readings at the V6 growth stage were used to monitor chlorosis level later in the season. Grain yield was determined by harvesting the two center rows using a plot combine or cutting plants from the two center rows of each plot and threshing with a stationary thresher. Grain moisture was measured by weighing approximately 500 g of field-moist grain and weighing the grain again after drying it at 65°C for 6 d. Moisture content of plot samples were recorded and used to adjust grain yields to a moisture content of 130 g kg-1.

Soil Sampling and Chemical Analysis

Plots were 4 rows wide and 7.6 m long and were intensively sampled to form the basis of multivariate analysis. Soil samples were collected from each plot at the 0-15 cm depth, and analyzed for pH using a 1:1 soil: water ratio (Watson and Brown, 1998). Iron DTPA (diethylene-triamine-penta-acetate) extraction used the method of Whitney (1998) on an ICP spectrometer. Soil organic matter (OM) was measured using the Walkley-Balck method (Combs and Nathan, 1998). Extractable potassium was determined by the ammonium acetate extraction and analyzed on an ICP spectrometer. Subsurface soil pH and DTPA-Fe were also measured at the 15-30 cm depth. Nitrate-N was measured to a depth of 0-60 cm with a 1 M KCl extraction (Gelderman and Beegle 1998) and using a Rapid Flow Analyzer (Alpkem, College Station, TX). This displacement percentage is compared to the total displacement of pure $CaCO_{2,}$ a method adapted from that of Huang et al., (2007).

The alkalinity stress Index (ASI) was created based on the methodology of Rogovska et al., (2006). This index looks at the relationships between relative yield, soil pH, and CCE. We calculated the relative yield decline for one unit of pH, and the relative yield decline for one unit of CCE. For this data, pH significantly decreased relative yield to a greater extent than the CCE equivalent, so we divided the difference in relative yield decline of CCE by the difference in relative yield in pH, which yielded a value of 0.48. This equation for soils in Western Kansas is listed in equation 1.

$$ASI = pH + 0.48CCE \qquad [1]$$

Data Analysis

Simple correlation analyses were performed to all measurements collected from each location. For factor analysis, all soil variables were standardized with a mean equal to 0, and a standard deviation equal to 1. Normality tests were conducted using PROC UNIVARIATE in SAS 9.2 (SAS Institute, 2010). Factors were extracted with the FACTOR procedure using Maximum Likelihood, and the Heywood procedure, which maximize variables at a correlation of 1 (Johnson, 1998). The Varimax procedure was used as an oblique orthogonal rotation method to determine the best fit. Rotation of factors is a way to get more meaningful estimate of the factors to get a linear transformation (Hair et al., 1987; Johnson, 1998). Underlying factor variables were accepted was determined if the Eigenvalues for the correlation matrixwere larger than one. The new variables are known as latent variables, meaning they are not directly measureable, but represent underlying factors that may be a combination of variables (Terra et al., 2006; Kaspar et al., 2004).

The PROC REG procedure in SAS was used to develop multiple linear regression models to select the set of soil variables (in this case, Factor 1 and 2) needed to predict plant CM readings and grain yield for all varieties and seed-applied fertilizer treatment combinations. Stepwise regressions were running using PROC STEPWISE, with the soil variables as predictor variables to determine how grain yield and CM readings (at V3 and V6) were predicted.

RESULTS AND DISCUSSION

Correlation Analysis and Variable Selection

The correlation analysis does not always reflect the actual relationships in true soil conditions. For example, the 0-15 surface pH variable and organic matter variable are not correlated significantly with any measured soil parameter (Table 3-3). A potential limitation of correlation analysis is that the regression coefficients in the equation change based on the other variables that are used in the regression, and tests of significance of the coefficients become unreliable when variables are highly correlated (Johnson, 1998). Nitrate-N was only positively correlated with electrical conductivity (EC); EC was correlated negatively with Ca, but Ca was not correlated with NO_3-N. For this reason, the simple correlation coefficients do not always exemplify the underlying relationships and multicollinearities in the soil. These correlation coefficients also show that many variables are often, but not always correlated with crop yields (Mallarino et al., 1999).

These relationships are difficult to express using the correlation analysis. However, from these relationships, we determined that the ASI factor and soil CCE measured the same parameter, and we could remove CCE from the analysis. This is expected, because the ASI index is directly determined by the CCE levels. Because these two variables show redundant information, we can eliminate one of the variables (Kasper et al., 2004). Since the ASI index also uses pH in the calculation of the index, pH can also be removed from the factor analysis set as redundant information.

Once the factor analysis was run, it was determined that the third factor created from this output was significant to only one variable, phosphorus, making it a trivial factor, and it was dropped from further analysis. There were two underlying factors that were determined by the varimax rotation to be significant (Table 3-4).

Factor 1: Plant Chlorosis Factor

Factor 1 contained six soil variables. Nitrate-N, EC, and subsurface- Fe were all positively correlated with the factor score, and Ca, subsurface-pH, and soil P levels all negatively impacted the factor score. This factor was arbitrarily assigned the label of “Plant Chlorosis”, as all of these factors have potential plant interactions that can make chlorosis worse. Nitrate-N, EC and profile Fe had a positive impact on this factor. The positive effect of NO_3-N is not always the case, high levels of NO_3-N, both applied as a fertilizer before the season, or present in the soil can actually increase iron chlorosis at high levels, especially in non-tolerant varieties (Wiersma, 2010). In a Mediterranean environment prone to chlorosis, Koutroubas et al., (1998) found that if N is applied over 80 kg N ha^{-1} to soybeans, yield responds negatively or not at all; however, they did not add Fe to this study, but the same negative response to nitrate content is found in conditions with Fe chlorosis under increases in NO_3- content. However, under conditions of iron deficiency, biological nitrogen fixation is often arrested (Chonkar and Chandel, 1991; Terry and Jolley, 1994), creating potential nitrogen deficiency. The application of a "starter N fertilizer" has been found to be beneficial to improve early soybean growth and yield (Azfa et al., 1987; Starling et al., 1998) under these situations. These soils may not have enough NO_3-N to be detrimental to growth, so potential synergistic relationships between the subsurface-Fe and the profile NO_3-N test can exist. Caliskan et al., (2008) found that Fe significantly improves N utilization of soybeans because combined usage of N and Fe had a synergistic effect on growth and yield of soybeans in a Mediterranean environment (Caliskan et al., 2008). Because our NO_3-N levels are adequate and low (between 6.7 and 17 mg kg^{-1}), the relationship between chlorosis levels and NO_3-N could be synergistic, with CM readings increasing as NO_3-N levels increase, as opposed to antagonistic, because of this positive relationship indicated by the factor analysis. There are not many studies that have looked at Fe in the subsoil. The positive effect that we found for subsoil Fe is contrary to the results of Booss et al, (1984), who found that higher levels of subsoil DTPA-Fe existed in the chlorotic grape vine plants versus the green plants in their factor analysis. Electrical conductivity (EC) and high soluble salts in soils generally have been shown to increase chlorosis with increasing salt levels (Franzen and Richardson, 2000). These high salt levels were also found to decrease nodule activity and N accumulation (Cordovilla et al., 1995). However, in our study, the EC levels were positive in the underlying Factor 1, along with soil NO_3-N. This indicates that EC may be directly reflecting nitrogen salt levels. In the North Central U.S., salts are formed through water movement and deposition ephemerally, and their calcic horizons are associated with long-term water movement in low areas of the field (Franzen and Richardson, 2000). In Western Kansas, the soils are well drained, and ephemeral salt deposition is a rare occurrence, as water rarely accumulates on the soils surface. The topography is generally flat, and soil water movement is more likely to be even in the soil profile. The EC levels at all sites except 1 and 6 (Finney County) were well below 1 m S^{-1} (Table 3-2).

The soil P, Ca, and subsurface-pH negatively impact the Plant Chlorosis factor. The solubility of iron in the soil decreases with the increase in pH and bicarbonate levels (Bloom et al., 2000). In calcareous soils, calcium carbonate buffers soil solutions, which negatively affects plant uptake of iron and utilization above a pH of 7.5 (Lindsay and Schwab,1982). In our soil, the subsurface-pH can negatively impact iron uptake, thus increasing chlorosis, especially later in the growing season when the rooting has expanded deeper in the soil profile. The only sites that experienced a decline in CM readings from V3 to V6 (locations 4, 5, and 7) had an increase in pH of 0.24 units in the subsurface compared to the surface pH, whereas locations that experienced no change or an increase in CM only exhibited a pH increase of 0.10 in the subsurface. The subsurface-pH was the only parameter that was significant in both Factor 1, and Factor 2, meaning that it highly influences Fe availability, even though the yield, subsurface-pH regression curve only had a r^2 value of 0.30 (Figure 3-1), the model was significant to a P value of <0.001. This is indicative that the regression analysis may not predict the complex interactions in soil.

Phosphorus also can negatively affect Fe availability. Our analysis show that the higher the P levels, the more negative the Plant Chlorosis factor coefficient was. Plant physiology developed unique mechanisms to handle P and Fe deficiencies. Under conditions of Fe deficiency, plants can exude phenolic molecules and organic acids that increase P mobility from traditionally unavailable sources (Römheld, 1987). These organic acid anions exuded in plant roots as a result of P deficiency (Hoffland et al., 1989) lowers rhizosphere pH, making micronutrients such as Mn, Fe and Zn to be more available in calcareous soils (Dinkelaker et al., 1989). The relationship between Fe and P is antagonistic. Under conditions of high P, plants are capable of luxury consumption (Tagliavini et al., 1991), generating higher levels of P in the leaves. Iron oxides inside the plant or in soil solution can become immobilized by excess P so that the availability of both plant and soil Fe could be decreased (Ayed, 1970).

Phosphorus and Ca availability are also related to one another. Like Fe/N, the P/Ca relationship can form a synergistic effect, except this effect is negative on the Plant Chlorosis Factor. Calcium has the potential to increase the plant absorption of P and K with high concentrations (Ishizuka and Tanaka, 1960). Under increasing calcium levels, the uptake of Fe, P, Mg, on dry beans were affected: P concentration increased in the plants, (corn (*Zea Mays* L.), common bean (*Phaseolus vulgaris*), and wheat(*Triticum subspecies*) while Fe, and Mg decreased (Fageria and Baligar, 1999). This means that high levels of calcium have the potential to be antagonistic to Fe uptake. It is fitting that locations that had Ca levels greater than 4,700 mg kg^{-1} (4, 5, and 7) were lower in CM SPAD values and yield.

Factor 2: Soil Iron Availability

The soil charactoristics that were significant in the Varimax rotation were the surface Fe level and Mg, that were positively correlated with "soil available Fe". -pH and ASI are negative values in Factor 2. The Alkalinity Stress Index uses pH and carbonates to calculate the alkalinity stress, and higher levels were found to correlate well to yield decline attributed to chlorosis (Rogovska et al., 2006). Like Sharma et al., (2008), our data found that DTPA Fe was negatively correlated with pH, and calcium carbonate level. However, they also found that DTPA Fe was positively correlated with OM, which was not the case in our study.

In Factor 2, Mg levels had a positive relationship with surface Fe. Magnesium content in soil solution was also found to influence availability of iron by Loeppert and Hallmark (1985). For Factor 2, it is fitting that Fe in the top 15 cm impact soil available Fe early in the season, as it is in seed germination zone. If there is little iron available in the surface, roots cannot access it, and plants have a greater potential to become chlorotic. This could be one of the reasons that plants grow out of chlorosis.

Relationship of Factors to Agronomic Parameters

By using thecalculated factors from multiple regression analysis, we reduce the impact of multicollinearities, and eliminate extraneous variables not important in the analysis. We also determine if the calculated factors are related to our measured agronomic parameters (Table 3-5). By splitting the groups into the four categories (two varieties by two fertilizer treatment combinations), we can evaluate how underlying factors may be relevant under different management conditions. This can be used to determine how important seed-applied Fe fertilizer is to a particular variety.

Without seed-applied Fe fertilizer, both varieties were highly influenced by the two factors for all agronomic parameters. Chlorophyll meter readings at V3 (CM1) for the non-tolerant variety, the Factor 2 explained 1.5 times more variability (defined by the coefficients in the linear analysis) than factor 1. In the tolerant variety, however, the plant chlorosis factor explained 1.8 times more variability than the soil available iron. This indicates that the CM readings in the tolerant variety are less influenced at V3 by lower levels of Factor 2 (high ASI values and subsurface-pH do not have such a negative effect). However, these two factors only account for 36-40% of the variability in CM values (Table 3-5). At V6, the two factors explain between 62 and 82% of the variation in CM levels. This variation is most influenced by the Plant Chlorosis factor (Factor 1) in both varieties; however, the tolerant variety is impacted to a greater degree. Yield is the factor that is most impacted by negative values of Factor 2 (high subsurface pH and ASI values). The Soil Available Fe factor explains over twice the amount of variation compared to the plant chlorosis factor in the model for yield for both varieties. However, in this case, the soil available Fe factor accounts for less variability in the tolerant variety than the non-tolerant variety, which is opposite to the second CM values. This is an indication that early season chlorosis scores may not be necessarily the best predictor of yield potential in Kansas.

With seed-applied fertilizer, the importance of the calculated soil factors is different. In the non-tolerant variety neither factor significantly affects CM1. In the tolerant variety with seed coating, the early CM level also showed that Factor 2 was not significant (soil Fe and Mg did not increase chlorosis and ASI and subsurface pH did not decrease chlorosis), but the Plant Chlorosis factor was significant. This indicates that there may be internal varietal differences to how plants process iron. Under adequate soil Fe amounts (with seed coating) in the tolerant variety, the coefficient for Plant Chlorosis is negative. This means that higher levels of NO_3-N, EC, and subsurface-Fe levels reduce the CM readings. Or, as previously mentioned, NO_3-N, and EC can negatively impact chlorosis scores. This could be that the particular variety had maximized the potential CM readings for the soil type, or an indicator that the tolerant variety may be more sensitive to nutrient imbalances once adequate Fe was met.

At V6, the non-tolerant variety is more impacted by the soil available iron than by the plant chlorosis factors. Like at V3 without seed coating, the non tolerant variety is more impacted by the soil available Fe, and the tolerant variety is more impacted by the Plant Chlorosis factor, this could indicate that the addition of an iron seed coating can delay the onset of iron chlorosis. The tolerant variety with seed coating is actually negatively impacted by the factor 2 scores. This could indicate that the variety has reached "maximum greenness", or more likely, the tolerant variety is better at using available iron, leaving more cheltated Fe in the profile. These excess iron concentrations in the profile can increase microbial competition for iron.

In the non-tolerant variety with seed coating, only Factor 2 significantly affected yield. This indicates that under adequate amounts of Fe provided by fertilizer, the non-tolerant variety could better handle conditions of low NO_3-N, EC, subsurface-Fe, high P, subsurface-pH, and Ca concentrations. In the tolerant variety, Factor 2 was not significant for GY, but the plant chlorosis factor (Factor 1) was significant. So, the tolerant variety does significantly reduce risk associated with factor 2 (soil available iron), but the tolerant variety is more susceptible to higher P and Ca levels and lower NO_3-N and EC levels. Helms et al., (2010) stated that planting a tolerant cultivar may reduce the prevalence of chlorosis, but may not maximize yields in the field. In this case, the non-tolerant variety may have the higher yield potential, and when we apply a Fe fertilizer to the non-tolerant variety, yield can be maximized by applying Fe fertilization to the non-tolerant variety.

Stepwise Analysis of Variables

To further evaluate some of the soil relationships between variables, we used a stepwise multiple regression analysis on all of the individual values. The Beta coefficients and the regression models (Table 3-6) indicate that numerous variables have some effect on the yield and CM readings in each of the treatment combinations. The factor analysis uses all soil parameters together to gauge the relationships and prediction power of our models. However, not all individual variables that were predicted in the underlying factors impacted the CM levels or yield in similar fashions, and not all variables in the underlying factors are significant in the stepwise regression (Table 3-7).

Chlorophyll meter readings will continue to respond to fertilizer application, including nitrogen, until something else limits the plant chlorophyll level. Under conditions that are both deficient in nitrate and iron, it is to be expected that both increases in Fe and increases in NO_3-N variables would positively increase CM readings (Shapiro et al., 2006). The stepwise analysis demonstrates that increases in NO_3-N in the soil improved the CM2 readings in all four treatment groups, and the CM one scores for all groups but the non-tolerant variety without seed coating. These increases could have been caused by low iron availability, or low nitrogen levels. Contrary to these increases in CM readings, the yield in the tolerant variety with seed coating was negatively impacted by higher nitrogen levels. This negative effect of high NO_3-N levels on chlorosis has been observed by other researchers (Wiersma, 2010; Lucena, 2000). This is further evidence that the tolerant variety may not be able to handle excesses of some soil nutrients like we concluded with our factor analysis. This same trend was observed in the EC levels, indicating that EC and NO_3-N could have been measuring similar parameters.

When P was significant, it negatively impacted yields and CM readings. However, P impacted the tolerant variety more, especially without seed applied Fe fertilizer. The non-tolerant variety did not experience a decline in CM readings like in the tolerant variety, but it did experience yield declines due to increasing P levels. The coefficients calculated by the model for the non-tolerant variety were 10 times smaller than the coefficients for the tolerant variety.

Surface Fe levels were important for yield in all four categories of data, and in all cases yield positively responded to higher soil Fe levels. In one instance in the tolerant variety the CM declined with seed coating. This could be due to a plateau effect. Even if plants are to consume excess amounts of nutrients like N and Fe, the SPAD values will plateau out and not increase past a certain level (Shapiro et al., 2006). However, at CM2, the seed coating again generated higher CM values. A similar trend occurred in the non-tolerant variety. This could indicate that the effects of seed coating are dissipated by V6. Subsurface iron levels were also important in sustaining the yield and CM readings for both varieties without seed coating. However, unlike surface Fe, subsurface Fe in the tolerant variety with seed coating was not significant. Without seed coating, the tolerant variety was significantly impacted by subsurface-Fe levels (Table 3-6).

Many researchers have indicated the importance of carbonates and pH levels in determining the risk of iron chlorosis. However, in this study the ASI index, which is comprised of CCE and pH, was significant in predicting yield loss and not in CM readings in the tolerant variety. With seed coating, the tolerant variety was able to maintain greener plants and higher CM levels in the presence of varying levels of calcium carbonate and pH, but yield was still negatively affected by ASI. The tolerant variety was also able to recover later in the season and not show yield damage resulting from high ASI levels.

Subsurface-pH generated the same response among agronomic parameters that the ASI index. Even though subsurface-pH was important in defining both factors in the factor analysis, it only significantly decreased CM and yield of the non-tolerant variety without seed coating. This indicates that the non-tolerant variety is most influenced by high levels of carbonates and higher pH in the subsurface rather than NO_3-N, EC, and P, like the tolerant variety. Under these environments with seed coating, the plants could have grown better, and were capable of getting higher yields. This higher growth potential use could lead to higher nutrient uptake, and more chances for negative internal nutrient interactions in the plant.

CONCLUSIONS

Factor analysis found two significant underlying factors in predicting soybean chlorosis in Western Kansas. Factor 1 was dubbed "Plant Chlorosis", and had NO_3-N and EC contributed to high levels of CM readings, and P and Ca had an antagonistic effect on plant greenness. Factor 2 was the "soil iron availability" factor, which was made up of DTPA-Fe and Mg levels that positively influenced factor 2, and the ASI index (made up of pH and carbonates), and subsurface pH levels that negatively impacted factor 2, especially without seed coating. These underlying factors were indicative of soil chlorophyll meter readings at V3 and V6, as well as in grain yields. The non tolerant variety was able to better utilize conditions with low soil NO_3-N, EC, subsurface-Fe or with high Ca, subsurface-pH and soil P levels compared to the tolerant variety, but is more susceptible to high levels of carbonates and a high ASI value. The seed treatment nullified both of the soil factors in the CM1 reading in the non-tolerant variety, and in yield, Factor 1 (plant chlorosis factor) did not significantly change yield. In the tolerant variety, it was the soil available iron factor (Factor 2) that became neutralized. The stepwise multiple regression analysis also found that there were relationships between individual variables. Calcium and Mg levels were present in both underlying factors, but only added in models for around 33% of the multiple regression scenarios. Calcium did not always decrease CM readings, and Mg did not always increase CM readings and yield. In the underlying factor analysis, EC and

NO3-N were positive factors, and contributed to an increase in CM values; however, in the stepwise analysis, EC and NO3-N increased CM readings; however, yield was negatively impacted by these parameters. Phosphorus, ASI, and subsurface-pH were always negative when they were significant, and subsurface-Fe and Fe were always positive, except in the case of the tolerant variety with seed coating, where additional iron did not improve CM1 reading further. This information is important in understanding how underlying factors impact chlorosis, and can potentially be used to develop crop recommendations based on nutrient levels.

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TABLES AND FIGURES

Table 3-1. Soil classification and weather data from seven irrigated locations in Western Kansas.

		Predominant Soil		Annual Climate Factors	
Location	County	Series	Subgroup	Temperature† °C	Precipitation‡ Mm
			2009		
1	Finney	Ulysses	Aridic Haplustolls	19.6 (-0.6)	339 (4)
2	Lane West	Richfield	Aridic Argiustolls	19.4 (-0.8)	317 (-20)
3	Lane East	Richfield	Aridic Argiustolls	19.4 (-0.8)	317 (-20)
			2010		
4	Thomas North	Ulysses	Aridic Haplustolls	19.5 (0.7)	310 (-44)
5	Thomas South	Ulysses	Aridic Haplustolls	19.5 (0.7)	310 (-44)
6	Finney	Ulysses	Aridic Haplustolls	21.1 (0.9)	290 (-45)
7	Lane	Richfield	Aridic Argiustolls	19.4 (-0.8)	137 (-205)

†Average temperature from April-August, standard deviation from the 50 year mean is presented in parenthesis

‡Total Precipitation from April-August, standard deviation from the 50 year mean is presented in parenthesis

Table 3-2. Soil Properties and Standard Deviations from all locations. Samples collected from 48 small plots at the 0-15 and 15-30 cm depth

	Location						
Parameter	1	2	3	4	5	6	7
pH	8.24 ± 0.13*	8.27 ± 0.12	8.18 ± 0.12	8.30 ± 0.14	8.50 ± 0.16	8.22 ± 0.14	8.14 ± 0.22
pH 2†	8.25 ± 0.16	8.32 ± 0.11	8.32 ± 0.10	8.53 ± 0.14	8.64 ± 0.06	8.34 ± 0.11	8.48 ± 0.08
ASI§	12.8 ± 1.17	11.2 ± 1.92	10.4 ± 2.06	13.1 ± 1.76	15.3 ± 1.52	13.8 ± 1.03	15.0 ± 1.09
Fe (mg kg^{-1})	1.97 ± 0.39	2.76 ± 0.45	3.26 ± 0.29	1.64 ± 0.22	1.49 ± 0.22	1.83 ± 0.20	1.79 ± 0.16
Fe 2† (mg kg^{-1})	2.28 ± 0.34	2.14 ± 0.33	1.99 ± 0.19	1.41 ± 0.35	1.61 ± 0.18	1.98 ± 0.19	1.83 ± 0.14
P § (mg kg^{-1})	28.5 ± 2.93	78.1 ± 10.0	68.7 ± 13.1	53.4 ± 15.1	66.4 ± 38.9	22.0 ± 7.52	109 ± 11.0
Ca (mg kg^{-1})	4116 ± 420	4428 ± 301	4467 ± 229	4827 ± 174	4734 ± 178	3824 ± 404	5194 ± 162
Mg (mg kg^{-1})	467 ± 67.3	710 ± 42.3	643 ± 41.4	317 ± 19.1	330 ± 19.7	644 ± 36.4	554 ± 31.5
NO3-N¶ (mg kg^{-1})	17.2 ± 6.42	6.97 ± 1.47	8.81 ± 1.92	7.02 ± 2.24	5.08 ± 1.31	14.6 ± 4.25	11.5 ± 3.54
CCE# (g kg^{-1})	93.0 ± 22.8	60.5 ± 38.9	44.8 ± 42.7	97.2 ± 34.5	138 ± 30.3	114 ± 21.2	140 ± 21.8
OM†† (g kg^{-1})	21.7 ± 1.60	19.4 ± 2.45	18.0 ± 1.70	21.9 ± 2.50	18.5 ± 2.02	20.5 ± 2.22	24.8 ± 1.91
EC§§ (m S^{-1})	0.91 ± 0.21	0.59 ± 0.11	0.78 ± 0.18	0.59 ± 0.10	0.54 ± 0.08	1.00 ± 0.22	0.64 ± 0.07

*Value is the Standard Deviation

†Soil Test pH and DTPA Fe for 15-30 cm depth

§ Soil Test Mehlich P

¶ Nitrate-N to a depth of 0-30 cm

Soil Effective Calcium Carbonate levels

†† Soil Organic Matter Levels

§§Soil Electrical Conductivity

Table 3-3. Pearson correlation coefficients between individual soil variables across locations

	pH	pH-2	P	Fe	Fe-2	OM	Ca	Mg	EC	NO3-N	CCE†	ASI
pH	1.00											
pH-2†	0.50*	1.00										
P§	-0.10	0.15	1.00									
Fe	-0.35	-0.55*	0.21	1.00								
Fe-2†	-0.36	-0.67*	-0.03	0.45	1.00							
OM¶	-0.27	-0.04	0.34	-0.30	0.02	1.00						
Ca	0.15	0.50*	0.51*	-0.22	-0.54*	0.14	1.00					
Mg	-0.40	-0.59*	0.08	0.65*	0.60*	-0.08	-0.38	1.00				
EC#	-0.33	-0.44	-0.36	0.13	0.40	0.08	-0.64*	0.32	1.00			
NO3-N††	-0.34	-0.40	-0.27	-0.03	0.39	0.29	-0.43	0.24	0.60*	1.00		
CCE§§	0.18	0.37	0.17	-0.64*	-0.26	0.30	0.19	-0.37	-0.04	0.07	1.00	
ASI¶¶	0.25	0.42	0.16	-0.65*	-0.28	0.27	0.20	-0.40	-0.07	0.04	0.99*	1.00

*Significant at the 0.05 probability level.
†Soil Test pH and DTPA Fe for 15-30 cm depth
§ Soil Test Mehlich P
¶ Soil Organic Matter Levels
# Soil Electrical Conductivity
†† Nitrate-N to a depth of 0-60 cm
§§ Soil Effective Calcium Carbonate levels
¶¶ Soil Alkalinity Stress Index = pH + 0.48CCE

Table 3-4. Rotated factor loadings determined for the four treatment types, including the measured variables to create the latent variables

Parameter	Plant Chlorosis Factor 1	Soil Fe Available Factor 2
pH-Subsurface†	-0.592*	-0.528*
P§	-0.471*	0.227
Fe	0.043	0.990*
Fe-Subsurface†	0.585*	0.431
OM¶	0.121	-0.305
Ca	-0.754*	-0.186
Mg	0.384	0.638*
EC#	0.755*	-0.305
NO3-N††	0.701*	-0.068
ASI§§	-0.077	-0.656*
Eigenvalues	3.922	2.018
Variability¶¶	0.51	0.49

*Significant at the 0.05 probability level.
†Soil Test pH and DTPA Fe for 15-30 cm depth
§ Soil Test Mehlich P
¶ Soil Organic Matter Levels
# Soil Electrical Conductivity
†† Nitrate-N to a depth of 0-60 cm
§§ Soil Alkalinity Stress Index = pH + 0.48CCE
¶¶ Percentage of variability accounted for by each factor

Table 3-5. Coefficients of Factor Regression in Comparison to Measured Chlorophyll meter (CM) readings at the V3 (CM1) and V6 (CM2) growth stage and grain yield (GY) variables.

Parameter†	R^2 Value‡	Intercept	Factor 1 Plant Chlorosis	Factor 2 Soil Available Fe	Factor 1	Factor 2
					P < F	
		Non Tolerant Variety Without Seed Coating				
CM 1	0.400	26.85	1.428	2.349	0.0006	<0.0001
CM 2	0.815	27.09	8.385	7.736	<0.0001	<0.0001
GY	0.760	20.24	6.203	15.85	<0.0001	<0.0001
		Non Tolerant Variety With Seed Coating				
CM 1	0.028	33.93	0.126	-0.494	0.7316	0.1561
CM 2	0.645	31.33	3.667	5.362	<0.0001	<0.0001
GY	0.578	31.04	-0.087	14.94	0.9554	<0.0001
		Tolerant Variety Without Seed Coating				
CM 1	0.356	28.65	2.398	1.363	<0.0001	0.0013
CM 2	0.747	30.22	7.974	6.284	<0.0001	<0.0001
GY	0.600	18.19	5.718	13.56	<0.0001	<0.0001
		Tolerant Variety With Seed Coating				
CM 1	0.225	34.46	-1.349	-0.511	<0.0001	0.0903
CM 2	0.618	33.92	5.281	-1.635	<0.0001	0.0011
GY	0.433	29.15	15.11	0.193	<0.0001	0.9199

†CM1, Chlorophyll meter readings at the V3 growth stage; CM2, Chlorophyll meter readings at V6 growth stage; GY, grain yield.

‡Value for the model of Agronomic Parameter=Coefficient(Factor1)+Coefficient(Factor2)

Table 3-6. Regression Analysis Coefficients and coefficient of determination (r^2) values generated by the stepwise regression analysis

Parameter†	Multiple regression parameters	r^2
	Non Tolerant Variety Without Seed Coating (n=81)	
CM1	93.3 - 0.70(ASI) - 7.43(pH-2) + 2.82(Fe-2)	0.502
CM2	151.2 - 1.21(ASI) - 0.04(Mg) + 10.8(EC) + 0.50(NO_3-N) - 16.1(pH-2)	0.900
Yield	9.56 - 0.13(ASI) - 0.005(P) + 0.96(Fe) - 1.17(pH-2) + 0.82(Fe-2)	0.820
	Non Tolerant Variety with Seed Coating (n = 79)	
CM1	2.84 + 0.005(Ca) + 2.36(OM) + 4.64(EC) + 0.23(NO_3-N)	0.489
CM2	-19.3 + 4.58(Fe) + 0.004(Ca) + 0.02(Mg) + 0.50(NO_3-N) + 5.89(Fe-2)	0.787
Yield	0.81 - 0.12(ASI) - 0.007(P) + 1.36(Fe) - 1.81(EC) +1 .02(Fe-2)	0.707
	Tolerant Variety Without Seed Coating (n= 82)	
CM1	17.71 - 0.62(ASI) - 0.05(P) + 0.002(Ca) + 0.30(NO_3-N) + 4.87(Fe-2)	0.604
CM2	-25.3 -0.07(P) + 2.42(Fe) + 0.002(Ca) + 0.05(Mg) + 9.82(EC) + 0.42(NO_3-N) + 4.54(Fe-2)	0.884
Yield	-1.47 - 0.07(ASI) - 0.01(P) + 1.18(Fe) - 0.001(Mg) + 1.24(Fe-2)	0.731
	Tolerant Variety with Seed Coating (n = 76)	
CM1	30.07 - 1.29(Fe) - 0.01(Mg) + 4.67(EC) + 0.27(NO_3-N)	0.469
CM2	11.39 - 0.04(P) + 0.03(Mg) + 4.64(EC) + 0.53(NO_3-N)	0.827
Yield	5.60 + 1.54(Fe) - 0.07(NO_3-N) - 0.001(Ca) - 1.51(EC)	0.817

†CM1, Chlorophyll meter readings at the V3 growth stage; CM2, Chlorophyll meter readings at V6 growth stage; GY, grain yield.

Table 3-7. Probability values of the variables selected using the PROC Stepwise procedure using 0.40 as an entry variable and 0.15 as criteria to remain in the model

Parameter†	ASI	pH-2	P	Fe	Fe - 2	Ca	Mg	NO3-N	EC	OM
	- p > F -									
				Non Tolerant Variety Without Seed Coating						
CM1	<0.001	<0.001			0.040					
CM2	<0.001	<0.001					<0.001	0.001	<0.001	0.126
GY	0.010	0.048	<0.001	<0.001	<0.001					
				Non Tolerant Variety with Seed Coating						
CM1						0.007		<0.001	0.001	<0.001
CM2			0.131	<0.001	0.060	0.010	<0.001	<0.001		
GY	<0.001		0.033	<0.001	0.058				0.003	
				Tolerant Variety Without Seed Coating						
CM1	0.001		0.014		0.005	0.021		0.004		
CM2			<0.001	0.034	0.005	0.128	<0.001	<0.001	0.026	
GY	0.132		<0.001	<0.001	<0.001		0.073			
				Tolerant Variety With Seed Coating						
CM1				<0.001		0.100	0.014	0.001	0.003	
CM2			<0.001		0.143		<0.001	<0.001	0.006	
GY	0.109			<0.001		0.008	0.094	<0.001	<0.001	

†CM1, Chlorophyll meter at V3 growth stage; CM2, Chlorophyll meter at V6 growth stage; GY, grain yield.

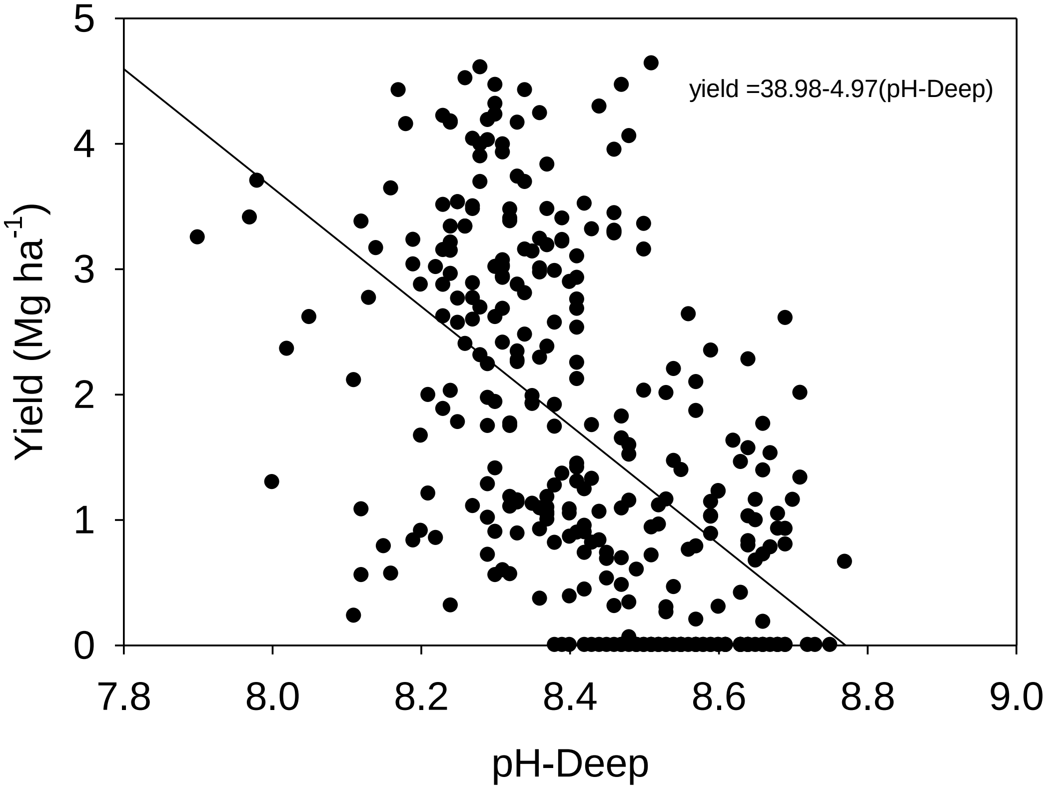

Figure 3-1. Subsurface pH vs Grain Soybean Yield. The regression analysis of the 15-30 cm depth pH, the only variable significant for both underlying factors

CHAPTER 4-OPTIMUM APPLICATION RATE OF CHELATED IRON FERTILIZER FOR IRON CHLOROSIS IN SOYBEANS

INTRODUCTION

In semi-arid calcareous soils with low organic matter, like those in western Kansas, inadequate amounts of iron (Fe) are available for plant growth. These conditions results in Fe deficiency. Iron deficiency is in nutrient disorder which presents as interveinal leaf yellowing. This is a widespread problem, costing millions of dollars worth of yield loss a year. There are several solutions that can be used to reduce chlorosis from a management standpoint. These methods include: choosing an appropriate variety, applying either inorganic (Godsey et al., 2003; Ligenfelser et al., 2005) or chelated forms of Fe to the furrow (Penas et al., 1990) at planting time, using chelated Fe as a seed coating (Karkosh et al., 1988; Goos and Johnson, 2001) or applying foliar Fe (Goos and Johnson, 2000; Godsey et al., 2003).

A 2009 study at three locations in Western Kansas showed a 50% yield increase, on average, in response to the addition of a 0.23 kg Fe ha^{-1} coating of chelated FeEDDHA [6% iron ethylene diamine-N,N'-bis (hydroxyphenyl) acetic acid] iron applied to the seed before planting. One of the major limitations of using chelated iron seed coating is the associated cost, which is why lower application rates are desirable. However, lower application rates do not have a sustained success rate found by other researchers (Karkosh et al., 1988; Goos and Johnson et al., 2001). Low rates of seed treatment (0.04 kg Fe ha^{-1}) were applied by Karkosh et al., (1988), and they found that there were significant yield increases only in the chlorosis tolerant variety, and Goos and Johnson et al., (2001) found that seed coating did not increase yield at low rates (0.04 and 0.07 kg ha^{-1}). Wiersma (2005) was one of the only studies that looked at the application of FeEDDHA at high rates. They applied 6 different rates of chelated iron seed coating (0, 0.13, 0.27, 0.40, 0.54, and 0.67 kg Fe ha^{-1}), and found that rates over 0.27 kg ha^{-1} provided sustained amounts of Fe to get high yield responses. The objective of this study was to evaluate various rates of seed-applied Fe fertilizer.

MATERIALS AND METHODS

The experiment was conducted on a Ulysses silt loam (Aridic Haplustolls) at the Northwest Research and Extension Center in Colby, KS (39 N and 101 W) in 2010 on soils where soybeans had exhibited severe Fe chlorosis in the past. Soil samples were collected from each block to a 0-15 cm depth, and analyzed for pH using a 1:1 soil: water ratio (Waterson and Brown, 1998). Soil organic matter (SOM) was measured using the Walkley-Balck method (Combs and Nathan, 1998). Iron was extracted using diethylene-triamine-penta-acetate (DTPA) solution (Whitney 1998). Extractable potassium was determined by an ammonium acetate extraction. Nitrate-N was measured with a 1 M KCl extraction (Gelderman and Beegle 1998). Exchangeable Calcium Carbonates were measured adding dilute HCl to calcareous soil and measuring gas displacement (Huang et al., 2007).

Soybeans were planted at 0.76 m row spacing with a seeding rate of 370,000 plants ha^{-1}. Post emergence control of weeds was completed as needed. The plots were 6.1 m by 15.2 m and set up in a randomized complete block design with three replications. Asgrow 3803, a non-tolerant variety, was selected for this study. Chelated FeEDDHA fertilizer, was mixed into a slurry with water and a protective seed coating adhesive polymer, and were applied at four different rates, 0, 0.07, 0.14, and 0.28 kg Fe ha^{-1}.

Plant population was counted at V3 (Pedersen, 2004). Chlorophyll meter readings were recorded at V3 and V6 with a SPAD 502 (Minolta, Ramsey, NJ) in 20 leaflets per plot, and averaged into one value to ascertain the effectiveness of seed coating. Plant height was recorded at the R7 growth stage. Grain yields were determined by harvesting the two center rows by hand, and then threshed. Moisture content of plot samples were recorded and used to adjust grain yields to a moisture content of 130 g kg^{-1}. The economic analysis used 2010 market prices for chelated Fe and soybean selling price, and assumed an operating cost (weed control, planting, and machinery costs) was around $250 per hectare. Data were analyzed in PROC GLIMMIX in SAS 9.1 (SAS Institute, 2010). Analysis of variance used Fe fertilizer rate as a fixed variable, and blocks as a random variable. Differences were deemed significant if the p value was < 0.05. Agronomic parameters were regressed using PROC REG against the different levels of Fe applied, and fit to a polynomial line. The optimum rate was determined when the slope of the Fe level was maximized or stabilized.

RESULTS AND DISCUSSION

Agronomic Parameters

Chlorosis developed shortly after emergence. Plant population varied based on the concentration of iron applied to the seed. The highest overall germination occurred in the 0.28 kg Fe ha^{-1}, which was 38% higher than the treatment without any Fe applied (Figure 4-1). The 0.07 and 0.14 kg Fe ha^{-1} application rates were equal. This higher plant population density may impact the plant "greenness" early (Wiersma, 2005).

At V3, the lowest CM value was the untreated control (Figure 4-2). The application of iron fertilizer caused the greatest increase in CM units at 0.07 kg Fe ha^{-1} (increasing 6.4 SPAD units, or 26% response). Between 0.07 and 0.14, there is only a 5% increase, which is not statistically significant, in response to a higher fertilizer application. Between 0.14 and 0.28, there is a larger increase, but it is only half the response to the low level of iron application (12%), and this response was not significant. Early in the season, the 0.14 and 0.28 kg Fe ha^{-1} applications were successful at raising the CM readings to equally high levels, even though the 0.28 kg ha^{-1} rate was slightly higher. Wiersma (2005) also found that SPAD values increased most between 0 and 0.13 kg Fe ha^{-1}, and at applications higher than that, the Fe available was in excess. After running a regression analysis, the equation revealed that the optimum Fe rate is at 0.24 kg Fe ha^{-1}.

At V6, there was a decline in SPAD values overall compared to the V3 value, indicating a worsening chlorosis (Figure 4-2). The 0 treatment was the lowest, and the 0.07 kg ha^{-1} treatment was higher, but experienced the same a decline of 17 SPAD units from V3 as the control did. The 0.28 and 0.14 kg Fe ha^{-1} were again, the same; however, the 0.28 kg ha^{-1} experienced a 16.3 unit decline from the first SPAD, whereas the 0.14 kg ha^{-1} only experienced a 9 unit decline, leaving the 0.14 kg ha^{-1} to be the greenest variety. This decline in chlorosis non-tolerant variety between V3 and V6 was also observed by Wiersma (2005). However, Wiersma (2005) found that higher levels of application demonstrated continued response. Using a regression analysis, the equation revealed that the optimum iron rate was applied around 0.18 kg Fe ha^{-1}.

Plant height was also indicative of Fe seed coating. The more iron that was added, the taller the plant was at maturity. Without any seed coating, plots had viable plants, and the stubble was less than 5 cm tall. The largest increase in plant height came after the addition of 0.07 kg Fe ha^{-1}, which added 30 cm to plant height (Figure 4-3). Both of the high levels of application (0.28 and 0.14 kg Fe ha^{-1}) were equally tall, indicating that the increased application over 0.14 may not be as effective as the lower application, however, regression analysis gives an the optimum Fe value of 0.21 kg Fe ha^{-1}.

The 0.14 kg Fe ha^{-1} rate provided the highest overall yield (Figure 4-4), even though it was the same as the 0.28 kg ha^{-1}, the 0.14 kg Fe ha^{-1} out yielded the 0.28 kg Fe ha^{-1} by 0.46 Mg ha^{-1}, which may have economic significance. There could be several reasons that the highest seed coating rate did not continue to respond over the 0.14 kg Fe ha^{-1} level. The soil test P levels in these plots were very high, over 100 mg kg^{-1}, and late in the season, the iron uptake could have been hampered by the deactivation of Fe in the plant leaf due to luxury consumption of P (Tagliavini et al., 1991). In the soybean cultivar ‘Forest’ several studies indicated that a good indicator for Fe chlorosis development is high P concentration and P/Fe ratio in plant leaves (Chaney and Coulumbe, 1982). The 0.07 kg ha^{-1} treatments did not yield significantly different from the control, which did not yield at all. The regression analysis puts optimum Fe levels for maximizing yield is 0.19 kg Fe ha^{-1}.

Economic Analysis

For 2010, FeEDDHA product was around $3.86 per kg of product (6% actual Fe), and soybeans were selling for around $4.05 per kg of beans. Assuming these values and Fe application rates, even at the high rates of application, for less than $20 per ha investment, profit can be improved between $5,000-7,000 per hectare (Table 4-2). These soils have previously not been able to carry soybeans to maturation, so even small additions of iron are economically worthwhile. So, even if the price of soybeans were $0.50 kg^{-1}, and the price of Fe was $100 per kg, all application levels would still profit, though the 0.14 kg Fe ha^{-1} would profit more than the higher application rates. Without seed coating, however, net profit to the producer is negative, because the producer would lose maintenance, seed, herbicide, and planting costs.

CONCLUSION

For all of the different agronomic parameters, results indicate that a level of 0.14 kg Fe ha^{-1} is just as effective of the high levels of 0.28 kg Fe ha^{-1} for all measured agronomic parameters except plant population. The addition of only 0.07 kg Fe ha^{-1} was also beneficial agronomically, but not to the level of the higher application level. Without any iron application, plants failed to grow. The increase in yield was dramatic, so, economically, using a chelated Fe source is effective, even if the Fe chelate cost $100 kg-1, and yields less than 1.0 Mg ha^{-1}. Planting soybeans in high P conditions may be risky, and without seed-applied Fe, the operational costs results in negative profit resulting from planting and maintenance; however, even low levels of seed coating of 0.07 kg Fe ha^{-1} provided a profit that was worth the investment.

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TABLES AND FIGURES

Table 4-1. Soil Parameters for optimum rate study in Colby Kansas

pH	OM†	CCE‡	P‡	Fe§	NO_3-N	Ca	Mg	EC
	------ g/kg -----		---------------- mg/kg ----------------					mS/cm
8.2	20.3	126	57	1.5	4.7	5697	349	0.5

†Soil organic matter
‡Effective Calcium Carbonate
§Soil test P and K: Soil test P determined by Mehlich-3 test
¶ Soil available Fe determined by DTPA extraction

Table 4-2. Calculated profit margins and price of fertilizer under the different applications of Fe

Fe Application Rate	Price Fe $ kg^{-1}	Yield Gained	Total Price† per ha	Total profit‡	Gross Profit§
0	0	0	0	0	-250
0.067	4.36	504	2042	2038	1788
0.134	8.61	1813	7345	7336	7086
0.267	17.18	1352	5475	5458	5208

†Assuming $4.05 per kg, 2010 market price in Western Kansas

‡ Yield price – iron price

§ Assuming an operating cost of $250 per hectare

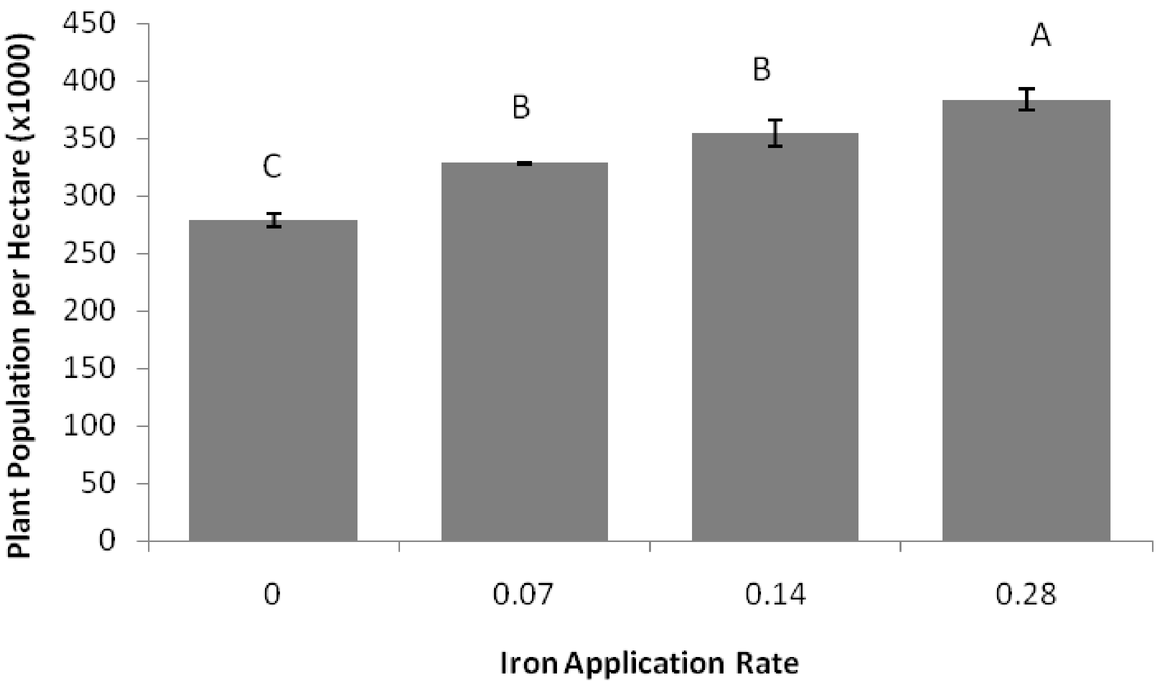

Figure 4-1. Plant population in response to different levels of seed coating at V3

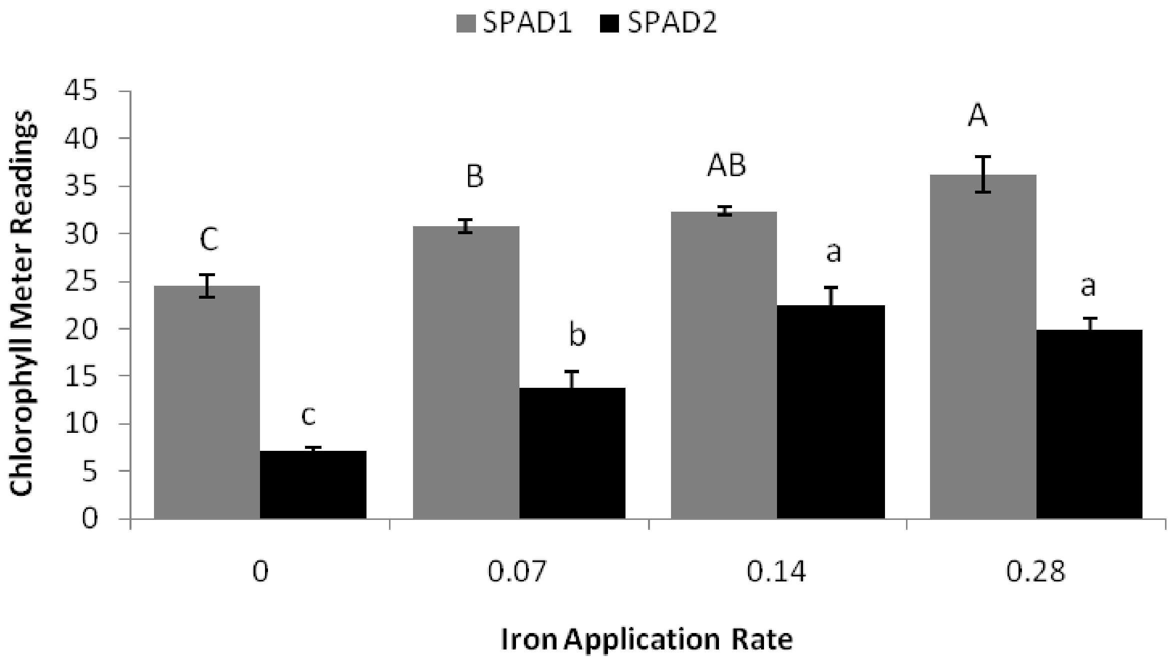

Figure 4-2. SPAD Chlorophyll Meter in response to increasing iron application readings at V3 and V6. Capital letters represents CM1 values, and small letters represent CM2

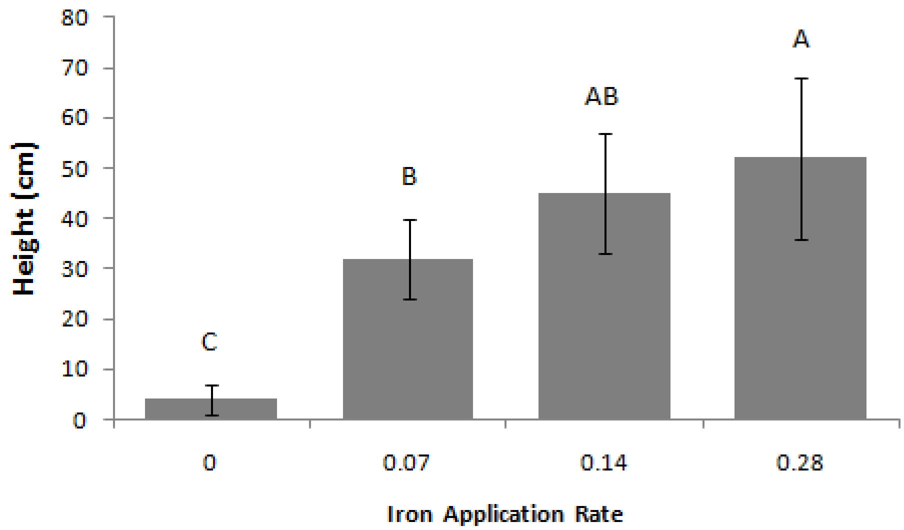

Figure 4-3. Plant height in response to seed coating at maturity (R7)

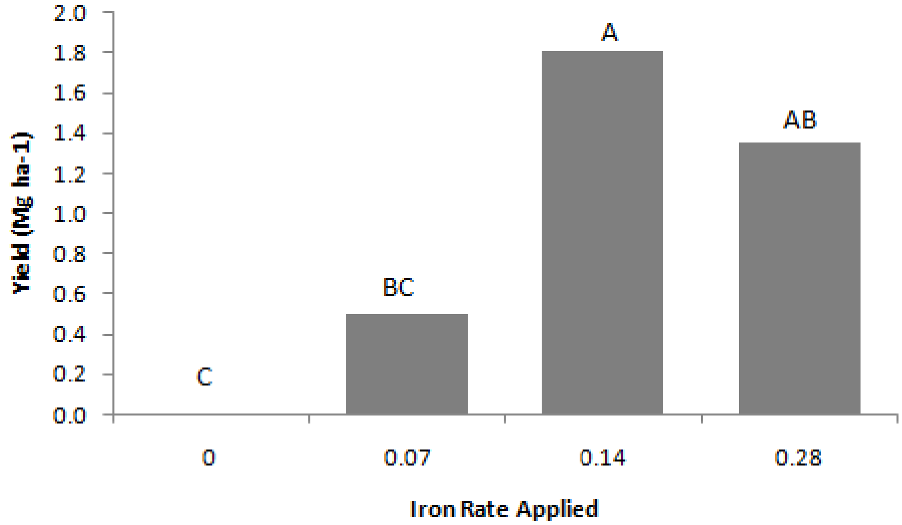

Figure 4-4. Grain yield in Mg ha-1 based on the different levels of Fe seed coating

Appendix A - SAS Code

Chapter 2: Agronomic Parameters

SAS Code, Chapter 2: Agronomic Rates

Individual Site Analysis

```
options nodate ls=90 ps=51 pageno=1;
/*using sas DDE - excel file must be open and active*/
filename soyNEW dde "excel|C:\Documents and
Settings\soilfert\Desktop\[soyNEW.xls]Sheet1!r97c1:r385c41";
data SoyNEW;
infile soyNEW firstobs=2 notab dlm='09'x dsd missover;
input Year  Location$   Rep   Var$  No    Seed$ Foliar$     SPAD1 SPAD2
Pop   thoplants_ha      Height      kghaNM      Yield kg_ha Mg_ha;
Run;

*Plant Population Analysis*

PROC MIXED data=SoyNEW;
     CLASS Rep Var Seed;
     MODEL thoplants_ha = Var|seed;
   RANDOM Rep;
LSMEANS var seed var*seed/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*SPAD Meter 1 Analysis*

PROC MIXED data=SoyNEW;
     CLASS Rep Var Seed;
     MODEL  SPAD1 = Var|seed thoplants_ha;
   RANDOM Rep;
LSMEANS var seed var*seed/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*SPAD Meter 2 Analysis*

PROC MIXED data=SoyNEW;
     CLASS  Rep Var Seed Foliar;
     MODEL SPAD2 = Var|seed|foliar thoplants_ha;
   RANDOM rep;
```

```
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=no);

*Height Analysis*

PROC MIXED data=SoyNEW;
     CLASS  Rep Var Seed Foliar;
     MODEL height = Var|seed|foliar thoplants_ha;
   RANDOM rep;
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=no);

*Yield Analysis*

PROC MIXED data=SoyNEW;
     CLASS  Rep Var Seed Foliar;
     MODEL Mg_ha = Var|seed|foliar thoplants_ha;
   RANDOM rep;
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=no);
```

Combined Site Analysis

```
options nodate ls=90 ps=51 pageno=1;
/*using sas DDE - excel file must be open and active*/
filename soyNEW dde "excel|C:\Documents and
Settings\soilfert\Desktop\[soyNEW.xls]Sheet1!r97c1:r385c41";
data SoyNEW;
infile soyNEW firstobs=2 notab dlm='09'x dsd missover;
input Year  Location$   Rep   Var$  No    Seed$ Foliar$     SPAD1 SPAD2
Pop   thoplants_ha      Height      kghaNM      Yield kg_ha Mg_ha;
Run;

*Plant Population Analysis*

proc print data=soynew;
run;

PROC MIXED data=SoyNEW;
     CLASS location Rep Var Seed;
     MODEL thoplants_ha = Var|seed;
```

```
   RANDOM location Rep;
LSMEANS var seed var*seed/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*SPAD Meter 1 Analysis*

PROC MIXED data=SoyNEW;
     CLASS location Rep Var Seed;
     MODEL  SPAD1 = Var|seed thoplants_ha;
   RANDOM location Rep;
LSMEANS var seed var*seed/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*SPAD Meter 2 Analysis*

PROC MIXED data=SoyNEW;
     CLASS location Rep Var Seed Foliar;
     MODEL SPAD2 = Var|seed|foliar thoplants_ha;
   RANDOM location rep;
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=no);



*Height Analysis*

PROC MIXED data=SoyNEW;
     CLASS location Rep Var Seed Foliar;
     MODEL height = Var|seed|foliar thoplants_ha;
   RANDOM location rep;
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=no);

*Yield Analysis*

PROC MIXED data=SoyNEW;
```

```
     CLASS  location Rep Var Seed Foliar;
     MODEL Mg_ha = Var|seed|foliar thoplants_ha;
   RANDOM location rep;
LSMEANS var seed var*seed foliar var*seed*foliar/pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
```

Chapter 3: Factor Analysis and Multiple Regression

```
options nodate ls=90 ps=51 pageno=1;
/*using sas DDE - excel file must be open and active*/
filename chp2 dde 'Excel|C:\Documents and
Settings\soilfert\Desktop\[chp2.xlsx]alldat!R49C1:R370C29';
data alldat;
infile chp2 firstobs=2 notab dlm='09'x dsd missover;
input Year  Location$ ID      Plot  Block Var$  Seed$ Foliar$ SPADJ
SPADA Yield metric RY pH      Phos  Fe    OM    Ca    Mg    EC    Nit
Carb  Zinc ph2 fe2 ASI  risk$;

*Checking for Multivariate Normality*

TITLE 'MULTIVARIATE NORMAL PROBABILITY PLOT';
 %OUTLIER(DATA=alldat, VAR = pH     Phos Fe     OM    Ca    Mg    EC
      Nit   Carb ph2 fe2 ASI, ID=ID, OUT=CHIPLOT, PVALUE=.0001,
PASSES=1, PRINT=YES);
run;

*This is the PCA with standardizing variables to determine the
Eigenvalues*

 PROC FACTOR METHOD=PRINCIPAL NFACT=2 S C SCREE SCORE OUT=PCSCORES;
  VAR Phos   Fe    OM    Ca    Mg    EC    Nit    ph2 fe2 ASI;
 TITLE2 'PRINCIPAL COMPONENT ANALYSIS USING THE FACTOR PROCEDURE';
RUN;

PROC PRINT;  VAR id FACTOR1-FACTOR4;
 TITLE2 'PRINTOUT OF STANDARDIZED PRINCIPAL COMPONENT SCORES';
 RUN;

PROC G3D; SCATTER FACTOR2*FACTOR1=FACTOR3 'Bubbles';
 TITLE2 '3-D PLOT OF STANDARDIZED PRINCIPAL COMPONENT SCORES';
RUN;

DATA; SET PCSCORES;
 /* The following commands are used to compute unstandardized principal
    component scores */

 PCSCRU1=FACTOR1*   3.92289387**.5;
 PCSCRU2=FACTOR2*    2.01838357**.5 ;
 PCSCRU3=FACTOR3*    1.52204489**.5 ;


PROC PRINT; VAR id PCSCRU1 - PCSCRU3;
```

```
 TITLE2 'PRINTOUT OF UNSTANDARDIZED PRINCIPAL COMPONENT SCORES';

RUN;


PROC G3D; SCATTER PCSCRU2 * PCSCRU1 = PCSCRU3;
 TITLE2 '3-D PLOT OF UNSTANDARDIZED PRINCIPAL COMPONENT SCORES';
 RUN;

PROC UNIVARIATE PLOT;
  VAR PCSCRU1 - PCSCRU3;
 TITLE2 'UNIVARIATE ANALYSES OF UNSTANDARDIZED PRINCIPAL COMPONENT
SCORES';
 RUN;
*Factor Analysis*;
PROC FACTOR METHOD=PRINCIPAL SCREE;
 VAR Phos   Fe    OM    Ca    Mg    EC    Nit   ph2 fe2 ASI;
 RUN;

 PROC FACTOR METHOD=ML NFACT=2 ROTATE=VARIMAX S C EV RES REORDER
DATA=alldat
  SCORE OUT=SCORES;
  VAR Phos  Fe    OM    Ca    Mg    EC    Nit   ph2 fe2 ASI;
  RUN;


 PROC FACTOR METHOD=ML NFACT=2 ROTATE=VARIMAX EV RES REORDER
DATA=alldat
  SCORE OUT=SCORES HEYWOOD RCONVERGE=1E-04;
  VAR ASI Phos    Fe Ca OM Mg EC    Nit   ph2 fe2;
  RUN;

proc plot data=scores;
plot factor1*factor2;
run;
 PROC PRINT DATA=SCORES;
  VAR ID FACTOR1-FACTOR2;
  RUN;

Proc Reg;
Model SPADJ= Factor1 Factor2;
MODEL SPADA= FACTOR1 FActor2;
MODEL Yield= Factor1 Factor2;
Run;


*Regression Analysis for pH2*

Proc Reg;
Model Yield = pH2
Run;

*Stepwise Regression Analysis*

proc stepwise data=alldat;
model SPADJ = ASI Phos  Fe Ca OM Mg EC    Nit   ph2 fe2/stepwise;
```

```
model SPADA = ASI Phos  Fe Ca OM Mg EC    Nit   ph2 fe2/stepwise;
model metric = ASI Phos Fe Ca OM Mg EC    Nit   ph2 fe2/stepwise;
run;
```

Chapter 4: Variable Rate Study

```
options nodate ls=90 ps=51 pageno=1;
/*using sas DDE - excel file must be open and active*/
filename soyNEW dde "excel|C:\Documents and
Settings\soilfert\Desktop\[soyNEW.xls]VR!r1c1:r13c20";
data SoyNEW;
infile soyNEW firstobs=2 notab dlm='09'x dsd missover;
input study Rate  Rep   SPAD1 SPAD2 thoplantsha dspad1      dspad2
height      yield kg_ha;
Run;


*this is specifically for plant population*;

PROC MIXED data=SoyNEW;
     CLASS rate rep;
     MODEL thoplantsha = rate;
   RANDOM Rep;
LSMEANS rate /pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*this is specifically for the SPAD1 parameter*;

PROC MIXED data=SoyNEW;
     CLASS rate rep;
     MODEL SPAD1 = rate;
   RANDOM Rep;
LSMEANS rate /pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*this is specifically for the SPAD2 parameter*;

PROC MIXED data=SoyNEW;
     CLASS rate rep;
     MODEL SPAD2 = rate;
   RANDOM Rep;
LSMEANS rate /pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
```

```
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*this is specifically for the height parameter*;

PROC MIXED data=SoyNEW;
     CLASS rate rep;
     MODEL height = rate;
   RANDOM Rep;
LSMEANS rate /pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);

*this is specifically for the yield parameter*;

PROC MIXED data=SoyNEW;
     CLASS rate rep;
     MODEL kg_ha = rate;
   RANDOM Rep;
LSMEANS rate /pdiff;
ods output diffs=ppp lsmeans=mmm;
 ods listing exclude diffs lsmeans;
ods graphics on;
run;
%include 'C:\Documents and Settings\soilfert\Desktop\[pdmix800.sas]';
%pdmix800(ppp,mmm,alpha=.05,sort=yes);
```

Appendix B - Raw Data

Year	Location	Plot	Block	Variety	Seed	Foliar	SPAD1	SPAD2	Yield	Relative Yield
2009	Garden City	101	1	T	Y	ED 6%	36.1	31.9	30.09	0.50
2009	Garden City	102	1	NT	N	ED 6%	24.6	32.3	35.07	0.58
2009	Garden City	103	1	NT	Y	N	31.1	38.3	44.77	0.74
2009	Garden City	104	1	T	N	ED 6%	33.6	36.1	34.76	0.58
2009	Garden City	105	1	T	Y	N	34.7	38.2	28.54	0.47
2009	Garden City	106	1	NT	N	N	26.6	31.6	16.38	0.27
2009	Garden City	107	1	NT	Y	ED 6%	32.6	36.3	44.62	0.74
2009	Garden City	108	1	T	N	N	33.1	36.2	36.75	0.61
2009	Garden City	109	1	T	Y	HE 4.5%	37.2	35	28.43	0.47
2009	Garden City	110	1	NT	N	HE 4.5%	33.3	32.3	24.47	0.41
2009	Garden City	111	1	NT	Y	HE 4.5%	36.4	34.9	47.35	0.79
2009	Garden City	112	1	T	N	HE 4.5%	34.5	36.6	33.43	0.55
2009	Garden City	201	2	T	Y	ED 6%	36	38.6	19.28	0.32
2009	Garden City	202	2	NT	N	ED 6%	27.8	35.8	29.47	0.49
2009	Garden City	203	2	NT	Y	N	31.4	34.5	42.66	0.71
2009	Garden City	204	2	T	N	ED 6%	31.4	37.1	38.18	0.63
2009	Garden City	205	2	T	Y	HE 4.5%	37.8	35.1	21.01	0.35
2009	Garden City	206	2	NT	N	HE 4.5%	31.8	37.5	33.50	0.56
2009	Garden City	207	2	NT	Y	HE 4.5%	34	41.2	31.50	0.52
2009	Garden City	208	2	T	N	HE 4.5%	37	39.5	34.02	0.56
2009	Garden City	210	2	NT	N	N	32.3	37	25.93	0.43
2009	Garden City	211	2	NT	Y	ED 6%	34.8	39.9	38.15	0.63
2009	Garden City	212	2	T	N	N	39.5	39.9	29.59	0.49
2009	Garden City	302	3	NT	N	ED 6%	35.2	43.8	41.03	0.68

2009	Garden City	303	3	NT	Y	ED 6%	38.6	43.2	45.08	0.75
2009	Garden City	304	3	T	N	ED 6%	36.8	43.8	46.61	0.77
2009	Garden City	305	3	T	Y	N	35.5	39.3	27.94	0.46
2009	Garden City	306	3	NT	N	N	33.4	43.7	41.10	0.68
2009	Garden City	307	3	NT	Y	N	40.4	44	47.98	0.80
2009	Garden City	308	3	T	N	N	37.5	43.9	46.68	0.77
2009	Garden City	309	3	T	Y	HE 4.5%	32.7	37.7	37.67	0.62
2009	Garden City	310	3	NT	N	HE 4.5%	36.8	41.4	46.77	0.78
2009	Garden City	311	3	NT	Y	HE 4.5%	38.1	44.1	60.31	1.00
2009	Garden City	312	3	T	N	HE 4.5%	40.7	43.1	47.66	0.79
2009	Garden City	402	4	NT	N	ED 6%	34.3	42.9	38.92	0.65
2009	Garden City	403	4	NT	Y	ED 6%	37.7	44.7	50.63	0.84
2009	Garden City	404	4	T	N	ED 6%	37.1	43.4	31.36	0.52
2009	Garden City	406	4	NT	N	N	38.9	43.2	42.97	0.71
2009	Garden City	408	4	T	N	N	37.7	43.9	44.06	0.73
2009	Garden City	411	4	NT	Y	N	41.9	44.2	29.37	0.49
2009	Healy 1	101	1	T	Y	ED 6%	29	38	52.11	0.79
2009	Healy 1	102	1	T	Y	N	26.2	35	52.43	0.79
2009	Healy 1	103	1	T	Y	HE 4.5%	28.5	34	58.35	0.88
2009	Healy 1	104	1	NT	Y	N	29.6	36.6	54.83	0.83
2009	Healy 1	105	1	NT	Y	ED 6%	32.1	33.6	56.91	0.86
2009	Healy 1	106	1	NT	Y	HE 4.5%	28.5	31	58.67	0.88
2009	Healy 1	107	1	NT	N	HE 4.5%	28.8	32	47.80	0.72
2009	Healy 1	108	1	NT	N	ED 6%	29.7	31.1	43.00	0.65
2009	Healy 1	109	1	NT	N	N	30.5	36.8	47.00	0.71
2009	Healy 1	110	1	T	N	HE 4.5%	28.5	32.7	44.92	0.68
2009	Healy 1	111	1	T	N	N	27.3	34.7	43.96	0.66
2009	Healy 1	112	1	T	N	ED 6%	29	34	38.53	0.58
2009	Healy 1	201	2	T	Y	N	30.8	34.4	47.96	0.72
2009	Healy 1	202	2	T	Y	ED 6%	30.3	32.9	49.56	0.75

2009	Healy 1	203	2	T	Y	HE 4.5%	28.8	34.6	43.48	0.66
2009	Healy 1	204	2	NT	Y	ED 6%	31.6	34.7	49.24	0.74
2009	Healy 1	205	2	NT	Y	N	29.3	36.7	48.92	0.74
2009	Healy 1	206	2	NT	Y	HE 4.5%	27	33.3	48.12	0.73
2009	Healy 1	207	2	NT	N	N	28.9	33.9	38.84	0.59
2009	Healy 1	208	2	NT	N	ED 6%	28.5	34.1	33.25	0.50
2009	Healy 1	209	2	NT	N	HE 4.5%	31.5	33.7	26.22	0.40
2009	Healy 1	210	2	T	N	HE 4.5%	29.4	33.8	23.66	0.36
2009	Healy 1	211	2	T	N	ED 6%	27.9	32.4	19.02	0.29
2009	Healy 1	212	2	T	N	N	29.4	33.2	22.54	0.34
2009	Healy 1	301	3	T	Y	HE 4.5%	30.3	42.4	62.02	0.93
2009	Healy 1	302	3	T	Y	N	30.7	36.7	62.66	0.94
2009	Healy 1	303	3	T	Y	ED 6%	31.8	38.9	50.51	0.76
2009	Healy 1	304	3	NT	Y	N	31.1	38	52.27	0.79
2009	Healy 1	305	3	NT	Y	ED 6%	31.7	35	55.47	0.84
2009	Healy 1	306	3	NT	Y	HE 4.5%	33.5	35.8	54.83	0.83
2009	Healy 1	307	3	NT	N	ED 6%	34.2	33.5	48.28	0.73
2009	Healy 1	308	3	NT	N	N	33.4	35.3	39.96	0.60
2009	Healy 1	309	3	NT	N	HE 4.5%	29.9	38	42.68	0.64
2009	Healy 1	310	3	T	N	N	30.4	37.5	35.81	0.54
2009	Healy 1	311	3	T	N	ED 6%	32.7	40.6	19.34	0.29
2009	Healy 1	312	3	T	N	HE 4.5%	33.2	39.4	33.73	0.51
2009	Healy 1	401	4	T	Y	HE 4.5%	33	33.9	60.27	0.91
2009	Healy 1	402	4	T	Y	ED 6%	33.9	35.7	62.18	0.94
2009	Healy 1	403	4	T	Y	N	34	34.7	59.31	0.89
2009	Healy 1	404	4	NT	Y	HE 4.5%	33.3	36.7	59.95	0.90
2009	Healy 1	405	4	NT	Y	N	29	35.9	66.34	1.00
2009	Healy 1	406	4	NT	Y	ED 6%	32.9	40	61.86	0.93
2009	Healy 1	407	4	NT	N	N	32.7	37.8	43.48	0.66
2009	Healy 1	408	4	NT	N	ED 6%	33.4	39.4	46.84	0.71

2009	Healy 1	409	4	NT	N	HE 4.5%	30.7	37.8	43.64	0.66
2009	Healy 1	410	4	T	N	ED 6%	30.7	35.3	39.80	0.60
2009	Healy 1	411	4	T	N	N	33.7	36.5	28.77	0.43
2009	Healy 1	412	4	T	N	HE 4.5%	33.7	34.9	26.38	0.40
2009	Healy 2	101	1	T	Y	ED 6%	32.5	41.7	67.14	0.97
2009	Healy 2	102	1	T	Y	HE 4.5%	31.2	39.6	66.34	0.96
2009	Healy 2	103	1	T	Y	N	31.4	39.7	59.79	0.87
2009	Healy 2	104	1	NT	Y	N	32.9	41.9	62.98	0.91
2009	Healy 2	105	1	NT	Y	ED 6%	32.6	40.9	61.70	0.90
2009	Healy 2	106	1	NT	Y	HE 4.5%	33.4	40.1	62.82	0.91
2009	Healy 2	107	1	NT	N	HE 4.5%	29.5	39.7	52.43	0.76
2009	Healy 2	108	1	NT	N	ED 6%	28.3	38.4	50.19	0.73
2009	Healy 2	109	1	NT	N	N	30.5	39.8	49.08	0.71
2009	Healy 2	110	1	T	N	HE 4.5%	30.2	38.8	46.84	0.68
2009	Healy 2	111	1	T	N	ED 6%	30.4	35.4	39.16	0.57
2009	Healy 2	112	1	T	N	N	28.8	36.7	28.61	0.42
2009	Healy 2	201	2	T	Y	N	31.8	39.8	68.90	1.00
2009	Healy 2	202	2	T	Y	HE 4.5%	31.6	39.4	65.70	0.95
2009	Healy 2	203	2	T	Y	ED 6%	31.6	37.3	44.76	0.65
2009	Healy 2	204	2	NT	Y	ED 6%	32.8	38.4	49.56	0.72
2009	Healy 2	205	2	NT	Y	N	34.2	37.1	45.56	0.66
2009	Healy 2	206	2	NT	Y	HE 4.5%	33.2	36.1	40.92	0.59
2009	Healy 2	207	2	NT	N	HE 4.5%	29.9	37.9	42.84	0.62
2009	Healy 2	208	2	NT	N	ED 6%	30.9	38.3	46.04	0.67
2009	Healy 2	209	2	NT	N	N	29.8	38.8	35.65	0.52
2009	Healy 2	210	2	T	N	HE 4.5%	29.7	39.7	49.56	0.72
2009	Healy 2	211	2	T	N	ED 6%	28.6	37.5	29.25	0.42
2009	Healy 2	212	2	T	N	N	28.7	36.5	24.78	0.36
2009	Healy 2	301	3	T	Y	HE 4.5%	32.9	40.1	65.70	0.95
2009	Healy 2	302	3	T	Y	ED 6%	31.3	38.7	57.87	0.84

2009	Healy 2	303	3	T	Y	N	32.3	38.8	54.99	0.80
2009	Healy 2	304	3	NT	Y	N	33.3	38	51.63	0.75
2009	Healy 2	305	3	NT	Y	ED 6%	30.9	39.7	61.86	0.90
2009	Healy 2	306	3	NT	Y	HE 4.5%	33.9	35.7	38.84	0.56
2009	Healy 2	307	3	NT	N	ED 6%	29	35.7	35.33	0.51
2009	Healy 2	308	3	NT	N	N	30.1	36.3	44.28	0.64
2009	Healy 2	309	3	NT	N	HE 4.5%	30.9	37.2	49.87	0.72
2009	Healy 2	310	3	T	N	HE 4.5%	28.9	38.8	50.51	0.73
2009	Healy 2	311	3	T	N	ED 6%	27.7	38.5	42.68	0.62
2009	Healy 2	312	3	T	N	N	28.7	40	44.12	0.64
2009	Healy 2	401	4	T	Y	HE 4.5%	33.4	38.8	68.42	0.99
2009	Healy 2	402	4	T	Y	ED 6%	32.4	38.5	39.80	0.58
2009	Healy 2	403	4	T	Y	N	33.9	39.8	59.31	0.86
2009	Healy 2	404	4	NT	Y	HE 4.5%	33	38.7	63.78	0.93
2009	Healy 2	405	4	NT	Y	ED 6%	33.4	40.2	64.10	0.93
2009	Healy 2	407	4	NT	N	N	27.8	39.5	51.95	0.75
2009	Healy 2	408	4	NT	N	HE 4.5%	26.5	38.8	51.15	0.74
2009	Healy 2	409	4	NT	N	ED 6%	30.1	40.3	44.76	0.65
2009	Healy 2	410	4	T	N	N	28.6	38.8	48.76	0.71
2009	Healy 2	411	4	T	N	ED 6%	27.9	40.3	51.63	0.75
2009	Healy 2	412	4	T	N	HE 4.5%	26.9	39.5	41.08	0.60
2010	Colby1	101	1	T	N	N	35.3	22	50.15	1.00
2010	Colby1	102	1	T	Y	N	34.8	24.9	54.07	1.00
2010	Colby1	103	1	NT	N	N	24.8	17	16.05	0.32
2010	Colby1	104	1	NT	Y	N	33.1	19.4	41.67	0.77
2010	Colby1	105	1	T	N	ED 6%	26.7	21.9	25.93	0.52
2010	Colby1	106	1	NT	Y	ED 6%	34.4	21.3	26.04	0.48
2010	Colby1	107	1	NT	N	ED 6%	25.9	15.5	0.00	0.00
2010	Colby1	108	1	T	N	HE 4.5%	26.7	13.2	0.00	0.00
2010	Colby1	109	1	NT	Y	HE 4.5%	34.1	24.8	19.67	0.36

2010	Colby1	110	1	T	Y	ED 6%	34.8	27.2	0.00	0.00
2010	Colby1	111	1	NT	N	HE 4.5%	29.2	11.9	30.12	0.60
2010	Colby1	112	1	T	Y	HE 4.5%	37.2	26.9	20.71	0.38
2010	Colby1	201	2	T	N	HE 4.5%	31.3	20.6	34.32	0.68
2010	Colby1	202	2	T	Y	HE 4.5%	36	26.3	51.59	0.95
2010	Colby1	203	2	NT	N	HE 4.5%	23	11.6	0.00	0.00
2010	Colby1	204	2	NT	Y	ED 6%	35.8	15.5	16.92	0.31
2010	Colby1	205	2	T	N	ED 6%	24.7	10.8	0.00	0.00
2010	Colby1	206	2	NT	Y	HE 4.5%	35.6	17.7	9.99	0.18
2010	Colby1	207	2	NT	N	ED 6%	24.9	9.8	0.00	0.00
2010	Colby1	208	2	T	N	N	23.9	6.9	0.00	0.00
2010	Colby1	209	2	NT	Y	N	35.5	20.6	3.85	0.07
2010	Colby1	210	2	T	Y	ED 6%	37.7	21.4	12.81	0.24
2010	Colby1	211	2	NT	N	N	27.2	8.3	0.00	0.00
2010	Colby1	212	2	T	Y	N	37.5	25.8	29.83	0.55
2010	Colby1	301	3	T	N	N	27.4	19	0.00	0.00
2010	Colby1	302	3	T	Y	N	31.1	26.4	23.30	0.43
2010	Colby1	303	3	NT	N	N	18.9	11.7	0.00	0.00
2010	Colby1	304	3	NT	Y	HE 4.5%	31.4	21.3	10.70	0.20
2010	Colby1	305	3	T	N	HE 4.5%	21.2	16.9	0.00	0.00
2010	Colby1	306	3	NT	Y	N	33.8	21.7	14.76	0.27
2010	Colby1	307	3	NT	N	HE 4.5%	25.5	9	0.00	0.00
2010	Colby1	308	3	T	N	ED 6%	25.5	12.1	0.00	0.00
2010	Colby1	309	3	NT	Y	ED 6%	34	22.4	11.56	0.21
2010	Colby1	310	3	T	Y	HE 4.5%	36.6	26	13.75	0.25
2010	Colby1	311	3	NT	N	ED 6%	26.3	11	0.00	0.00
2010	Colby1	312	3	T	Y	ED 6%	35.6	28	19.81	0.37
2010	Colby1	401	4	T	N	HE 4.5%	25.9	13.9	0.00	0.00
2010	Colby1	402	4	T	Y	HE 4.5%	34.2	24.8	15.26	0.28
2010	Colby1	403	4	NT	N	HE 4.5%	27.2	8	0.00	0.00

2010	Colby1	404	4	NT	Y	N	34	22	18.16	0.34
2010	Colby1	405	4	T	N	ED 6%	25.1	12.6	0.00	0.00
2010	Colby1	406	4	NT	Y	ED 6%	35.7	21.6	11.89	0.22
2010	Colby1	407	4	NT	N	ED 6%	27.1	10.3	0.00	0.00
2010	Colby1	408	4	T	N	N	27.3	12.8	0.00	0.00
2010	Colby1	409	4	NT	Y	HE 4.5%	34.8	20.8	15.18	0.28
2010	Colby1	410	4	T	Y	N	36.2	24.5	13.15	0.24
2010	Colby1	411	4	NT	N	N	24.1	9.5	0.00	0.00
2010	Colby1	412	4	T	Y	ED 6%	37.1	23.1	13.77	0.25
2010	Colby2	101	1	T	N	N	28.1	12.8	0.00	0.00
2010	Colby2	102	1	T	Y	N	38.3	25.2	17.18	0.34
2010	Colby2	103	1	NT	N	N	24.4	8.5	0.00	0.00
2010	Colby2	104	1	NT	Y	N	34.8	20	18.23	0.36
2010	Colby2	105	1	T	N	ED 6%	24.2	9	0.00	0.00
2010	Colby2	106	1	NT	Y	ED 6%	36.7	22.4	15.22	0.30
2010	Colby2	107	1	NT	N	ED 6%	23.5	11.2	0.00	0.00
2010	Colby2	108	1	T	N	HE 4.5%	22.7	11.6	0.00	0.00
2010	Colby2	109	1	NT	Y	HE 4.5%	36.3	18.6	11.67	0.23
2010	Colby2	110	1	T	Y	ED 6%	34.5	23.5	20.65	0.41
2010	Colby2	111	1	NT	N	HE 4.5%	23.1	9.2	0.00	0.00
2010	Colby2	112	1	T	Y	HE 4.5%	38.2	25.5	16.53	0.33
2010	Colby2	201	2	T	N	HE 4.5%	27.7	14.6	0.00	0.00
2010	Colby2	202	2	T	Y	HE 4.5%	35.3	24.7	21.65	0.43
2010	Colby2	203	2	NT	N	HE 4.5%	28.5	6.9	0.00	0.00
2010	Colby2	204	2	NT	Y	ED 6%	33.6	19.7	9.84	0.20
2010	Colby2	205	2	T	N	ED 6%	24.1	17.8	0.00	0.00
2010	Colby2	206	2	NT	Y	HE 4.5%	34.3	21.5	24.20	0.48
2010	Colby2	207	2	NT	N	ED 6%	22.2	8.7	0.00	0.00
2010	Colby2	208	2	T	N	N	20.7	9.5	0.00	0.00
2010	Colby2	209	2	NT	Y	N	33.9	20.9	4.52	0.09

2010	Colby2	210	2	T	Y	ED 6%	36.5	28.4	17.19	0.34
2010	Colby2	211	2	NT	N	N	22.6	8.2	0.00	0.00
2010	Colby2	212	2	T	Y	N	34.5	24.7	11.77	0.23
2010	Colby2	301	3	T	N	N	27.3	21.7	0.00	0.00
2010	Colby2	302	3	T	Y	N	33.2	24.6	29.85	0.60
2010	Colby2	303	3	NT	N	N	25.3	10.5	0.00	0.00
2010	Colby2	304	3	NT	Y	HE 4.5%	30.3	21.9	2.73	0.05
2010	Colby2	305	3	T	N	HE 4.5%	26.2	15.8	0.00	0.00
2010	Colby2	306	3	NT	Y	N	31.7	20.7	12.28	0.24
2010	Colby2	307	3	NT	N	HE 4.5%	18.6	9.8	0.00	0.00
2010	Colby2	308	3	T	N	ED 6%	18.7	13.7	6.16	0.12
2010	Colby2	309	3	NT	Y	ED 6%	29.3	23.5	26.19	0.52
2010	Colby2	310	3	T	Y	HE 4.5%	33.1	26	15.53	0.31
2010	Colby2	311	3	NT	N	ED 6%	17	7.8	0.00	0.00
2010	Colby2	312	3	T	Y	ED 6%	34.1	26.5	33.83	0.67
2010	Colby2	401	4	T	N	HE 4.5%	21.6	10.4	0.00	0.00
2010	Colby2	402	4	T	Y	HE 4.5%	30.7	22.9	21.79	0.43
2010	Colby2	403	4	NT	N	HE 4.5%	17.6	7.9	0.00	0.00
2010	Colby2	404	4	NT	Y	N	30.6	16.1	2.99	0.06
2010	Colby2	405	4	T	N	ED 6%	16.9	17.8	0.00	0.00
2010	Colby2	406	4	NT	Y	ED 6%	28.7	19.6	6.85	0.14
2010	Colby2	407	4	NT	N	ED 6%	21.1	8.6	0.00	0.00
2010	Colby2	408	4	T	N	N	21.7	7.5	0.00	0.00
2010	Colby2	409	4	NT	Y	HE 4.5%	31.8	19.1	13.92	0.28
2010	Colby2	410	4	T	Y	N	33.1	24	22.69	0.45
2010	Colby2	411	4	NT	N	N	20.2	8.1	0.00	0.00
2010	Colby2	412	4	T	Y	ED 6%	33.2	25.1	38.72	0.77
2010	GC10	101	1	T	N	N	30.8	44.3	16.16	0.62
2010	GC10	102	1	T	Y	N	39.2	42.2	10.91	0.42
2010	GC10	103	1	NT	N	N	22.8	31.8	17.23	0.67

2010	GC10	104	1	NT	Y	N	30.8	28.2	11.68	0.45
2010	GC10	105	1	T	N	ED 6%	26.1	37.4	3.45	0.13
2010	GC10	106	1	NT	Y	ED 6%	31.9	36.2	17.53	0.68
2010	GC10	107	1	NT	N	ED 6%	26	35.8	10.66	0.41
2010	GC10	108	1	T	N	HE 4.5%	25.7	41	13.51	0.52
2010	GC10	109	1	NT	Y	HE 4.5%	35.1	36	20.89	0.81
2010	GC10	110	1	T	Y	ED 6%	39.5	43.6	12.37	0.48
2010	GC10	111	1	NT	N	HE 4.5%	25.6	34.6	13.68	0.53
2010	GC10	112	1	T	Y	HE 4.5%	33.4	44.4	25.85	1.00
2010	GC10	201	2	T	N	HE 4.5%	29	43.3	17.52	0.68
2010	GC10	202	2	T	Y	HE 4.5%	38.6	42.8	16.27	0.63
2010	GC10	203	2	NT	N	HE 4.5%	25.7	33.6	18.44	0.71
2010	GC10	204	2	NT	Y	ED 6%	32.3	29.6	8.26	0.32
2010	GC10	205	2	T	N	ED 6%	27.4	38.3	4.66	0.18
2010	GC10	206	2	NT	Y	HE 4.5%	34.3	34.7	18.89	0.73
2010	GC10	207	2	NT	N	ED 6%	21.1	35.7	10.90	0.42
2010	GC10	208	2	T	N	N	26	42	10.26	0.40
2010	GC10	209	2	NT	Y	N	30.7	37.6	20.28	0.78
2010	GC10	210	2	T	Y	ED 6%	33.6	42.1	13.39	0.52
2010	GC10	211	2	NT	N	N	23	36.7	14.83	0.57
2010	GC10	212	2	T	Y	N	33.1	45.5	14.11	0.55
2010	GC10	301	3	T	N	N	33	44.8	12.67	0.49
2010	GC10	302	3	T	Y	N	37	40.3	13.19	0.51
2010	GC10	303	3	NT	N	N	26.4	36.2	16.05	0.62
2010	GC10	304	3	NT	Y	HE 4.5%	34.7	35.2	16.87	0.65
2010	GC10	305	3	T	N	HE 4.5%	28.3	38	6.54	0.25
2010	GC10	306	3	NT	Y	N	33.8	34.5	17.93	0.69
2010	GC10	307	3	NT	N	HE 4.5%	26.4	33.6	15.67	0.61
2010	GC10	308	3	T	N	ED 6%	32.4	41.2	8.43	0.33
2010	GC10	309	3	NT	Y	ED 6%	33.6	38.5	16.71	0.65

2010	GC10	310	3	T	Y	HE 4.5%	36.6	40.4	8.38	0.32
2010	GC10	311	3	NT	N	ED 6%	22.1	37.9	15.56	0.60
2010	GC10	312	3	T	Y	ED 6%	32	45	16.20	0.63
2010	GC10	401	4	T	N	HE 4.5%	32.4	41	12.09	0.47
2010	GC10	402	4	T	Y	HE 4.5%	37.9	35.3	15.06	0.58
2010	GC10	403	4	NT	N	HE 4.5%	26.1	33.2	14.25	0.55
2010	GC10	404	4	NT	Y	N	34.4	32.9	15.76	0.61
2010	GC10	405	4	T	N	ED 6%	27.3	38	5.47	0.21
2010	GC10	407	4	NT	N	ED 6%	25.4	33.4	15.45	0.60
2010	GC10	408	4	T	N	N	32.3	42.3	12.12	0.47
2010	GC10	409	4	NT	Y	HE 4.5%	34.2	38.7	21.46	0.83
2010	GC10	410	4	T	Y	N	36.8	39.1	7.07	0.27
2010	GC10	411	4	NT	N	N	23.7	38.7	13.29	0.51
2010	GC10	412	4	T	Y	ED 6%	35.6	43.7	17.07	0.66
2010	Healy10	101	1	T	Y	N	36.1	36	12.39	0.33
2010	Healy10	102	1	NT	N	N	20.8	31.4	0.00	0.00
2010	Healy10	103	1	T	Y	ED 6%	34.1	28.4	0.00	0.00
2010	Healy10	104	1	T	N	N	26.9	31	0.00	0.00
2010	Healy10	105	1	NT	N	ED 6%	23.4	20.7	0.00	0.00
2010	Healy10	106	1	T	Y	HE 4.5%	37.8	33.6	0.00	0.00
2010	Healy10	107	1	NT	Y	N	38	31.3	8.91	0.24
2010	Healy10	108	1	NT	N	HE 4.5%	27.1	25.6	0.00	0.00
2010	Healy10	109	1	T	N	ED 6%	27.8	24.2	0.00	0.00
2010	Healy10	110	1	T	N	HE 4.5%	23.7	33.6	0.00	0.00
2010	Healy10	111	1	NT	Y	ED 6%	38	30.1	16.44	0.44
2010	Healy10	112	1	NT	Y	HE 4.5%	38.3	30.6	13.35	0.36
2010	Healy10	201	2	T	Y	HE 4.5%	38.6	37.2	8.26	0.22
2010	Healy10	202	2	NT	N	HE 4.5%	23.6	23.5	0.00	0.00
2010	Healy10	203	2	T	Y	ED 6%	37.3	37.3	8.83	0.23
2010	Healy10	204	2	T	N	HE 4.5%	25.8	27.6	0.00	0.00

2010	Healy10	205	2	NT	N	ED 6%	22.1	25.5	10.18	0.27
2010	Healy10	206	2	T	Y	N	39.1	30.7	0.00	0.00
2010	Healy10	207	2	NT	Y	ED 6%	40.3	33.6	37.58	1.00
2010	Healy10	208	2	NT	N	N	26.3	24.3	7.85	0.21
2010	Healy10	209	2	T	N	ED 6%	31.1	31	0.00	0.00
2010	Healy10	210	2	T	N	N	29.2	29.8	0.00	0.00
2010	Healy10	211	2	NT	Y	HE 4.5%	40.5	36.3	27.06	0.72
2010	Healy10	212	2	NT	Y	N	38.3	32.3	5.75	0.15
2010	Healy10	301	3	T	Y	N	34.3	39.3	4.44	0.12
2010	Healy10	302	3	NT	N	N	29	25.2	0.00	0.00
2010	Healy10	303	3	T	Y	HE 4.5%	32.8	35.7	10.59	0.28
2010	Healy10	304	3	T	N	N	25.7	28.8	0.00	0.00
2010	Healy10	305	3	NT	N	HE 4.5%	22.1	25	11.27	0.30
2010	Healy10	306	3	T	Y	ED 6%	34.7	32.6	0.00	0.00
2010	Healy10	307	3	NT	Y	HE 4.5%	36.4	33	0.00	0.00
2010	Healy10	308	3	NT	N	ED 6%	25.8	29.7	5.03	0.13
2010	Healy10	309	3	T	N	HE 4.5%	26.9	29.5	0.00	0.00
2010	Healy10	310	3	T	N	ED 6%	27	32.2	0.00	0.00
2010	Healy10	311	3	NT	Y	N	33.2	31.7	32.68	0.87
2010	Healy10	312	3	NT	Y	ED 6%	36.5	33.6	31.13	0.83
2010	Healy10	401	4	T	Y	HE 4.5%	40	34	0.00	0.00
2010	Healy10	402	4	NT	N	HE 4.5%	28.1	25.7	0.00	0.00
2010	Healy10	403	4	T	Y	N	37	36.3	4.60	0.12
2010	Healy10	404	4	T	N	HE 4.5%	30	31.6	0.00	0.00
2010	Healy10	405	4	NT	N	ED 6%	26	28	0.91	0.02
2010	Healy10	406	4	T	Y	ED 6%	35.6	36.3	0.00	0.00
2010	Healy10	407	4	NT	Y	N	40.4	33.5	27.72	0.74
2010	Healy10	408	4	NT	N	N	22.1	16.7	0.00	0.00
2010	Healy10	409	4	T	N	ED 6%	26.9	31.6	0.00	0.00
2010	Healy10	410	4	T	N	N	24.7	25.2	0.00	0.00

2010	Healy10	411	4	NT	Y	ED 6%	39.2	31.3	34.87	0.93
2010	Healy10	412	4	NT	Y	HE 4.5%	41.5	31.2	17.13	0.46

Soil Parameters

Year	Location	Plot	pH	P	Fe	OM	Ca	Mg	EC	Nitrate	Carb	Zinc	ASI
2009	Garden City	101	8.34	29.50	1.94	2.04	4431.53	415.20	0.50	7.78	8.33		9.51
2009	Garden City	102	8.15	28.90	1.81	2.27	4466.69	418.61	0.70	13.54	10.00		9.55
2009	Garden City	103	8.29	30.00	1.83	2.09	4513.55	434.75	0.76	18.55	7.25		9.31
2009	Garden City	104	8.41	25.50	1.77	2.00	4500.34	426.58	0.70	9.93	10.00		9.81
2009	Garden City	105	8.34	26.90	1.74	2.29	4498.17	427.39	0.70	13.57	11.67		9.97
2009	Garden City	106	8.37	30.00	1.59	2.00	4364.02	396.86	0.90	11.00	11.67		10.00
2009	Garden City	107	8.28	31.40	1.72	2.22	4413.41	421.60	0.80	15.21	11.67		9.91
2009	Garden City	108	8.33	28.60	1.61	2.22	4421.53	399.73	0.90	19.32	10.00		9.73
2009	Garden City	109	8.36	27.00	2.05	2.04	4443.53	416.39	0.70	13.22	8.33		9.53
2009	Garden City	110	8.38	29.40	1.59	2.02	4497.09	411.77	0.90	11.66	11.67		10.01
2009	Garden City	111	8.35	27.60	1.74	2.02	4379.49	400.64	0.70	14.26	11.00		9.89
2009	Garden City	112	8.32	34.40	1.68	2.00	4180.61	375.38	0.89	13.15	10.00		9.72
2009	Garden City	201	8.12	24.50	1.77	2.20	4289.46	408.69	0.63	12.12	8.33		9.29
2009	Garden City	202	8.36	24.80	1.57	1.98	4356.60	397.62	0.72	14.55	8.33		9.53
2009	Garden City	203	8.32	29.10	1.68	2.02	4342.12	414.49	0.78	11.62	15.00		10.42
2009	Garden City	204	8.31	30.50	1.60	2.13	4367.24	425.37	0.95	15.95	10.00		9.71
2009	Garden City	205	8.48	24.80	1.79	2.16	4385.69	422.54	0.65	13.05	8.33		9.65
2009	Garden City	206	8.31	29.70	1.64	2.18	4399.58	421.82	0.98	13.78	8.33		9.48
2009	Garden City	207	8.39	28.30	1.70	2.13	4375.05	418.34	0.85	15.51	8.33		9.56
2009	Garden City	208	8.20	28.40	1.69	2.16	4384.04	437.34	0.97	20.82	6.67		9.13
2009	Garden City	210	8.26	28.90	1.71	2.18	4377.53	447.10	0.97	19.55	8.33		9.43
2009	Garden City	211	8.29	28.30	1.98	2.00	4213.92	424.82	0.92	12.07	10.00		9.69
2009	Garden City	212	8.23	25.40	1.94	2.02	4141.08	446.49	1.01	18.19	6.67		9.16
2009	Garden City	302	8.34	23.90	1.87	2.20	3853.60	486.18	0.97	20.19	8.33		9.51

2009	Garden City	303	8.15	27.90	2.26	2.11	3733.20	513.55	1.09	16.41	10.00	9.55
2009	Garden City	304	8.17	26.70	2.11	2.27	3436.53	546.35	1.30	14.75	8.33	9.34
2009	Garden City	305	8.27	23.20	2.22	2.31	3548.66	517.40	0.68	27.11	10.00	9.67
2009	Garden City	306	8.17	24.80	2.15	2.31	3684.99	522.54	1.17	35.55	11.67	9.80
2009	Garden City	307	8.09	33.30	2.12	2.27	3507.50	528.32	1.13	23.00	4.25	8.69
2009	Garden City	308	8.13	27.00	2.19	2.27	3475.12	551.10	1.20	32.53	10.00	9.53
2009	Garden City	309	8.33	26.40	2.53	2.22	4222.35	556.03	0.68	26.52	17.90	10.84
2009	Garden City	310	8.18	27.00	2.26	1.96	4340.58	533.86	1.35	23.13	13.33	10.05
2009	Garden City	311	8.06	33.20	2.40	2.31	4173.76	574.47	1.36	16.37	8.33	9.23
2009	Garden City	312	8.18	27.40	2.40	2.11	4373.18	572.56	1.04	19.87	11.67	9.81
2009	Garden City	402	7.97	33.30	2.46	2.67	3308.40	567.58	1.02	14.45	3.33	8.44
2009	Garden City	403	8.07	34.60	2.43	2.42	3339.68	576.37	1.02	33.15	6.67	9.00
2009	Garden City	404	8.05	30.60	2.35	2.44	3649.04	575.29	0.94	17.75	10.00	9.45
2009	Garden City	406	7.86	30.30	3.58	2.36	3131.22	588.94	0.74	12.15	8.33	9.03
2009	Garden City	408	7.53	31.70	3.29	2.49	2932.39	647.13	0.97	14.85	8.33	8.70
2009	Garden City	411	6.79	38.40	8.17	2.36	2463.92	533.24	0.75	14.51		6.79
2009	Healy 1	101	8.20	95.50	2.57	2.04	3912.95	730.67	0.62	6.81	6.67	9.13
2009	Healy 1	102	8.25	79.10	2.39	1.89	4138.14	744.12	0.63	5.95	8.33	9.42
2009	Healy 1	103	8.29	79.90	2.24	2.09	4142.68	734.38	0.65	6.33	8.33	9.46
2009	Healy 1	104	8.34	76.30	2.31	2.18	4237.80	684.87	0.56	4.38	10.00	9.74
2009	Healy 1	105	8.32	79.10	2.21	2.73	4363.97	712.62	0.54	5.31	3.33	8.79
2009	Healy 1	106	8.38	75.90	2.12	2.09	4316.01	720.04	0.52	6.53	10.00	9.78
2009	Healy 1	107	8.35	84.30	3.07	2.07	4421.49	716.33	0.55	5.44	8.33	9.52
2009	Healy 1	108	8.27	81.80	2.32	2.13	4486.12	712.34	0.56	7.15	8.33	9.44
2009	Healy 1	109	8.27	83.80	2.36	2.00	4457.81	724.81	0.60	6.64	14.20	10.26
2009	Healy 1	110	8.27	90.30	2.22	1.89	4299.53	681.40	0.62	6.67	5.50	9.04
2009	Healy 1	111	8.36	101.00	2.29	2.09	4413.72	673.67	0.57	6.21	11.67	9.99
2009	Healy 1	112	8.32	99.30	2.53	2.04	4410.77	685.97	0.52	4.87	5.00	9.02
2009	Healy 1	201	8.29	88.50	2.40	2.24	3718.41	763.34	0.52	8.97	12.50	10.04
2009	Healy 1	202	8.27	81.70	2.06	2.11	3814.94	748.19	0.56	8.30	11.67	9.90

2009	Healy 1	203	8.37	70.00	2.10	1.98	4134.26	792.89	0.59	5.98	3.33		8.84
2009	Healy 1	204	8.34	70.80	1.90	1.98	4145.00	680.03	0.55	8.07	5.00		9.04
2009	Healy 1	205	8.41	73.90	1.89	2.02	4390.75	737.11	0.52	8.06	6.67		9.34
2009	Healy 1	206	8.34	76.00	1.97	2.27	4375.82	758.82	0.55	7.69	3.33		8.81
2009	Healy 1	207	8.34	78.10	3.00	1.98	4811.63	729.78	0.51	5.33	1.67		8.57
2009	Healy 1	208	8.43	72.70	2.97	1.98	4956.79	750.30	0.54	6.15	8.33		9.60
2009	Healy 1	209	8.39	73.90	2.91	2.02	4928.36	789.62	0.51	7.21	6.67		9.32
2009	Healy 1	210	8.43	82.20	2.72	2.13	4940.05	771.41	0.50	5.54	5.00		9.13
2009	Healy 1	211	8.37	95.10	2.82	2.33	4876.55	710.91	0.58	8.48	1.67		8.60
2009	Healy 1	212	8.36	89.20	3.11	2.13	4761.40	706.23	0.54	5.74	5.00		9.06
2009	Healy 1	301	8.18	86.20	3.60	1.97	3748.85	733.42	0.97	7.53	5.40		8.94
2009	Healy 1	302	8.27	77.20	3.39	1.87	4025.51	743.50	0.64	7.33	6.67		9.20
2009	Healy 1	303	7.91	74.80	3.29	1.91	4390.38	760.11	0.59	10.65	1.67		8.14
2009	Healy 1	304	8.00	69.60	3.17	1.63	4670.93	729.40	0.64	5.39	1.67		8.23
2009	Healy 1	305	8.11	77.00	2.94	1.85	4728.54	725.41	0.32	7.69	6.67		9.04
2009	Healy 1	306	8.16	72.20	2.90	1.85	4454.68	707.85	0.98	5.87	0.00		8.16
2009	Healy 1	307	7.86	76.20	3.11	1.78	4578.95	662.35	0.63	6.74	6.67		8.79
2009	Healy 1	308	8.26	65.30	2.88	1.70	4654.93	645.43	0.58	8.15	1.67		8.49
2009	Healy 1	309	8.27	69.20	2.82	1.74	4677.58	737.42	0.60	8.29	8.33		9.44
2009	Healy 1	310	8.20	81.60	2.86	1.78	4795.51	721.69	0.61	7.51	6.67		9.13
2009	Healy 1	311	8.26	102.00	3.46	1.70	4248.97	608.62	0.80	6.03	1.67		8.49
2009	Healy 1	312	8.22	75.40	3.02	1.48	4557.57	714.14	0.61	5.93	8.33		9.39
2009	Healy 1	401	8.28	59.50	3.35	2.08	4248.53	671.42	0.64	7.52	7.65		9.35
2009	Healy 1	402	8.19	57.40	3.23	1.80	4298.50	661.15	0.59	7.08	1.67		8.42
2009	Healy 1	403	8.30	72.50	3.31	1.80	4078.00	736.93	0.59	7.79	1.67		8.53
2009	Healy 1	404	8.23	64.60	3.11	1.57	4409.49	656.59	0.53	4.73	15.00		10.33
2009	Healy 1	405	8.25	74.10	3.14	1.61	4626.18	642.31	0.55	8.50	13.33		10.12
2009	Healy 1	406	8.22	72.10	3.02	1.72	4550.16	739.57	0.59	5.22	8.33		9.39
2009	Healy 1	407	8.28	70.60	3.05	1.70	4661.08	645.14	0.57	5.83	1.67		8.51
2009	Healy 1	408	8.37	65.00	2.95	1.48	4558.79	630.91	0.53	5.33	0.00		8.37

2009	Healy 1	409	8.16	66.80	2.87	1.74	4550.35	718.73	0.58	8.88	6.67	9.09
2009	Healy 1	410	8.41	78.80	2.87	1.74	4525.28	708.04	0.50	8.17	1.67	8.64
2009	Healy 1	411	8.24	78.50	3.02	2.40	4544.55	644.82	0.50	11.43	6.67	9.17
2009	Healy 1	412	8.33	82.50	2.90	1.76	4512.73	684.17	0.72	7.61	0.00	8.33
2009	Healy 2	101	8.10	61.70	3.44	1.63	4003.74	642.82	0.54	9.80	5.00	8.80
2009	Healy 2	102	8.31	60.60	3.48	1.54	4100.83	641.34	0.57	9.04	3.33	8.78
2009	Healy 2	103	8.15	66.50	3.36	1.74	4230.80	767.18	0.58	8.09	1.67	8.38
2009	Healy 2	104	8.15	64.20	3.22	1.76	4454.18	639.97	0.64	7.80	8.33	9.32
2009	Healy 2	105	7.94	70.90	3.25	1.70	4608.98	618.40	0.65	6.93	10.00	9.34
2009	Healy 2	106	8.17	71.90	3.09	1.74	4555.35	715.40	0.56	6.36	1.67	8.40
2009	Healy 2	107	8.28	72.20	3.08	1.76	4541.95	621.06	0.68	5.75	1.67	8.51
2009	Healy 2	108	8.20	64.30	3.43	1.70	4591.45	611.36	0.64	6.55	0.00	8.20
2009	Healy 2	109	8.31	66.90	2.79	1.59	4610.85	723.17	0.68	8.99	1.67	8.54
2009	Healy 2	110	8.25	63.70	2.96	1.76	4634.57	673.98	0.53	5.76	6.67	9.18
2009	Healy 2	111	8.36	72.60	2.75	1.59	4707.29	648.97	0.81	9.93	1.67	8.59
2009	Healy 2	112	8.24	79.50	2.92	1.78	4434.67	645.15	0.52	10.52	8.33	9.41
2009	Healy 2	201	8.19	59.60	3.41	1.93	4382.51	652.71	0.83	11.32	1.67	8.42
2009	Healy 2	202	8.13	65.40	3.28	1.87	4398.01	651.65	0.82	8.07	5.00	8.83
2009	Healy 2	203	8.07	5.32		1.93	4379.20	731.73	0.79	9.59		8.07
2009	Healy 2	204	8.23	68.30	3.29	1.85	4671.36	624.34	0.73	6.64	8.33	9.40
2009	Healy 2	205	8.16	77.20	3.10	1.87	4705.00	583.48	0.74	10.14	1.67	8.39
2009	Healy 2	206	8.34	71.10	3.10	1.76	4593.08	675.43	0.73	8.41	6.67	9.27
2009	Healy 2	207	8.17	76.00	3.05	1.78	4621.91	625.04	0.84	15.37	8.33	9.34
2009	Healy 2	208	8.37	64.30	3.14	1.70	4660.44	609.84	0.72	7.21	0.00	8.37
2009	Healy 2	209	8.18	69.60	3.25	1.82	4437.69	662.45	0.48	9.37	1.67	8.41
2009	Healy 2	210	8.28	79.30	3.28	1.97	4504.75	662.38	0.51	6.36	1.67	8.51
2009	Healy 2	211	8.24	72.50	3.27	1.82	4479.72	628.60	0.49	8.98	0.00	8.24
2009	Healy 2	212	8.42	36.60	3.04	1.14	4935.73	593.34	0.53	9.24	0.00	8.42
2009	Healy 2	301	8.07	87.00	3.61	2.12	3733.86	627.76	0.81	8.18	0.00	8.07
2009	Healy 2	302	8.13	81.00	3.24	2.02	4037.90	653.40	0.71	10.29	3.33	8.60

2009	Healy 2	303	7.89	75.00	3.39	2.06	4397.34	698.04	0.87	7.35	10.00		9.29
2009	Healy 2	304	8.16	76.90	3.15	1.85	4531.07	631.02	0.94	10.82	3.75		8.69
2009	Healy 2	305	8.21	82.30	2.86	1.93	4449.71	576.28	0.87	7.91	6.67		9.14
2009	Healy 2	306	8.16	77.20	2.92	1.85	4665.90	688.79	0.96	7.42	17.50		10.61
2009	Healy 2	307	8.29	82.30	3.03	1.80	4544.08	617.12	0.82	10.76	8.33		9.46
2009	Healy 2	308	8.25	75.20	3.03	1.87	4666.97	623.27	0.78	8.35	10.00		9.65
2009	Healy 2	309	8.30	67.90	3.03	1.97	4504.29	647.62	1.00	9.90	1.67		8.53
2009	Healy 2	310	8.08	68.00	3.32	1.85	4663.52	644.94	0.91	9.62	15.00		10.18
2009	Healy 2	311	8.27	85.40	3.23	2.10	4442.00	645.24	0.88	8.18	0.00		8.27
2009	Healy 2	312	8.09	69.90	3.26	1.89	4483.82	641.67	0.83	9.45	10.00		9.49
2009	Healy 2	401	7.99	86.00	3.94	1.91	3858.11	640.71	1.10	9.89	6.67		8.92
2009	Healy 2	402	8.17	55.70	3.38	1.74	4605.05	544.68	1.36	11.30	0.00		8.17
2009	Healy 2	403	8.11	72.30	3.17	1.87	4286.47	664.55	1.05	8.38	6.67		9.04
2009	Healy 2	404	8.37	64.70	3.30	1.72	4707.28	588.34	0.73	7.86	8.33		9.54
2009	Healy 2	405	8.11	65.60	3.36	1.65	4551.30	592.17	0.97	12.59	3.00		8.53
2009	Healy 2	407	8.18	69.40	3.77	1.59	4471.80	600.93	0.81	7.00	1.67		8.41
2009	Healy 2	408	8.22	75.30	3.17	1.93	4592.68	630.70	0.89	5.07	0.00		8.22
2009	Healy 2	409	8.09	55.80	4.14	1.76	4489.48	664.74	0.89	8.78	1.67		8.32
2009	Healy 2	410	8.24	68.90	3.15	1.85	4421.70	669.06	0.78	8.88	0.00		8.24
2009	Healy 2	411	8.07	61.80	3.57	1.57	4229.59	624.26	0.95	9.07	6.67		9.00
2009	Healy 2	412	7.95	66.90	3.97	1.82	4359.35	665.82	0.93	11.09	0.00		7.95
2010	Colby1	101	8.10	37.80	2.36	2.31	4194.25	363.57	0.50	6.76	5.40	0.75	8.86
2010	Colby1	102	7.79	40.60	2.08	2.46	4240.10	355.39	0.70	5.91	3.60	0.67	8.29
2010	Colby1	103	8.18	55.50	2.03	2.64	4619.89	348.96	0.60	9.36	3.60	0.69	8.68
2010	Colby1	104	8.06	47.10	1.90	2.38	4541.40	331.57	0.60	6.87	6.50	0.73	8.97
2010	Colby1	105	8.20	44.10	1.86	2.36	4693.85	329.40	0.60	8.21	3.60	0.75	8.70
2010	Colby1	106	8.18	60.90	1.81	2.57	4717.74	322.63	0.60	7.48	3.60	1.01	8.68
2010	Colby1	107	8.32	63.30	1.77	2.46	4695.32	314.55	0.50	3.77	5.40	0.84	9.08
2010	Colby1	108	8.29	58.10	1.74	2.50	4761.20	317.62	0.60	6.16	5.40	0.86	9.05
2010	Colby1	109	8.30	53.00	1.70	2.43	4778.24	301.54	0.50	8.47	10.50	0.82	9.77

2010	Colby1	110	8.33	56.00	1.68	2.64	4827.97	305.77	0.60	5.44	7.30	0.84	9.35
2010	Colby1	111	8.29	58.00	1.71	2.46	4860.62	303.33	0.50	7.75	6.50	0.86	9.20
2010	Colby1	112	8.29	77.50	1.96	2.41	4717.92	305.98	0.80	10.23	14.30	1.02	10.29
2010	Colby1	201	8.06	28.50	1.98	2.17	4758.95	347.50	0.60	4.24	2.50	0.58	8.41
2010	Colby1	202	8.33	38.40	1.82	2.29	4756.98	334.25	0.70	6.80	3.30	0.65	8.79
2010	Colby1	203	8.15	53.00	1.77	2.27	4633.08	313.83	0.70	8.47	13.10	0.75	9.98
2010	Colby1	204	8.40	53.50	1.64	2.31	4872.57	337.48	0.70	6.48	10.20	0.74	9.83
2010	Colby1	205	8.30	66.40	1.64	2.31	4802.33	323.71	0.70	8.02	13.10	0.82	10.13
2010	Colby1	206	8.38	64.50	1.58	2.17	5232.93	385.88	0.80	7.73	14.20	0.76	10.37
2010	Colby1	207	8.26	75.10	1.59	2.29	4904.45	325.70	0.70	7.74	12.70	0.82	10.04
2010	Colby1	208	8.40	85.20	1.70	2.41	4891.16	328.78	0.80	6.86	12.70	1.00	10.18
2010	Colby1	209	8.23	82.30	1.67	2.17	4910.39	321.58	0.70	6.56	12.70	0.92	10.01
2010	Colby1	210	8.44	93.40	1.73	2.36	4761.15	326.09	0.90	4.76	14.50	0.97	10.47
2010	Colby1	211	8.47	84.70	1.82	2.32	4763.88	321.31	0.50	7.53	14.50	0.87	10.50
2010	Colby1	212	7.98	75.20	1.74	2.36	4840.52	308.07	0.50	10.65	13.50	0.91	9.87
2010	Colby1	301	8.43	36.40	1.47	2.28	4940.43	307.54	0.50	6.74	11.30	0.68	10.01
2010	Colby1	302	8.27	57.00	1.63	2.39	4902.72	304.32	0.50	6.42	12.70	0.71	10.05
2010	Colby1	303	8.37	53.30	1.53	2.45	4902.89	314.49	0.50	6.80	11.30	0.74	9.95
2010	Colby1	304	8.30	42.60	1.45	2.26	4823.95	291.06	0.50	13.77	12.40	0.60	10.04
2010	Colby1	305	8.40	35.50	1.42	2.10	5006.33	302.66	0.50	11.44	12.70	0.65	10.18
2010	Colby1	306	8.36	35.70	1.37	2.08	4935.40	305.99	0.50	7.84	13.80	0.52	10.29
2010	Colby1	307	8.44	46.00	1.42	2.10	4922.61	301.25	0.50	9.12	11.30	0.58	10.02
2010	Colby1	308	8.38	54.20	1.57	2.00	4955.19	318.27	0.50	7.98	11.30	0.71	9.96
2010	Colby1	309	8.40	52.20	1.45	2.10	4852.77	306.26	0.50	10.03	10.90	0.69	9.93
2010	Colby1	310	8.40	51.50	1.63	1.78	4910.18	310.13	0.60	8.36	10.00	0.69	9.80
2010	Colby1	311	8.20	67.10	1.67	2.04	4825.25	299.70	0.70	6.67	8.00	0.82	9.32
2010	Colby1	312	8.37	48.70	1.51	1.91	4948.40	318.43	0.60	11.84	10.00	0.67	9.77
2010	Colby1	401	8.38	35.90	1.46	1.95	4958.46	290.94	0.50	4.44	10.00	0.48	9.78
2010	Colby1	402	8.31	52.90	1.60	2.08	4884.82	297.43	0.50	4.99	10.00	0.61	9.71
2010	Colby1	403	8.37	42.00	1.48	2.06	4946.84	303.51	0.50	4.54	10.00	0.58	9.77

2010	Colby1	404	8.43	45.70	1.43	1.91	4867.12	301.38	0.50	6.48	12.00	0.49	10.11
2010	Colby1	405	8.38	40.00	1.44	1.84	4915.56	299.45	0.60	3.68	10.00	0.51	9.78
2010	Colby1	406	8.47	43.30	1.37	2.00	4858.20	297.04	0.50	4.94	12.00	0.49	10.15
2010	Colby1	407	8.36	52.30	1.43	1.91	4992.33	308.77	0.50	4.73	12.00	0.54	10.04
2010	Colby1	408	8.44	55.80	1.40	1.80	4884.63	301.92	0.60	4.03	10.00	0.56	9.84
2010	Colby1	409	8.40	35.40	1.27	1.78	4938.10	313.21	0.50	5.74	8.00	0.50	9.52
2010	Colby1	410	8.18	36.60	1.49	1.74	4911.93	310.67	0.50	4.90	8.00	0.50	9.30
2010	Colby1	411	8.47	48.80	1.46	1.74	4880.26	313.09	0.60	4.92	8.00	0.51	9.59
2010	Colby1	412	8.35	40.00	1.40	1.74	4998.72	316.33	0.60	4.29	8.00	0.47	9.47
2010	Colby2	101	8.53	32.80	1.46	1.89	5135.93	318.02	0.50	3.46	12.00	0.40	10.21
2010	Colby2	102	8.38	30.20	1.45	2.07	5043.71	322.05	0.50	4.19	16.00	0.35	10.62
2010	Colby2	103	8.57	37.50	1.41	1.80	4956.64	331.33	0.50	4.47	9.36	0.43	9.88
2010	Colby2	104	8.36	40.50	1.39	1.83	4855.26	323.33	0.60	6.05	14.00	0.46	10.32
2010	Colby2	105	8.49	42.90	1.39	1.89	4805.68	309.26	0.50	5.09	12.00	0.45	10.17
2010	Colby2	106	8.41	33.10	1.35	2.07	4893.87	310.11	0.50	4.86	12.00	0.35	10.09
2010	Colby2	107	8.45	36.60	1.42	1.89	4862.16	309.14	0.50	4.64	10.00	0.43	9.85
2010	Colby2	108	7.85	54.80	1.65	1.98	4785.75	325.96	0.60	4.75	10.00	0.77	9.25
2010	Colby2	109	8.11	44.90	1.45	1.78	4899.02	329.85	0.50	7.92	12.30	0.48	9.83
2010	Colby2	110	8.42	33.40	1.31	1.76	4893.52	336.42	0.50	6.34	10.50	0.44	9.89
2010	Colby2	111	8.48	36.50	1.33	1.80	4965.82	344.60	0.60	5.61	6.50	0.46	9.39
2010	Colby2	112	8.53	52.00	1.50	2.18	4956.30	358.99	0.50	5.33	12.30	0.56	10.25
2010	Colby2	201	8.58	21.20	1.25	1.76	5029.41	365.54	0.40	4.02	10.50	0.29	10.05
2010	Colby2	202	8.62	22.50	1.24	1.76	4947.89	382.42	0.50	3.04	8.80	0.31	9.85
2010	Colby2	203	8.67	44.60	1.37	1.87	4886.41	379.07	0.50	4.32	7.00	0.44	9.65
2010	Colby2	204	8.45	39.40	1.27	1.74	4842.75	376.06	0.40	4.90	12.30	0.40	10.17
2010	Colby2	205	8.68	28.70	1.15	1.62	4870.78	355.20	0.50	3.65	12.30	0.26	10.40
2010	Colby2	206	8.52	32.50	1.24	1.76	4834.61	352.57	0.50	4.72	12.30	0.33	10.24
2010	Colby2	207	8.48	33.30	1.32	1.70	4787.26	318.70	0.50	3.99	14.00	0.40	10.44
2010	Colby2	208	8.48	62.70	1.40	1.87	4658.28	321.08	0.60	4.68	13.70	0.61	10.40
2010	Colby2	209	8.52	55.50	1.36	1.68	4715.56	325.18	0.60	6.04	14.00	0.61	10.48

2010	Colby2	210	8.52	45.00	1.28	1.62	4737.45	321.09	0.60	6.39	12.30	0.51	10.24
2010	Colby2	211	8.34	79.30	1.48	1.89	4738.74	322.06	0.60	6.48	14.00	0.68	10.30
2010	Colby2	212	8.61	84.90	1.57	2.09	4766.75	324.84	0.60	5.17	14.00	0.88	10.57
2010	Colby2	301	8.66	35.20	1.46	1.62	4737.17	344.72	0.50	4.88	14.00	0.35	10.62
2010	Colby2	302	8.72	30.90	1.22	1.55	4723.27	358.71	0.50	2.74	14.00	0.36	10.68
2010	Colby2	303	8.51	51.60	1.51	1.62	4722.00	353.08	0.50	3.95	14.00	0.45	10.47
2010	Colby2	304	8.68	33.90	1.28	1.49	4606.13	337.78	0.50	4.30	15.20	0.46	10.81
2010	Colby2	305	8.46	31.20	1.20	1.47	4692.50	334.92	0.60	3.24	14.00	0.34	10.42
2010	Colby2	306	8.67	39.60	1.36	1.53	4735.89	332.52	0.50	4.80	18.50	0.40	11.26
2010	Colby2	307	8.08	51.10	1.31	1.62	4755.96	339.48	0.50	3.00	14.80	0.56	10.15
2010	Colby2	308	8.61	64.50	1.43	1.87	4608.12	325.97	0.60	3.69	13.00	0.68	10.43
2010	Colby2	309	8.60	60.90	1.33	1.77	4687.37	314.51	0.50	5.07	13.00	0.63	10.42
2010	Colby2	310	8.67	69.90	1.46	1.81	4673.92	315.63	0.50	5.14	16.70	0.77	11.01
2010	Colby2	311	8.62	83.90	1.35	1.68	4650.85	317.73	0.50	5.21	16.70	0.65	10.96
2010	Colby2	312	8.62	93.60	1.75	1.89	4724.69	317.75	0.50	6.42	13.00	0.80	10.44
2010	Colby2	401	8.58	119.00	1.58	2.02	4582.64	307.21	0.50	5.37	18.20	1.07	11.13
2010	Colby2	402	8.58	109.00	1.62	1.91	4655.22	331.04	0.50	4.72	21.20	1.00	11.55
2010	Colby2	403	8.52	113.00	1.58	1.98	4548.12	314.59	0.50	7.37	14.50	1.07	10.55
2010	Colby2	404	8.56	124.00	1.84	1.96	4463.70	314.69	0.50	6.30	17.60	1.18	11.02
2010	Colby2	405	8.54	119.00	1.87	2.00	4554.67	321.62	0.60	4.45	18.20	1.15	11.09
2010	Colby2	406	8.48	112.00	1.77	2.17	4469.64	305.74	0.60	4.25	14.50	1.27	10.51
2010	Colby2	407	8.56	122.00	1.86	2.13	4473.46	314.77	0.60	3.74	17.60	1.40	11.02
2010	Colby2	408	8.48	142.00	1.91	2.26	4437.92	315.08	0.60	5.38	16.40	1.52	10.78
2010	Colby2	409	8.41	150.00	2.00	2.26	4331.54	305.12	0.70	6.56	16.40	1.43	10.71
2010	Colby2	410	8.53	134.00	1.95	2.04	4454.09	314.29	0.70	7.48	14.50	1.34	10.56
2010	Colby2	411	8.50	133.00	1.87	2.06	4552.95	322.47	0.70	8.34	18.20	1.27	11.05
2010	Colby2	412	8.52	140.00	1.76	2.02	4538.92	327.95	0.80	7.15	16.40	1.25	10.82
2010	GC10	101	8.17	20.80	1.83	1.96	3490.22	619.35	1.50	17.36	10.90	0.86	9.70
2010	GC10	102	8.41	18.00	1.79	1.98	3807.21	643.68	0.80	13.11	10.90	0.86	9.94
2010	GC10	103	8.29	30.10	2.00	2.06	3752.31	643.39	0.90	17.41	10.90	1.07	9.82

2010	GC10	104	8.16	36.80	2.12	2.43	3783.74	670.39	1.20	16.56	10.90	1.26	9.69
2010	GC10	105	7.67	26.40	2.15	2.04	3735.89	660.45	1.20	15.78	12.70	1.54	9.45
2010	GC10	106	8.21	21.60	1.89	2.17	3561.82	673.37	1.00	9.13	12.70	1.03	9.99
2010	GC10	107	8.21	22.00	1.71	2.13	3527.19	676.34	1.30	14.06	17.60	0.64	10.67
2010	GC10	108	8.21	23.60	1.87	2.28	3371.83	711.38	1.10	11.28	15.70	0.84	10.41
2010	GC10	109	8.20	22.60	1.81	2.34	3388.97	702.37	1.30	19.86	12.50	0.87	9.95
2010	GC10	110	8.13	23.10	1.92	2.09	3399.12	672.11	1.60	10.34	11.50	0.86	9.74
2010	GC10	111	8.25	18.60	1.85	1.96	3832.94	717.42	1.30	15.88	9.80	0.72	9.62
2010	GC10	112	8.17	16.50	1.94	2.19	3716.11	723.76	1.10	12.99	11.50	0.73	9.78
2010	GC10	201	8.18	26.50	1.83	2.11	3149.06	660.56	1.30	19.19	9.80	1.12	9.55
2010	GC10	202	8.10	34.10	1.97	2.23	3053.38	640.32	1.10	9.19	13.10	0.91	9.93
2010	GC10	203	8.11	42.40	2.15	2.14	3482.47	673.99	0.90	14.21	16.40	1.37	10.41
2010	GC10	204	8.10	39.40	2.05	2.25	3466.67	672.37	1.10	17.97	11.50	1.16	9.71
2010	GC10	205	8.13	32.50	1.76	2.29	3612.60	680.80	0.90	21.07	12.50	0.91	9.88
2010	GC10	206	8.34	19.00	1.59	2.12	3631.55	659.82	0.70	14.53	11.50	0.61	9.95
2010	GC10	207	8.17	19.70	1.65	2.14	3627.49	666.97	0.90	17.50	9.80	0.62	9.54
2010	GC10	208	8.36	16.40	1.56	2.10	3609.86	675.97	0.80	7.63	17.90	0.51	10.87
2010	GC10	209	8.22	16.90	1.70	1.78	3713.49	652.77	1.00	17.33	11.50	0.64	9.83
2010	GC10	210	8.37	23.50	1.77	1.89	3655.22	654.45	0.80	9.90	9.80	1.52	9.74
2010	GC10	211	8.28	17.60	1.73	2.00	3852.77	658.08	0.70	19.21	11.50	0.67	9.89
2010	GC10	212	8.36	16.60	1.75	2.04	3874.77	680.74	0.80	14.33	9.80	0.68	9.73
2010	GC10	301	8.11	35.50	1.70	2.04	2690.01	638.22	1.30	21.51	11.50	0.76	9.72
2010	GC10	302	8.17	23.70	2.04	2.21	3326.30	666.67	1.10	11.28	13.10	0.91	10.00
2010	GC10	303	7.76	10.60	2.61	1.55	4542.36	616.34	0.70	12.71	9.80	0.27	9.13
2010	GC10	304	8.10	22.30	1.78	1.95	3918.99	637.22	1.10	22.30	13.10	0.75	9.93
2010	GC10	305	8.16	22.30	1.89	2.16	3791.98	616.72	1.00	18.48	9.80	0.75	9.53
2010	GC10	306	8.24	17.20	1.99	2.12	4026.60	631.02	1.10	7.51	9.80	0.60	9.61
2010	GC10	307	8.23	14.00	1.57	2.14	4216.28	582.97	1.20	21.29	11.50	0.56	9.84
2010	GC10	308	8.28	13.60	1.58	2.00	4137.25	619.78	1.10	13.14	9.80	0.58	9.65
2010	GC10	309	8.25	17.10	1.75	1.81	3666.98	580.23	1.20	21.19	9.80	0.57	9.62

2010	GC10	310	8.22	14.90	1.61	1.95	4350.41	598.98	1.00	9.67	9.80	0.53	9.59
2010	GC10	311	8.34	14.90	1.74	1.87	4307.07	614.63	0.80	15.89	9.80	0.52	9.71
2010	GC10	312	8.42	8.53	1.47	1.34	4647.53	591.37	0.70	9.76	11.50	0.23	10.03
2010	GC10	401	8.26	14.50	1.87	1.80	4368.32	631.70	0.90	17.30	8.20	0.83	9.41
2010	GC10	402	8.19	30.90	2.04	2.33	4210.29	638.60	1.00	14.72	7.81	1.42	9.28
2010	GC10	403	8.29	30.70	1.91	2.42	4072.37	632.56	0.80	10.53	12.50	1.36	10.04
2010	GC10	404	8.36	23.10	1.80	2.20	4185.79	637.68	0.80	12.13	10.70	1.12	9.86
2010	GC10	405	8.28	26.30	1.78	2.23	3977.72	611.02	1.10	12.57	10.90	1.25	9.81
2010	GC10	407	8.25	21.00	1.81	2.44	4171.84	596.52	0.90	15.67	10.90	0.86	9.78
2010	GC10	408	8.34	16.40	1.63	2.03	4137.26	589.29	1.00	8.27	9.38	0.74	9.65
2010	GC10	409	8.29	17.10	1.74	1.72	4088.56	576.51	0.70	22.29	10.70	0.64	9.79
2010	GC10	410	8.24	18.50	1.71	2.14	4279.38	619.57	0.90	11.61	8.90	0.69	9.49
2010	GC10	411	8.29	17.10	1.71	1.67	4302.68	604.52	0.80	10.24	11.90	1.07	9.96
2010	GC10	412	8.32	18.30	1.74	1.89	4233.93	621.74	0.70	10.69	11.90	0.98	9.99
2010	Healy10	101	7.79	133.00	1.99	2.84	4924.13	532.82	0.60	15.33	11.90	2.97	9.46
2010	Healy10	102	8.37	100.00	1.74	2.42	5145.49	549.73	0.60	16.51	13.56	2.18	10.27
2010	Healy10	103	8.35	120.00	1.78	2.80	5011.77	533.30	0.50	10.89	13.60	3.08	10.25
2010	Healy10	104	8.40	108.00	1.74	2.42	4978.78	503.89	0.80	9.34	14.30	2.25	10.40
2010	Healy10	105	8.35	117.00	1.84	2.31	5079.09	519.74	0.60	17.79	15.25	2.51	10.49
2010	Healy10	106	8.40	104.00	1.70	2.37	5043.53	513.33	0.60	11.31	14.30	2.40	10.40
2010	Healy10	107	8.30	115.00	1.81	2.69	5098.98	532.86	0.70	10.52	15.38	2.80	10.45
2010	Healy10	108	8.32	115.00	1.98	2.63	4953.59	502.73	0.70	10.38	13.46	2.91	10.20
2010	Healy10	109	8.34	127.00	1.91	2.76	5120.19	507.51	0.70	12.92	11.54	3.12	9.96
2010	Healy10	110	8.47	117.00	1.91	2.57	5033.81	510.34	0.60	12.80	15.40	2.68	10.63
2010	Healy10	111	8.36	130.00	2.55	2.57	5023.90	511.63	0.70	9.11	15.40	3.41	10.52
2010	Healy10	112	8.22	104.00	1.97	2.35	5396.21	587.90	0.60	10.17	17.90	2.42	10.73
2010	Healy10	201	8.36	131.00	1.84	2.87	5297.12	595.76	0.70	14.80	15.69	3.15	10.56
2010	Healy10	202	8.29	117.00	1.83	2.62	5301.05	584.44	0.60	16.06	13.73	2.65	10.21
2010	Healy10	203	8.05	122.00	1.69	2.64	5353.85	593.73	0.70	15.40	13.70	2.53	9.97
2010	Healy10	204	8.09	109.00	1.56	2.39	5339.44	576.25	0.60	9.58	13.70	2.34	10.01

2010	Healy10	205	8.28	104.00	1.68	2.32	5314.98	562.50	0.60	9.68	14.30	2.20	10.28
2010	Healy10	206	8.33	95.20	1.52	2.28	5378.68	567.75	0.60	10.53	12.50	1.91	10.08
2010	Healy10	207	8.26	114.00	1.73	2.41	5448.83	582.66	0.60	15.78	15.70	2.50	10.46
2010	Healy10	208	8.28	106.00	1.71	2.48	5368.86	582.25	0.60	10.92	15.70	2.34	10.48
2010	Healy10	209	8.20	105.00	1.63	2.41	5437.75	571.61	0.60	12.76	12.50	2.48	9.95
2010	Healy10	210	8.30	105.00	1.87	2.41	5349.82	572.51	0.60	11.16	17.31	2.52	10.72
2010	Healy10	211	7.77	114.00	1.87	2.55	5390.01	579.53	0.60	10.00	13.46	2.72	9.65
2010	Healy10	212	8.26	111.00	1.71	2.39	5368.50	597.96	0.60	6.69	13.50	2.47	10.15
2010	Healy10	301	8.27	93.50	1.68	2.44	5428.80	594.09	0.60	8.29	7.55	1.90	9.33
2010	Healy10	302	8.27	97.40	1.81	2.41	5368.30	602.67	0.60	9.54	12.50	1.94	10.02
2010	Healy10	303	8.28	113.00	1.85	2.91	5304.73	597.06	0.70	5.99	11.32	2.68	9.86
2010	Healy10	304	8.32	107.00	1.73	2.57	5297.13	586.31	0.70	11.84	12.50	2.30	10.07
2010	Healy10	305	8.31	89.00	1.71	2.28	5346.89	588.90	0.60	10.78	11.30	1.85	9.89
2010	Healy10	306	8.32	92.50	1.62	2.23	5454.54	587.10	0.60	11.68	17.90	1.73	10.83
2010	Healy10	307	8.29	93.20	1.71	2.35	5316.61	571.06	0.60	14.11	11.30	2.00	9.87
2010	Healy10	308	8.24	100.00	1.80	2.60	5375.57	575.39		4.69	13.21	2.12	10.09
2010	Healy10	309	7.90	117.00	2.06	2.41	5033.65	493.58	0.70	24.93	15.09	2.70	10.01
2010	Healy10	310	7.67	93.60	1.66	2.48	5125.84	508.04	0.70	15.01	15.10	1.97	9.78
2010	Healy10	311	7.82	112.00	1.64	2.37	5060.88	514.80	0.60	8.44	16.98	2.11	10.20
2010	Healy10	312	7.99	105.00	1.60	2.16	5140.34	521.60	0.60	9.69	15.10	1.76	10.10
2010	Healy10	401	7.90	106.00	1.80	2.32	5164.91	558.99	0.70	13.42	13.20	2.01	9.75
2010	Healy10	402	8.00	114.00	1.82	2.50	5029.99	543.34	0.60	11.04	17.90	2.19	10.51
2010	Healy10	403	7.87	113.00	1.75	2.57	5043.67	542.98	0.60	10.61	14.30	2.26	9.87
2010	Healy10	404	8.03	116.00	1.69	2.41	5118.11	547.68	0.60	7.35	12.50	2.24	9.78
2010	Healy10	405	7.89	95.00	1.60	2.21	5070.12	537.03	0.60	12.31	12.50	1.78	9.64
2010	Healy10	406	8.01	98.10	1.71	2.21	5071.68	533.95	0.60	12.06	12.50	1.99	9.76
2010	Healy10	407	7.91	97.00	1.78	2.30	5162.52	549.12	0.60	11.06	12.50	1.88	9.66
2010	Healy10	408	7.87	113.00	1.85	2.41	5063.24	543.48	0.60	12.81	17.90	2.37	10.38
2010	Healy10	409	7.66	113.00	1.80	2.48	5041.40	541.79	0.80	10.84	10.70	2.02	9.16
2010	Healy10	410	7.86	130.00	1.89	2.87	5011.31	548.54	0.70	11.48	12.50	2.54	9.61

2010	Healy10	411	8.00	107.00	1.95	2.46	4973.39	534.01	0.70	3.55	17.90	2.17	10.51
2010	Healy10	412	7.86	120.00	1.87	2.84	5164.08	576.82	0.70	10.34	14.30	2.50	9.86