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Soil and Plant Property Differences among High-yield Soybean Areas in Arkansas

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Soil and Plant Property Differences among High-yield Soybean Areas in Arkansas

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Abstract

Continued achievement of soybean [*Glycine max* (L.) Merr.] yields greater than 6719 kg ha^{-1} (100 bu ac^{-1}) will depend on decreasing the yield gap, which is contingent on gathering more information regarding the soil physical, chemical, and microbiological environment and the main plant factors contributing to high-yield soybean. Therefore, understanding the main factor differences between high- and average-yield areas may provide insight for making management decisions to increase yields. The objectives of this study were i) to evaluate the effects of region and soil depth on soil property differences between high- and average-soybean-yielding areas, ii) to determine which soil properties are most related to ultra-high soybean yields, and iii) to identify correlations among aboveground biomass and seed nutrient concentrations from various growth stages and soil properties for high- and average-yielding fields. In each of seven regions of the "Grow for the Green" yield contest in Arkansas, one contest-entered, high-yield (HY) area in close proximity to one average-yield (AY) area were plant-sampled at three growth stages in 2015 and soil sampled from two depth intervals (0- to 10- and 10- to 20-cm) in each yield area immediately prior to or just after harvest in 2014 and 2015. In 2014 and 2015, yields in the AY areas averaged 4633 kg ha^{-1} (69 bu ac^{-1}), while yields in the HY areas averaged 5647 kg ha^{-1} (84 bu ac^{-1}). Averaged across soil depth and years, selected measured soil properties differed ($P < 0.05$) between HY and AY areas within at least one region. Averaged across regions, Shannon's microbial diversity was greater ($P < 0.05$) in HY than in AY areas. Averaged across growth stage, some plant properties were greater ($P < 0.05$) in HY areas, while others were greater ($P < 0.05$) in AY areas across regions. Since this study encompassed a wide variety of landscapes and soybean management systems across Arkansas, results of this study have the potential to help growers better understand soil and plant properties in their own fields that contribute

to or hinder achieving ultra-high soybean yields, which may contribute to minimizing the soybean yield gap.

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Table of Contents

List of Tables

Introduction

Chapter 3

List of Figures

Chapter 2

Chapter 3

Introduction

As agricultural production has intensified over the past few decades due to increasing global human and livestock population, producers have become more dependent on agrochemicals as a relatively reliable method of crop production and protection that helps with economic stability of their operations. However, increasing use of chemical inputs causes several negative effects, including pathogen resistance to applied agents and non-target environmental impacts, like NO_3^- pollution of ground and surface water, soil acidification, and production of the greenhouse gas N_2O through denitrification (Gray and Smith, 2005). In addition, the majority of agrochemical applications never reach the plant itself (Lugtenburg and Kamilova, 2009). The growing cost of fertilizer and pesticides, consumer demand for pesticide-free food, and climate change caused by greenhouse gas emissions has led to a path for increasing yields, while maintaining current agrochemical application rates.

In order to increase yields of soybean [*Glycine max* (L.) Merr.], a moderate- to high-yielding C_3 tropical legume, it is necessary to understand the basis of past yield increases (Table 1). Attempts to improve and/or maximize yield have focused on either the plant itself, through breeding, or the environment in which a crop is produced (i.e., management practices such as tillage and crop rotation). Additionally, studying specific soil and plant parameters associated with exceptionally high yields may help to meet the global demand for food as nations are struggling with food shortages and hunger.

Although studies researching soil properties relating to yield have been explored in the upper Midwest (Kravchenko and Bullock, 2000; Anthony et al., 2012) and in the south (Cox et al., 2003), focus to increase yield has been drawn mostly on landscape properties (i.e., slope, elevation, curvature) plus genetics and plant breeding efforts. There is still an enormous amount of potential information that can be gleaned from the suite of soil and plant properties that this study will aim to elucidate from in-field observations.

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Table 1. Summary of Arkansas' annual average soybean yield and national rank along with the 1st, 2nd, and 3rd ranked states and their average soybean yield from 2007 to 2015. Units are kg ha^{-1} and are rounded to nearest whole number. Data provided by USDA-NASS (2015).

	Arkansas		**1st - ranked state**		**2nd - ranked state**		**3rd - ranked state**	
Year	**Rank**	**Yield**	**State**	**Yield**	**State**	**Yield**	**State**	**Yield**
2007	16	2419	IA	3494	NE	3427	OH	3158
2008	9	2553	IL	3158	IA	3124	NE	3124
2009	24	2520	NE	3662	IA	3427	IN	3292
2010	15	2352	NE	3527	IL	3460	IA	3427
2011	17	2587	NE	3629	IA	3460	OH	3225
2012	12	2889	WV	3292	PA	3225	MD	3158
2013	14	2922	NE	3561	IN	3427	KY	3326
2014	9	3228	IL	3766	IN	3632	LA	3632
2015	8	3292	NE	3897	IA	3796	IL	3763

Chapter 1

Literature Review

Literature Review

Soybean Production in the United States

More soybean [*Glycine max* (L.) Merr.] are grown in the United States (US) than anywhere else in the world, and more than half that are harvested are exported to Eastern Asia, where the wild progenitor of soybean grows, the European Community, Mexico, and others (UACES, 2014). Additionally, soybean is currently the second most widely grown crop in the United States in terms of hectares planted and harvested (USDA-NASS, 2015).

The need to increase the yield of soybean and other crops has been recognized in order to keep up with the demand caused by increased world populations and greater individual incomes (Tacarindua et al., 2013). From 1924 to 2012, the average US soybean yield increased annually by 23 kg ha^{-1} yr^{-1}, from 739 kg ha^{-1} to 2661 kg ha^{-1}, but research suggests that continued increases in average yields will depend on decreasing the "yield gap", defined as the difference between current and "potential yield", the yield of a cultivar grown with the best technologies without limitations on nutrient and water availability and biological stresses effectively controlled (Cooper, 2003; Egli, 2008b; Egli and Hatfield, 2014; van Roekel and Purcell, 2014).

Explaining the large yield gap that exists between high-yielding areas of some fields and the average field on a US farm may require more emphasis on knowledge of agronomics and the production environment, since the average US producer has access to and can grow the same cultivars that are used in large-scale agronomic production and in research plots (Egli and Hatfield, 2014; Specht et al., 1999). Further, in order for a crop production program to be successful, knowledge of the site variables and their interactions is required (Sawchik and Mallarino, 2008).

Unfortunately, yield is always dependent on the environment in which the crop is produced, technology availability and application, and skill and talent of the producer (Egli, 2008a). For example, yield differences between years can often be attributed to weather variability during the growing season (Amuri et al., 2008). Further, soybean are often more productive in certain geographic areas. In a regional analysis by Egli and Cornelius (2009), the maximum soybean yield documented varied among experiments and national regions, with the Midwest having the greatest average yield (2936 kg ha^{-1}), followed by the Upper South (2641 kg ha^{-1}) and the Deep South (2509 kg ha^{-1}). Analysis of yield in 169 counties in Arkansas, Iowa, Kentucky, and Nebraska, between 1972 and 2003, demonstrated no evidence of a plateau for soybean yields, and yield growth depended in part on the gap between actual farmer field yields and the theoretical yield potential (Egli, 2008a).

Yield plateaus have been shown to be illusions, simply the result of unfavorable weather conditions or some other yield-affecting stress (Egli, 2008a), but maximum potential soybean yield can be estimated from record farmer yields, crop simulation models, and yields from well-managed agricultural experiment station studies (Egli and Hatfield, 2014). Prior to the 1966 National Yield Contest, the commonly accepted soybean yield maximum was thought to be 4000 to 4500 kg ha^{-1} (Cooper, 2003). However, during the 1996 yield contest, two growers achieved yields of 6000 kg ha^{-1}, and by 1968, yields of 7310 kg ha^{-1} were obtained (Cooper, 2003). Up to 8000 kg ha^{-1} was achieved in maximum yield research in the 1980s, and a contest field yielded greater than 9000 kg ha^{-1} in 2006 (Egli, 2008a). Continually increasing yields is important not only for matters regarding world population increases, but the argument is strengthened by the need to mitigate crop production expansion onto poorer quality soils, which use of may damage the environment and threaten sustainability (Egli, 2008b). Farmers that understand the cause of spatial and temporal inconsistencies of soybean yield within their fields may be better able to actualize site-specific management practices (Kaspar et al., 2004).

Soybean Production in Arkansas

In 2015, Arkansas ranked 11th in planted soybean area nationwide, with 1,282,853 ha, and achieved the 8th greatest average yield by state, 3292 kg ha^{-1} (USDA-NASS, 2015). Soybean comprises the single largest acreage of any Arkansas row crop, where nearly 1.4 million hectares of soybean are planted every year, providing close to one-third of total cash receipts for all crops produced in Arkansas (UACES, 2014). Soybean yields for Arkansas increased by an average of 30 to 45% between 1972 and 2003, most likely attributed to cultivar improvement and better agricultural management practices (e.g., narrow rows, improved weed control, earlier plantings, conservation tillage implementation, increased irrigation, and reduction of harvest losses) (Egli, 2008a). From 1999 to 2015, the average soybean yield for the state of Arkansas increased from 1881 kg ha^{-1} to 3427 kg ha^{-1} (USDA-NASS, 2015).

Arkansas soybean production is primarily concentrated in the Southern Mississippi Alluvial Valley, with Mississippi County surpassing all other counties in area planted (118,573 ha) and harvested (118,330 ha) in 2014, but Desha County led the state in productivity in 2014 with a mean yield of 4172 kg ha^{-1} (USDA-NASS, 2015).

"Grow for the Green" Soybean Yield Contest

Before 1966, the year of the first soybean yield contests, the belief was that the maximum soybean grain yield was near 4500 kg ha^{-1} (van Roekel and Purcell, 2014). Recently, however, the largest verified soybean yields in a yield contest were produced in Missouri, as reported by the MO Soybean Association, where yields of 9400, 10390, and 10790 kg ha^{-1} were achieved during Missouri soybean yield contests in 2006, 2007, and 2010, respectively (van Roekel and Purcell, 2014). Yield contest production provides incentive not only to the farmer in terms of cash prizes, but to the state to conduct research that may lead to identifying particular soil properties, management practices, or physiological processes that contribute to maximum-yielding areas and fields (van Roekel and Purcell, 2014). Yield contests are currently conducted in 14 states in the US, including AL, AR, IL, KS, KY, MI, MO, NC, OH, PA, SC, SD, VA, and WI (van Roekel and Purcell, 2014).

In 1999, the Arkansas Soybean Promotion Board, together with the Arkansas Soybean Association, established two programs to recognize farmers who produce high yields. The first program was a race to recognize the producer who first achieved a yield greater than 6719 kg ha^{-1} (100 bu ac^{-1}), which was achieved in 2013 by three separate producers, and the second program developed was an annual yield contest. Initially, and until 2010, the contest was statewide with no divisions. In 2011, the contest was split into production system divisions with categories of early-season, full-season, and double-crop production. Finally, in 2013, the contest reached its present form, with eight categories, seven of which are geographic divisions within the state (Figure 1), and the last a statewide contest reserved for non-genetically-modified (GMO) varieties. Within each of these eight categories, cash prizes of $10000, 7500, and 5000 are awarded for 1st, 2nd, and 3rd places, respectively.

Yield contest research may provide useful information about yield potentials in various areas. However, one must be wary to recognize selected examples of high yields tend to occur when associated with favorable seed selection, soil management, environmental conditions, and good fortune (Specht et al., 1999).

Agricultural Management Practices Contributing to High Yields

Although particular crop management practices make significant contributions to large soybean yields and are important in maintaining high yield levels, it seems unlikely that management alone will be the sole factor in yield growth in the future. Improved management can eventually show diminishing returns, as past developments make the next increment in yield increase more difficult (Egli, 2008a). For enhanced yields to be achieved, other methods of improving yields besides agricultural practices must be critically studied, identified, and implemented on a field-scale level. Many agronomic practices have added to soybean yield improvements in the US. However, earlier planting, on narrower rows, with better stress control, and increased plant populations have had the largest contribution due to increasing light interception and crop growth rate during the vegetative period (Specht et al., 1999; Board et al., 2003).

Row Spacing and Plant Populations

A common question among producers that plant soybean involves optimal row spacing, since equipment costs can be reduced when multiple crops are planted with the same equipment (Lambert and Lowenberg-DeBoer, 2003). Soybean grown in narrow rows generally out-yield those grown in wide rows in northern latitudes of the US (i.e., IA and north), perhaps related to better weed control and seasons without drought stress (De Bruin and Pedersen, 2008; Heatherly et al., 2001). In southern regions of the US; however, May and later plantings grown in narrow rows (i.e., ≤ 50 cm) typically produce greater yields than those grown in wide rows. In Arkansas, the University of Arkansas recommends row or drill spacings narrower than 76 cm, where the yield from narrow row systems (≤ 50 cm) exceeds wide row systems (≥ 100 cm) in both irrigated and dryland conditions (Heatherly et al., 2001; UACES, 2014).

Wide rows are most likely utilized by producers mainly since they already have equipment at wide row spacings for other crops (Heatherly et al., 2001). Wide row planting in the mid-southern US combines pre- and post-emergence and post-cultivation herbicides, while narrow row production does not allow the option of post-cultivation herbicides and therefore greatly relies on pre- and post-emergence, broadcast herbicides (Heatherly et al., 2001).

Conversely, soybean produced in narrow rows, which are generally any row spacing less than 1 m (Edwards and Purcell, 2005), may also reduce weed competition and reduce the amount of herbicide needed to control growth of weeds, although yield may be increased or remain stationary (Lambert and Lowenberg-DeBoer, 2003). Advantages of planting in narrow rows include faster closure of the canopy, increased leaf area development, and more light interception early in the growing season, which suppresses weeds and increases crop growth rate, dry matter accumulation, and ultimately final yield (De Bruin and Pedersen, 2008; Edwards and Purcell, 2005; Lambert and Lowenberg-DeBoer, 2003; Nelson and Renner, 2001; Reddy et al., 2003).

In both irrigated and dryland environments at the Delta Research Extension Center in Stoneville, MS in 1994 through 1996, use of narrow versus wide rows resulted in less weeds at soybean maturity, and cultivars grown in narrow rows yielded similar to or greater than cultivars grown in wide rows; however, costs associated with weed management are greater in narrow rows than wide rows (Heatherly et al., 2001). In Iowa in 2004 through 2006, De Bruin and Pedersen (2008) noted an average yield increase of 248 kg ha^{-1} when switching from 76 cm to 38 cm row spacing.

Nevertheless, abiotic and biotic stresses may limit the yield response of soybean planted in narrow rows. Moisture stress in particular has been noted to reduce yields in narrow rows in KS, NE, TX, ND, and IA (De Bruin and Pedersen, 2008). The yield advantage ascribed to narrow row spacing may be uncertain over years and negligible without irrigation, wherein narrow rows produce greater yields when growing-season rainfall is high, and wide rows produce greater yields with lower rainfall (Heatherly et al., 2001). Therefore, choice of row spacing should be based on other presumptions than narrow row systems will have greater yields than wide row systems (Heatherly et al., 2001), especially since smaller farms will perhaps not see as much of a benefit converting to narrow row production, but large farms (> 144 ha) could economically benefit more from narrow row production (De Bruin and Pedersen, 2008).

Along with row spacing, seeding rate and resultant plant population may have direct effects on yield. Seed costs have risen quickly as a result of glyphosate-resistant cultivars, and after chemical costs, seeds are the second greatest direct investment for the soybean grower, necessitating optimum seeding rates to produce optimal plant populations, ultimately affecting final yields (Lee et al., 2008; Rigsby and Board, 2003; UACES, 2014). The optimal plant population for seeding soybean, which can change by nearly 100% from year to year even with the same variety sown in the same location as a result of adverse environmental conditions, minimizes seed costs and lodging, and avoids diseases and other problems (Edwards and Purcell, 2005; Lee et al., 2008; Rigsby and Board, 2003). For example, in Arkansas on 56-cm rows, the greatest yields were achieved at plant populations of 210,000 plants ha^{-1} in 1997 and 540,000 plants ha^{-1} in 1998 (Lee et al., 2008).

State extension agencies suggest that soybean seeding rates in the mid-south range from 300,000 to 516,000 seeds ha^{-1} for 38-cm row widths (Edwards and Purcell, 2005; Lee et al., 2008). Greater seeding rates associated with current planting recommendations include protection against low emergence rates caused by either poor seed quality or stress incurred after planting, so using high-vigor seeds may reduce the risk when seeding rates are decreased in order to lessen production cost (Lee et al., 2008). While poor growing conditions require a greater optimal plant population than good conditions (Carpenter and Board, 1997), seeding rates that were sufficient to achieve optimal final plant populations were 30 and 17% less than recommended seeding rates in Iowa for 38- and 76-cm row spacings, respectively (De Bruin and Pedersen, 2008). Required seeding rates to achieve optimal plant populations for May and June seedings were well-below recommended seeding rates in a

Lexington, KY field experiment, but June seeding rates were greater since more plants were required to balance with the smaller plants associated with later plantings to achieve the same yield (Lee et al., 2008).

More plants are often required to achieve optimal yields in dry soils, due to smaller rates of emergence and slower crop growth and canopy development rates, and for early maturing cultivars, since the R1 growth stage is achieved sooner, resulting in smaller plants and reduced canopy closure (Lee et al., 2008). In multiple field experiments, yields from moderate plant populations did not differ from the high populations, but were significantly greater than low plant populations (Carpenter and Board, 1997; Edwards and Purcell, 2005; Rigsby and Board, 2003). Furthermore, increasing plant populations past a certain number can cause yields to plateau (Edwards and Purcell, 2005).

Crop growth rate (CGR) and total dry matter equilibration, which occurs as a result of diffuse and dense plant populations, are important yield compensation mechanisms and occur mainly during vegetative and early reproductive soybean growth, leading to the same number of pods per square meter (Carpenter and Board, 1997; Rigsby and Board, 2003). For example, a maturity group V variety in two different plant populations (low at 80,000 plants ha^{-1}, vs. high at 200,000 plants ha^{-1}) resulted in similar yields when CGR equilibrated near 50 d after emergence (Rigsby and Board, 2003). Yield compensation at low populations with less canopy development occurs by maintenance of CGR and partitioning greater amounts of dry matter per square meter into branches (Carpenter and Board, 1997; Lee et al., 2008).

Tillage and Crop Rotation

Whether or not to till is becoming more common of a question in sustainable agriculture, especially one farmers will ask if yield is affected. The primary purpose of tillage should promote adequate pore space for root expansion more so than to control weeds, and should occur with a minimum number of passes when the soil is not too wet; otherwise, infiltration of water is reduced (UACES, 2014). DeFelice et al. (2006) stated that, although the national average between no-tillage (NT) and conventional tillage (CT) is insignificant, NT has resulted in greater soybean yields in the southern, western, and mid-western US (Houx et al., 2014). Yields have been reported to be greater under NT by 5.3% in a nationwide study (Toliver et al., 2012), 6% greater on a silty clay loam in Nebraska and a silt loam in Wisconsin (Dickey et al., 1994; Pederson and Lauer, 2003), and 35% greater on a different silt loam in Wisconsin (Temperly and Borges, 2006) compared to CT methods. In other studies, NT has been shown to have a positive effect on early growth, but not result in statistically greater yields (Brye et al., 2004a; Verkler et al., 2009). For example, Yusuf et al. (1999) reported yields of 2104 kg ha^{-1} under CT and 2194 kg ha^{-1} under NT management on a silt loam in Illinois, while a 4-yr study on a silt loam in Mississippi by Reddy et al. (2003) reported an average yield of 1830 kg ha^{-1} under CT and 1960 kg ha^{-1} under NT. Suggestions for no yield difference or reduced yields under NT compared to CT may be due to brown stem rot [*Cadophora gregata*] (Adee et al., 1994), herbicide usage and cover crop implementation (Reddy et al., 2003), or a short-term NT history (Brye et al., 2004a). Short-term NT history cannot overcome the lack of good soil structure and poor drainage conditions characteristic of CT practices (Parajuli et al., 2013; Reddy et al., 2003) until repeated years of NT have occurred (Dickey et al., 1994); therefore, NT tends to exhibit greater yields on moderate- to well-drained soils (DeFelice et al., 2006).

In addition to tillage, crop rotation can have a significant impact on yield, which can be dependent on what crop is grown and in what order the rotation occurs. In Arkansas, soybean rotated with rice (*Oryza sativa* L.), sorghum (*Sorghum bicolor* L. Moench), corn (*Zea mays* L.), or cotton (*Gossypium hirsutum* L.) increase soybean yield on average 336 kg ha^{-1}, due to breaking disease, weed, and insect cycles, and an increase in soil tilth (UACES, 2014). First-year soybean after five years of consecutive corn produced 8 to 14% greater soybean yield than other rotation sequences using corn and soybean (Adee et al., 1994; Pederson and Lauer, 2003). However, Lund et al. (1993) observed that, when grown in rotation with wheat (*Triticum aestivum* L.) and corn, regardless of chronology, no soybean yield differences existed. In a field study by Kurtz et al. (1993), systems in which rice was grown for at least two years before soybean, average soybean yield increased by at least 604 kg ha^{-1} (655 kg ha^{-1} for two years of rice; 800 kg ha^{-1} for three years of rice). It was also observed that soybean yields increased around half the time when grown in rotation with rice. Parajuli et al. (2013) noted that soybean yields after rice were consistently greater than soybean yields after corn and continuous soybean. Soybean yields either decreased or remained static with longer a duration of soybean in rotation (Adee et al., 1994; Kurtz et al., 1993; Parajuli et al., 2013; Temperly and Borges, 2006), which may be a result of soybean cyst nematode [*Heterodera glycines*] buildup (Edwards et al., 1988).

Besides independent effects of tillage and rotation practices on crop yields, interactions between the two have been examined. Yields have been reported to be greatest under rotation sequences involving corn and rice practicing NT and decrease successively thereafter as follows: CT combined with crop rotation, continuous crop under NT, and continuous crop using CT (DeFelice et al., 2006; Edwards et al., 1988; Houx et al., 2014). For instance, soybean yields in continuous cropping were demonstrated to be 17% less with NT and 14% less with CT compared to being in rotation (Lund et al., 1993). Soybean yields for NT and rotation with corn have been shown to be 29 to 92% greater than for other treatments (Edwards et al., 1988), which is probably due to the fact that pest buildup, especially soybean cyst nematode, is eliminated (Edwards et al., 1988). There may be a tendency for soybean yields to be greater under CT based on the previous crop in a rotation. For instance, Parajuli et al. (2013) observed that soybean yields under CT were greater following rice than yield following corn, perhaps a result of the soil moisture remaining elevated after the rice crop. Other studies have also demonstrated that continuous soybean produced the lowest yields under CT (Parajuli et al., 2013; Temperly and Borges, 2006) and regardless of tillage (Conley et al., 2011; Pederson and Lauer, 2003). Over time, however, soybean yields were lowest in CT irrespective of rotation (Edwards et al., 1988).

Planting Date and Maturity Group

In a regional analysis conducted by Egli and Cornelius (2009), no agricultural factor was demonstrated to affect soybean production more than planting date; however, planting date effects on yield can vary considerably due to variations in rainfall amounts and distribution. In Arkansas, planting has occurred one day earlier every year, on average, since 1985 (UACES, 2014). Producers have a rather long window to plant in the Midwest, Upper South, and Deep South regions of the US, which provides a longer time opportunity to finish planting before critical yield loss dates and thus avoid substantial yield losses (Egli and Cornelius, 2009); however, the negative effects of late planting on yield are well-known (Egli and Bruening, 2007). Delaying planting beyond a critical date produces soybean that do not have the same yield potential as early plantings, and shifts reproductive growth of all soybean maturity groups into a less favorable environment later in the growing season (Bastidas et al., 2008; Egli and Bruening, 2000; Egli and Cornelius, 2009). Later in the season, days are shorter and air temperatures and solar radiation are lower, and usually less-available soil moisture is present (Board et al., 2003; Egli and Bruening, 2000).

Delaying planting results in a shorter vegetative (V) growth and flowering and pod set periods, but seed fill duration is not consistently shorter, and therefore fewer seeds per unit area can occur (Egli and Bruening, 2000; Egli and Cornelius, 2009; UACES, 2014). The combination of temperature and photoperiod is most likely responsible for earlier flowering and shorter vegetative growth duration of late-planted soybean, lessening the time period needed for optimal yield (Board et al., 2003; Egli and Bruening, 2000; UACES, 2014).

Sub-optimal weather conditions and double-cropping after winter crops are the primary factors attributed to a late planting date, and a key method of increasing yield of delayed-planted soybean is to avoid environmental stresses that decrease crop growth rate between VE and R5 (as defined by Fehr et al., 1971). However, compared with optimal planting dates, soybean planted late may not be as tolerant of stresses as a result of the shorter vegetative growth period (Linkemer et al., 1998; UACES, 2014).

Rapid decreases in yield as a result of delayed planting begins to occur in the Midwest, Upper South, and Deep South by May 30, June 7, and May 27, respectively, with the Upper South, including Arkansas, declining in yield at a rate of 1.1% per day (Egli and Cornelius, 2009; Salmeron et al., 2016). Furthermore, research by the University of Arkansas demonstrated that yield potential decreases by at least 33.6 kg ha^{-1} (0.5 bu ac^{-1}) each day for every day sown after June 15 (UACES, 2014). The results of earlier flowering, including shorter plants, fewer nodes, and less vegetative mass at R5, is associated with lower yields in late plantings for maturity groups (MGs) I through IV (Egli and Bruening, 2000). Yield reduction due to late planting was not smaller or relieved by irrigation in the narrow row, high population treatment in Lexington, KY in 1996, 1997, and 1998 (Egli and Bruening, 2000). Delaying planting in Nebraska from May 1 to June 15 reduced soybean yield by 745 kg ha^{-1} in 2003, which had a cool spring and warm summer, and by 1950 kg ha^{-1} in 2004, which had a warm spring and cool summer (Bastidas et al., 2008).

Soybean varieties that are adapted to long growing seasons have a longer growth cycle, but yield does not necessarily increase proportionately (Egli and Bruening, 2000). Irrigation requirements are reduced in early planted, short-season crops due to a shorter growth period, and have therefore been popular adoptions for producers in the mid-southern US. Although historical data indicate drought stress risk is minimized by early sowing, a field study in Fayetteville, AR demonstrated that early sowing did not ensure reduced irrigation requirements (Edwards and Purcell, 2005). Sowing MGs V, VI, and VII cultivars in late May and June is risky for maximum yields even when coupled with irrigation (Heatherly and Spurlock, 1999). However, irrigation requirements among MGs varied by year in a field study conducted in Fayetteville, AR in 2001, 2002, and 2003 (Edwards and Purcell, 2005).

Traditional soybean production in the mid-south historically uses MG V and later cultivars planted in May and later into soil that has been disked in the fall and left untilled before planting (Heatherly et al., 2001). Moisture deficits for soybean cultivars in the traditional system can be detrimental since reproductive growth is occurring during the latter part of the growing season when moisture levels are low (Heatherly and Spurlock, 1999). The Early Season Soybean Production System (ESPS), involves preparing the seedbed in autumn, using a pre-plant, foliar herbicide to kill winter and spring weeds, and seeding relatively earlier maturing cultivars (MGs III-IV as opposed to MGs V-VI) into a stale seedbed in April, and has the potential to improve yields in the Lower Mississippi River Delta region of eastern AR, and the mid-southern US in general, by avoiding late season drought and insect and disease pressures (Edwards and Purcell, 2005; Heatherly and Spurlock, 1999). However, the ESPS requires greater seeding rates and narrower rows compared to a traditional soybean production system (Edwards and Purcell, 2005; Heatherly and Spurlock, 1999; Purcell et al., 2007). Additionally, an earlier start to a growing season would presumably lessen irrigation needs, and moreover would decrease the amount of water that the crop transpires (Edwards and Purcell, 2005; Purcell et al., 2007). Thus seeding early maturing cultivars in April would allow the critical reproductive growth in soybean to occur during periods of adequate soil moisture and greater rainfall amounts, with the partial potential to avoid drought (Heatherly and Spurlock, 1999).

In a dryland study in northeastern TX at two locations, MG III and IV cultivars sown in April yielded significantly more grain than traditional MG V through VII varieties sown in May (Heatherly and Spurlock, 1999). Additionally, MG II cultivars seeded in late April and early May in KY yielded more than MG III, IV, and V soybean (Heatherly and Spurlock, 1999). In the southern US, April plantings together with earlier maturing cultivars (MG III through V) resulted in consistent yield increases over traditional systems (MG V through VII planted in May and June) (Egli and Cornelius, 2009). The ESPS usually produces greater yields since reproductive growth occurs before drought is prone to develop later in the growing season (Egli and Cornelius, 2009).

Soybean planted in mid-April in the upper mid-south (AR, KY, MO, TN) may not be practical in clay or other poorly-drained soils, as rain is normally more plentiful and the soil is still relatively cool (Heatherly and Spurlock, 1999; Ray et al., 2006). However, as global warming increases temperatures, it is possible that late April and early May plantings may be even more successful in the future (Egli and Cornelius, 2009).

Irrigation

Soybean produces nearly 135 kg ha^{-1} for every 2.5 cm of water transpired throughout the growing season (UACES, 2014). Research has demonstrated that when high-yield soybean factors are ranked according to relative importance, availability of water ranks near the top (Egli and Bruening, 2004; Heatherly and Spurlock, 1999; Purcell et al., 1997; UACES, 2014; van Roekel et al., 2015). In fact, the same soybean varieties average 670 to 1340 kg ha^{-1} less without irrigation, and irrigation at the correct time, especially in the early and late parts of the season, is critical to maximizing yield (UACES, 2014). Drought stress during mid-July to late August is a large problem for late-planted soybean in the southeastern US (Board et al., 2003). In Arkansas, the value of irrigation is obvious; irrigated yields were historically 70% greater than dryland yields from 1972 to 2003 (Egli, 2008a). However, seasonal water deficit and/or local rain event timing may account for 36 to 90% of the annual yield variation in soybean in dryland and irrigated environments, while the yield response to drought depends on occurrence, amount, and extent of the water deficit (Bastidas et al., 2008; Sadras and Calvino, 2001; Specht et al., 1999). Furthermore, water deficits are not easily measured and are relative depending on several crop (i.e., species, genotype, management practices, etc.) and environmental (i.e., amount, extent, soil properties, terrain, etc.) factors and their interactive relationships (Kaspar et al., 2004; Purcell et al., 2004; Ray et al., 2006).

The consensus in academia states that most physiological processes occurring within a plant, such as photosynthesis and biomass accumulation, are unaffected unless greater than 60% of available soil water is gone (Purcell et al., 1997; Ray et al., 2006). However, an exception is with N_2 fixation, which can be affected when only 50% of available soil water is depleted and may greatly limit yield (Purcell et al., 1997; Ray et al., 2006). Nitrogen fixation in soybean is very sensitive to water deficits as a result of decreased nodule formation and decreased nodule size, leading to insufficiencies in N for protein in the seed (Sadeghipour and Abbasi, 2012; Vadez and Sinclair, 2002). Therefore, there is an assumption that increasing N_2 fixation water deficit tolerance will increase yield in soybean (Purcell et al., 1997). Certain cultivars, such as ‘Jackson’, will increase nodule mass in response to water shortages (Purcell et al., 1997). Unfortunately, water deficits sufficient to impede N_2 fixation may not be readily observed; thus, small water deficits may negatively affect accumulation of N and therefore yield (Purcell et al., 2004; Ray et al., 2006).

Drought stress also contributes to abortion of flowers, leading to a decrease in number of pods per plant, number of seeds per pod, seed weight, and overall soybean yield during the seed filling period (Sadeghipour and Abbasi, 2012). Moisture deficits could similarly either affect the seed growth rate through reduction of CO_2 accumulation and total photosynthesis, thereby reducing the capacity for growth, accelerate senescence, thereby shortening the seed filling period, but not affecting seed growth rate, and ultimately reducing seed size and yield, or reduce the crop growth rate during most of the vegetative and early reproductive periods, which may significantly reduce seed size (Egli and Bruening, 2004; Linkemer et al., 1998; Sinclair et al., 2007). Additionally, dry matter accumulation into soybean seeds in non-irrigated environments stops before accumulation ceases in irrigated environments (Egli and Bruening, 2004).

Conversely, proper internal drainage, whether in irrigated fields or dryland production systems, is nearly as essential as irrigation to soybean production, and yields are reduced by as much as by 58%, with reduced seed number contributing to 63% of the difference, in poorly drained fields (Linkemer et al., 1998; UACES, 2014). Low O_2 availability for root respiration, which inhibits N and mineral uptake and impedes root growth and nodulation in soybean, is the main reason for reduced yields in poorly drained, waterlogged soil conditions (Linkemer et al., 1998). In a field study in Baton Rouge, LA, the greatest yield losses (93%) associated with waterlogging occurred during a 1-week period beginning at R3, while the second most sensitive time periods were 1-week periods beginning at R1 or R5, where yield losses of 67% were reported (Linkemer et al., 1998). Because waterlogging may occur in certain soils at any time throughout the growing season, producers must select cultivars that are tolerant to stress at sensitive periods (Linkemer et al., 1998). Greater tolerance for moisture stress is crucial for minimizing yield differences between irrigated and dryland production systems, as unlike genetic technology that is immediately adopted by producers, agronomic innovations require either long learning periods, substantial investments, or both (Specht et al., 1999).

Biotic Stresses

Although agricultural management factors may be entirely in control for optimal high yield, biotic stresses may reduce yield or even decimate entire fields. Pest control and routine fungicide and insecticide applications are needed as key factors in eliminating biotic stresses in high-yielding soybean (van Roekel et al., 2015).

Weeds

Interactions between crops and weeds are complex. However, although cultivars vary in competitiveness, soybean is efficient in resistance to weeds by forming a dense canopy to restrict light penetration to the soil surface (Nelson and Renner, 2001). Disparities between photosynthetic rates, nodulation, and leaf orientation among cultivars may all affect the competition between soybean plants and weeds (Nelson and Renner, 2001).

Before the advent of glyphosate-resistant soybean cultivars, mixtures of post-emergence herbicides were necessary for control of the broad spectrum of weeds (Nelson and Renner, 2001). Applying glyphosate to glyphosate-resistant cultivars does not result in substantial injury and allows for quick closure of the canopy, but application of other herbicides may cause chlorosis, necrosis, or stunting, and damage may last for up to three weeks (Nelson and Renner, 2001). Post-emergent herbicides applied during V5 reduced or delayed canopy development and reduced yield in a field study conducted in 1997 and 1998 in Saginaw, MI (Nelson and Renner, 2001).

Not only do weeds reduce yields of the current crop by competition, weeds are responsible for reducing harvest efficiency and causing foreign matter dockage (UACES, 2014). Importance should also be placed in scouting fields post-harvest to identify weed species diversity and abundance, not only for the next crop if double-cropping or in rotation, but for soybean in the following planting (UACES, 2014).

While proper herbicide selection is important for multiple crop production scenarios, chemical control should only be a small part of a weed control program that includes crop rotation, seedbed preparation, appropriate row spacing, and fundamental awareness of herbicide timing and over-reliance on herbicides (UACES, 2014). The use of cover crops, defined as those planted in the fall and desiccated through the use of herbicides the next spring before planting of the summer crop, for weed control is not overarching, as only species-specific, partial suppression occurs during the early stages of crop growth, which may or may not result in any effect on yield (Reddy et al., 2003).

Nematodes

Yield may be suppressed by as much as 50% due to large population densities of nematodes under the right conditions (UACES, 2014). Historically in Arkansas, Soybean Cyst nematodes (SCN; *Heterodera glycines*) have been the most widespread nematode species, but in recent years Root Knot nematodes (RKN; *Meloidogyne incognita*) have surpassed SCN as the state's most common nematode (UACES, 2014). Root Knot nematodes are also the most damaging species of nematode and will kill infected plants in sandy soils if population densities and the severity of other stresses are high (UACES, 2014). Planting a cultivar resistant to nematodes can result in a yield improvement of up to 10 to 25% from the previous year, depending on the severity of the previous infestation problem; although, where RKN was extremely severe, yield improvement can be much greater (UACES, 2014).

A few nematicides are available on the market for use in soybean, but, in general, nematodes are managed much more efficiently and economically through utilization of resistant cultivars and crop rotation (UACES, 2014).

Diseases Caused by Pathogenic Bacteria, Fungi, and Viruses

Diseases in Arkansas reduce soybean yields an estimated 10%, although in specific fields and with certain diseases, yield losses may be much greater (UACES, 2014). Because soybean pathogens are not confined to any particular area in the state, accurate disease diagnosis and an education and awareness of the potential for disease loss are crucial for the continued success of soybean production in Arkansas (UACES, 2014).

Bacterial blight, caused by *Pseudomonas savastanoi* pv. *glycinea* and which occurs in all soybean-growing regions of the world, is the most common bacterial infection of soybean (UACES, 2014). Although a limited problem in AR, blight has been reported to cause significant yield losses from susceptible cultivars under heavy bacterial blight disease pressure (UACES, 2014). Control of blight consists of growing resistant cultivars, and fewer plant populations grown on wide rows is advisable for fields with a history of the disease (UACES, 2014). Bacterial pustule, caused by *Xanthomonas axonopodis* pv. *glycines*, is also a worldwide disease, but is not as common in AR as bacterial blight due to highly resistant cultivars (UACES, 2014).

Besides bacterial species that may affect final yield of soybean, several different fungal species are also pathogenic to soybean throughout the growing season. Refer to Table 1 for detailed information on pathogenic fungi in Arkansas.

In addition to bacterial and fungal pathogenic infections, viral infections can be problematic in Arkansas. Soybean mosaic virus (SMV) occurs in all areas of the world and may cause yield losses up to 94%, but has not been extensively studied in Arkansas (UACES, 2014). Bean pod mottle virus (BPMV), which was first discovered in Arkansas in 1951, may cause yield losses up to 60%, but has not been thoroughly studied in Arkansas (UACES, 2014). Further, SMV and BPMV may synergistically interact to cause yield losses up to 86% when in combination (UACES, 2014). Other viruses that may cause soybean yield losses up to nearly 100% are tobacco ringspot virus and soybean vein necrosis virus (UACES, 2014).

Soil Properties Responsible for High Yields

Since many large-scale production fields contain a variety of soil series, variability in soil chemical and physical properties within fields is more prevalent than uniform conditions (Cox et al., 2003). Nevertheless, the combined effects of soil properties may be able to explain a portion of any resulting yield variability, but the exact relationship between soil properties and yield depend on the specific field and year (Kravchenko and Bullock, 2000). Reducing the yield gap that exists between high-yielding areas of some fields and the average field on a US farm becomes more complicated and less likely when soil properties are included, since not only does the potential exist for yield gap variation within a field, but significant changes to the soil itself may be challenging at best (Egli and Hatfield, 2014).

Fertility

As soybean yields increase over time, larger nutrient inputs will be required, and current state fertility recommendations are not likely to be adequate for a soybean crop with yields greater than 5000 kg ha^{-1} (Freeborn et al., 2001; van Roekel et al., 2015). However, fertility relationships with yield are not always consistent (Cox et al., 2003), and can vary considerably across fields and years

(Sawchik and Mallarino, 2008). Soybean requires 16 nutrients for growth and production of seed (Freeborn et al., 2001). Soybean yield field experiments show that fertilizer rate is a more important factor influencing response than fertilizer application time (i.e., fall vs. spring) (Gan et al., 2002; UACES, 2014).

Management of N fertilizers for soybean production is complex, as the crop can utilize both soil N and atmospheric N_2 through symbiotic fixation (Gan et al., 2002); which source is more important depends on the availability of soil inorganic N (Purcell et al., 2004). Hence, when the presence of N in the soil is abundant, N_2 fixation provides little N to the soybean plant, and vice versa (Purcell et al., 2004). Additionally, the proportion of N received from either source may change due to environmental conditions, such as drought (Purcell et al., 2004). The soybean seed requires the most N from the R5 to R8 growth stage (Freeborn et al., 2001), but some N application at planting, as a starter application, may be useful for germination and early season establishment, growth, and development.

A positive yield response to various amounts of N application in soybean has been observed, but not always, which may be influenced by soil water status at application timing (Gan et al., 2002; Ray et al., 2006). Soybean grown on the majority of soils do not show a yield effect after application of low rates (25 to 35 kg N ha^{-1}) of pre-plant N (Ray et al., 2006). However, soybean yield under drought conditions was increased by 18% after application of 336 kg N ha^{-1} compared to treatments without fertilizer (Purcell et al., 2004). In a 1-yr field experiment with one cultivar under both irrigated and dryland production, split applications of 224 kg N ha^{-1} at V6 and 112 kg N ha^{-1} at R2 to non-irrigated plots increased plot yield by nearly 18% over other non-irrigated plots, while, in the same study, fertilizer had no effect on yield in irrigated plots (Ray et al., 2006). In Suffolk, VA, in 1997 through 1999, foliar-applied N to leaves of R5 soybean at rates of 45, 90, and 135 kg ha^{-1} increased yields by 123, 160, and 243 kg ha^{-1}, respectively, over the unamended control yield (i.e., 2640 kg ha^{-1})

(Freeborn et al., 2001). Additionally, yield was increased by 130 and 220 kg ha^{-1} over the control of 2280 kg ha^{-1} when 34 kg N ha^{-1} were applied to leaves in split applications at the R4 and R5 growth stages (Freeborn et al., 2001). In Stoneville, MS in 1999 to 2001, application of 35 kg N ha^{-1} early in the season resulted in greater expenses, no significant increase in yield, and thus smaller net returns in both irrigated and dryland production systems for glyphosate-resistant and traditional cultivars (Heatherly et al., 2003). Where positive responses were observed, the soil had either very low inherent N, low N mineralization capacity, or low pHs that impaired nodulation and thus N_2 fixation (Heatherly et al., 2003).

Nitrogen fertilizer responses may only occur under high-yield-potential sites in years of adequate moisture, or in environments that have low soil OM or are water-stressed (Freeborn et al., 2001). Yield increases as a result of high rates of pre-plant-applied N can usually be attributed to increased seed number, resulting from an enhancement of plant processes known to occur in early reproductive growth rather than during seedfill (Ray et al., 2006). Agricultural management practices, initial soil fertility levels, OM concentration, nodulation levels, presence of *Bradyrhizobium japonicum* in the rhizosphere, and timing are all factors that regulate crop response to N application (Gan et al., 2002; Purcell et al., 2004).

In contrast to the potential benefits, large amounts of N fertilizer applied before reproductive growth may decrease the activity of *Bradyrhizobia* spp., inhibiting N_2 fixation by reducing root-hair infection and nodule number and mass, and the magnitude of inhibition will likely depend on the N-form applied, season, light intensity, temperature, and other soil fertility conditions (Freeborn et al., 2001; Heatherly et al., 2003; Ray et al., 2006; Sadeghipour and Abbasi, 2012; van Roekel et al., 2015). Symbiotic N_2 fixation begins after nodules are formed, peaks soon after initiation of flowering, and continues at high rates until seed fill is nearly complete (Mastrodomenico and Purcell, 2012; van

Roekel et al., 2015). As the N is remobilized to the seed, senescence of plant tissue begins (Freeborn et al., 2001; van Roekel et al., 2015). Since N_2 fixation is more sensitive to water deficits than uptake and assimilation of soil N, a yield limitation is imposed in both irrigated and non-irrigated environments for crops that receive N solely from N_2 fixation (Ray et al., 2006). Nitrogen fixation is also negatively affected by excess moisture, salinity, acidity, low P amounts, and the occurrence of foreign substances (Sadeghipour and Abbasi, 2012). Legumes, such as soybean, are essential, both agronomically and economically, to many cropping systems due to their ability to fix available atmospheric N_2 and release a portion to the soil to the benefit of subsequent crops. Consequently, N_2 fixation is the most important environmental pathway for introducing N to the soil (Sadeghipour and Abbasi, 2012).

In Arkansas, soybean yield responses to K fertilizers are generally more pronounced and frequent than responses to P fertilization (UACES, 2014). Additionally, soil test K (STK) more accurately predicts response to K fertilization than soil test P (STP) predicts P fertilization requirements (UACES, 2014). However, soil K levels fluctuate throughout the year, and are generally the greatest when samples are collected in the fall (UACES, 2014). In a corn-soybean rotation in Iowa and Illinois, both positive and negative correlations were observed between crop yield and soil P and K concentrations (Kravchenko and Bullock, 2000). In Iowa, soybean grain yield was positively correlated to STP, STK, and plant K (Sawchik and Mallarino, 2008). In slightly acidic and neutral soils in Minnesota, yield was optimized at STP concentrations of 15 mg kg^{-1} or more, while in slightly alkaline soils, yield was optimized at STP levels of 30 mg kg^{-1} or more (Anthony et al., 2012). However, soybean yield was unrelated to levels of P-fertilizer applications (Anthony et al., 2012). In Brooksville, MS in 1998, soybean yield was doubled in fields with low P and K concentrations compared to those fields with optimal P and K concentrations, suggesting that some factor(s) other than P and K nutrition was influencing final yield (Cox et al., 2003).

In addition to N, P, and K, micronutrients are important for optimal soybean production. Some micronutrients in Arkansas are not in short supply, while others may be toxic. For example, Mg deficiencies are rare, as most water used for irrigation in Arkansas is groundwater where Mg is abundantly present (UACES, 2014). Copper, Fe, and Zn deficiencies have not been recognized as nutrient- or yield-limiting in Arkansas (UACES, 2014). However, Cl, which can enter a field from irrigation water, can be a concern if levels reach a toxic threshold in poorly drained soils and may reduce yields (UACES, 2014).

Boron deficiency in soybean is not considered widespread, but it is an issue in northeast AR, and is therefore the most common micronutrient deficiency in AR, as was first noted in silt-loam soils in the early 2000s (UACES, 2014). Soils most susceptible to B deficiency are those located between Interstate 40 and the MO state line and west of Crowley's Ridge that have a history of groundwater irrigation with large concentrations of $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$, with soil pHs greater than 7.0 on sandy and silt loam surface textures (Freeborn et al., 2001; UACES, 2014). Boron deficiency occurs more widespread during years with little rainfall on shallow and compacted soils (UACES, 2014).

The role of B within the plant includes synthesis of the cell wall, transportation of sugars, division of cells, elongation of roots, and regulation of plant hormone levels (Freeborn et al., 2001). Applications of soil B to a silt-loam soil in Missouri produced no significant differences in yield, even with a split application (Freeborn et al., 2001). However, in Arkansas on a silt-loam soil, soybean yield increased up to 538 kg ha^{-1} over the unamended control yield of 2861 kg ha^{-1} when B was applied at R1 at a rate of 3 kg ha^{-1} (Freeborn et al., 2001). In addition, at another site in Arkansas on a silt-loam soil, yield increased 569 kg ha^{-1} over the unamended control yield of 2257 kg ha^{-1} when B was applied at R1 at a rate of 4 kg ha^{-1} (Freeborn et al., 2001). However, research conducted in Suffolk, VA from 1997 to 1999 demonstrated no yield response to reproductive-stage N or B applications over three different yield potentials and different application rates and times (Freeborn et al., 2001). Residual soil B levels of 0.1 to 0.2 mg kg^{-1} were shown to be adequate to achieve high soybean yields in non-water-limited production systems (Freeborn et al., 2001). However, B toxicity also can occur, most likely with soybeans grown on soils with a pH < 6.0 and soil test B greater than 2.5 mg kg^{-1} (UACES, 2014).

Manganese regulates ureide levels, in which increasing the soil Mn supply increases ureide degradation, thereby decreasing sensitivity to drought (Vadez and Sinclair, 2002). In some eastern AR loamy soils with soil test Mn levels less than 10 mg kg^{-1}, final yields have responded to Mn fertilization (UACES, 2014). Conventional soybean varieties are less sensitive to Mn, and possibly other micronutrient deficiencies, than glyphosate-resistant varieties, especially after spraying with glyphosate, due to glyphosate chelating with Mn and other metal cations in the plant and soil, temporarily reducing nutrient availability (UACES, 2014).

Though S is regarded as one of the essential macronutrients for crop growth with requirements similar to P, S fertilization has received little attention for many years, since fertilizer and mostly atmospheric inputs supplied soils with sufficient S levels (Zhao et al., 2008). However, recently S deficiency has become recognized as a factor limiting crop production, especially on deep sandy soils in Arkansas (UACES, 2014; Zhao et al., 2008). Sulfur is required for protein and enzyme synthesis, as well as being a part of two amino acids, methionine and cysteine (Zhao et al., 2008). Sulfur fertilizer has been shown in pot experiments in China to increase the abundance and mass of nodules, perhaps lowering soil pH and creating a more favorable environment for microbial activity, enhancing N_2 fixation, and thus reducing reliance on N fertilizers (Zhao et al., 2008).

Molybdenum is essential for legumes since Mo is required by nodule-forming rhizobia bacteria to fix atmospheric N_2 into plant-available ammonium (NH_4^+) (Brye et al., 2004; UACES, 2014). In contrast to most other micronutrients, Mo availability increases as soil pH increases; therefore, Mo deficiencies are likely to occur on acid soils, wherein stunted plants with pale green or yellow leaves have few or no root nodules (Brye et al., 2004; UACES, 2014). Furthermore, on acidic soils with inherent low fertility, P and K uptake from fertilizer applications may be limited if Mo is not also applied or present in adequate amounts (UACES, 2014). When needed, Mo application rates between 14 and 28 g Mo ha^{-1} are sufficient to counteract any plant deficiencies (UACES, 2014).

Soil Organic Matter

The long history of cultivated agriculture in eastern Arkansas, combined with the warm and wet climate, which is favorable for rapid soil organic matter (SOM) decomposition, has resulted in generally low SOM concentrations in the top 10 to 15 cm of most cultivated agricultural soils (Amuri et al., 2008). Additionally, the absence of additions of organic soil amendments and extensive reliance on inorganic fertilizers in the agricultural production regions of Arkansas has accelerated the depletion of SOM (Amuri et al., 2008). Furthermore, long-term CT has been reported to break down soil aggregates and increase the concentrations of available organic substrates for microorganisms, thus resulting in rapid SOM decomposition and C loss as CO_2 (Amuri et al., 2008). Coarse-textured soils' water and nutrient availability may be improved through increasing the OM content through applications of organic amendments such as poultry litter or by cover cropping (Kaspar et al., 2004).

Soybean yield exhibited positive correlations with 10 cm SOM concentration and Zn content in a field study in Arkansas (Brye et al., 2004). In Illinois and Iowa, in a corn-soybean rotation from 1994 to 1997, 18 cm SOM concentration had the greatest consistent positive influence on soybean yield compared to cation exchange capacity and P and K concentrations, but SOM content was more important in influencing yield in soils with low SOM content than soils with a greater SOM content (i.e., 28 versus 64 mg kg^{-1}) (Kravchenko and Bullock, 2000). However, in a field study in Iowa, soybean yield was uncorrelated to 15 cm SOM in multiple fields (Sawchik and Mallarino, 2008).

Soil pH and Electrical Conductivity

Soil pH is a dynamic property and may fluctuate 1.0 or more units throughout the year (UACES, 2014), but the optimum soil pH for soybean production is between 6.5 and 7.0, and production may not lose significant yield when grown on clayey soils with pH as low as 5.2 (UACES, 2014). However, yield reductions as a result of soil acidity usually occur on sandy and silt-loam soils at pH values less than 5.5. Additionally, if soil pH levels are less than 5.0, liming should take priority over fertilization (UACES, 2014). When soil pH is lower than desirable, lime is best applied in the autumn months, especially following rice if in a soybean-rice rotation (UACES, 2014). In a corn-soybean rotation in MN, yield was most strongly correlated to 15 cm soil pH, with yields consistently lower in alkaline pH areas (Anthony et al., 2012).

Alkaline soil pHs in the Mississippi River Delta region in eastern Arkansas can be attributed to increased concentrations of Ca, Mg, and bicarbonates in groundwater used for irrigation (Brye et al., 2004). Soil Fe and Zn contents decrease as pH increases, but the effect is stronger on soils with low C contents (Kaspar et al., 2004).

Electrical conductivity is another soil property that may contribute to yield. Soil EC correlates strongly with clay content, water content, salinity, SOM concentration, and CEC (Kaspar et al., 2004).

Biological Effects on Soil and Plant Properties

Because microorganisms exist in nearly all environments, and since microbes occupy the base of the food chain, microbes are the first organisms to react to changes in the environment (Biolog, 2007). Microbes contribute to soil nutrient levels, plant processes and functions, and overall crop health and productivity (Balser et al., 2002; Larkin, 2003). Furthermore, soil microbial communities are affected by inherent soil properties and current conditions, crop management approaches, and aboveground vegetation presence and type (Balser et al., 2002; Larkin, 2003), and are therefore often a precursor to changes in the health of the environment as a whole (Biolog, 2007).

*Community Level Physiological Profiling and the EcoPlate^TN^*

Certain species of chemoheterotrophic bacteria utilize specific organic sources of C and energy for growth, and the ability of species to use diverse substrates can be used to identify and characterize cultures and communities (Konopka et al., 1998). Although community level physiological profiling (CLPP) involves inoculating plates with mixed cultures of microbes, where only a small percentage are culturable, CLPP is effective at detecting spatial and temporal change in soil communities, is widely used, and provides information regarding functional aspects of soil communities (Balser et al., 2002; Biolog, 2007; Haack et al., 1995; Konopka et al., 1998; Larkin, 2003). Haack et al. (1995) noted that substrate oxidation patterns are sometimes nonlinear, meaning there is a lag phase, a log phase, and a stationary phase, common to bacterial growth curves.

The Biolog EcoPlate™ is a system of three replications of wells, where each well contains one of 31 of the most utilized C sources for soil microbial (primarily bacterial) community analysis (Biolog, 2007). EcoPlates™ have been shown to be more effective at distinguishing minute changes in the environment compared to other methods (Balser et al., 2002), such as phospholipid fatty-acid analysis (Biolog, 2007), and are quicker, simpler, and less labor intensive and costly than culturing (Konopka et al., 1998). Nevertheless, challenges may arise when working with EcoPlates™. For example, oligotrophs, those organisms that can survive with low nutrient concentrations, may give all-negative responses in microplates, and, additionally, color that develops in the blank well may occur as a result of spore formation or cell lysis (Haack et al., 1995). Furthermore, a strong correlation exists between inoculum cell density and color development rate in the EcoPlate^{TM}, which can lead to mistaking community differences for total populations (Haack et al., 1995). Therefore, for proper analysis and sound results, it is crucial that metabolically active cells be inoculated and the same amount is inoculated across wells (Balser et al., 2002; Haack et al., 1995; Konopka et al., 1998). Moreover, Haack et al. (1995) and Konopka et al. (1998) reported no correlation between substrate oxidation and amount of growth, number of species, or species richness and Haack et al. (1995) demonstrated a lack of similarity in replicates, due to heterogeneity in the soil samples that were collected. In addition, the timing of sample collection is important. Sugiyama et al. (2014) showed that the EcoPlate^{TM} response of samples collected from the rhizosphere was 1.5 to 3 times greater than that of bulk soil samples during soybean growth. Additionally, community composition changed throughout the soybean growing season (Sugiyama et al., 2014).

Rhizosphere

The rhizosphere, the fraction of soil influenced by the root, is up to 1,000-fold richer in bacterial numbers and activity than the surrounding bulk soil (Van Loon, 2007). The high population densities of rhizobacteria are caused by the secretion of organic substances and metabolites from the root (Johansson et al., 2004; Lugtenberg and Kamilova, 2009), which feeds the abundant bacteria surrounding the root. A certain assemblage of rhizobacteria known as plant growth-promoting rhizobacteria (PGPR) can enhance soil fertility through stimulation of nutrient delivery and uptake by plant roots (Johansson et al., 2004; Van Loon, 2007; Bhattacharrya and Jha, 2012). Plant growth-promoting rhizobacteria (PGPR) are characterized as highly adaptable in a wide variety of environments, exhibiting enhanced growth rates, and having biochemical versatility, which helps metabolize a wide range of natural and xenobiotic compounds (Bhattacharrya and Jha, 2012). Additionally, PGPR can be defined as non-pathogenic, rhizosphere-colonizing bacteria that are able to stimulate growth of host plants (Bhattacharyya and Jha, 2012).

Nutrient Cycling and Availability

Nitrogen is the primary plant nutrient that becomes limiting in agricultural ecosystems due to heavy losses by rainfall, mineral leaching, and crop harvest (Bhattacharrya and Jha, 2012). Biological N_2-fixation (BNF), the conversion of atmospheric N_2 gas into NH_4^+ in nodules of leguminous plants (Lugtenberg and Kamilova, 2009), is a well-known, high energy-demanding, oxygen-sensitive process exclusively driven by bacteria that belong to the genera *Rhizobium*, *Sinorhizobium*, *Bradyrhizobium*, *Mesorhizobium*, and *Azorhizobium*, collectively termed rhizobia (Barea et al., 2005). Rhizobia are the only organisms known to possess the key enzyme complex nitrogenase (Steenhoudt and Vanderleyden, 2000; Barea et al., 2005), which is necessary for BNF. Nodulation begins when the plant releases compounds that act as signals for the bacterium to secrete Nod (nodulation) factors. Nod factors are perceived by plant root hairs and function in a hormone-like fashion to induce root nodulation within which rhizobia bacteria reside to fix atmospheric N (Hayat et al., 2010). Additionally, Nod factors act as the primary molecules that induce soybean plant growth (Gray and Smith, 2005). The bacterium grows at the expense of sucrose and other carbohydrates produced by the leaves of the host, but provides fixed N in the form of NH_4^+ for amino acid biosynthesis in return (van Loon, 2007; Juge et al., 2012). This symbiosis is a prime example of an intimate relationship between a soil bacterium and its host plant, and illustrates the rudimentary concept behind the term PGPR. Further inoculation of genistein into wild *Bradyrhizobium japonicum* increased overall soybean yield and protein content and increased nodule number and weight (Pan et al., 2002; Bhattacharrya and Jha, 2012), while *Bacillus cereus* UW85 has been shown to enhance soybean nodulation under field conditions (Dashti et al., 1998; Pan et al., 2002; Gray and Smith, 2005). Biological N_2-fixation currently accounts for 65% of N utilized in agriculture, and will continue to be of great importance in future sustainable crop systems (Hayat et al., 2010). However, other elements and essential plant nutrients, such as P, will also be important.

The P cycle in the biosphere has been described as mostly sedimentary due to the lack of substantial interchanges with the atmosphere, with microorganisms playing a significant central role in the P cycle by means of oxidation and reduction of P compounds. Soils have a large reservoir for total P due to regular application of P fertilizers (Rodriguez and Fraga, 1999; Bhattacharrya and Jha, 2012); however, a significant portion of the soluble inorganic phosphate applied to soil as fertilizer is quickly immobilized by Fe and Al in acid soils and by Ca in alkaline soils soon after application, thus becoming unavailable (Rodriguez and Fraga, 1999; Dobbelaere et al., 2003). Plant yield can be enhanced due to greater concentrations of soil inoculants (Rodriguez and Fraga, 1999), as these microorganisms are able to solubilize insoluble mineral P through the production of various organic acids. This results in acidification of the surrounding soil, releasing soluble orthophosphate ions ($H_2PO_4^-$ and HPO_4^{-2}) that can be taken up by plants (Rodriguez and Fraga, 1999; Dobbelaere et al., 2003; Bhattacharrya and Jha, 2012).

Another major component of soil P is contained in SOM. In organic compounds, bacteria are able to solubilize organic P by means of phosphatase enzymes (Rodriguez and Fraga, 1999; Dobbelaere et al., 2003), where concentrations are greater in the rhizosphere. There are considerable populations of phosphate-solubilizing bacteria in plant rhizospheres, where a greater concentration is commonly present in comparison with non-rhizosphere soil (Johansson et al., 2004; Van Loon, 2007;

Lugtenberg and Kamilova, 2009). Considering that P availability is a limiting step in plant nutrition, this evidence suggests a fundamental contribution of phosphate-solubilizing bacteria to plant nutrition and, therefore, to the improvement of plant growth and productivity (Rodriguez and Fraga, 1999).

Although Fe is one of the most abundant minerals on Earth, in soil, oxidized Fe is extremely insoluble and relatively unavailable for direct assimilation by microorganisms. To overcome the lack of availability in aerobic soils, soil microorganisms secrete low-molecular-weight Fe-binding molecules, siderophores, which bind to Fe^{3+}. From here the siderophore can be transported back to the microbe, making the oxidized Fe available for microbial growth (Dobbelaere et al., 2003), or utilization by plants. Soybean plants transport the Fe-siderophore complex through the plant, at which time Fe is released from the siderophore and becomes available (Gray and Smith, 2005). As a result of the abundance of microbial siderophores in soils, along with their Fe-binding capacity and chemical stability, these compounds may contribute significantly to increased plant growth and yield.

Plant Responses

Soybean growth promotion by PGPR is not always correlated with increased nodulation and N_2 fixation. Genistein and PGPR increased soybean yield in 1997, but yield was not increased by genistein or PGPR in 1996, which may have been due to a period of drought (Pan et al., 2002). The experiments were conducted at the Emile A. Lods Research Station associated with McGill University on a sandy loam soil. Barley was grown the previous year at the 1996 site and corn the previous year at the 1997 site.

Two field experiments were conducted in 1994 located at the University of Manitoba's Plant Science Research Stations at Winnipeg and Carman, Manitoba. The previous year's crop at the Winnipeg site, a clay, was winter wheat, and the previous crop at the Carman site, a clay loam, was oat

(*Avena sativa* L.). Inoculation of soybean with *Bacillus cereus* strain UW85 resulted in increases in seed emergence and yield, shoot height, and root length (Bullied et al., 2002). Plant yield increased with this same strain from 0 to 139%, and nodulation increased 31 to 39%, which was influenced by site, growing season, and cultivar (Bullied et al., 2002).

According to Cattelan et al. (1999), seven bacterial isolates from the rhizosphere selected for plant growth experiments significantly increased at least one aspect of early soybean growth (i.e., shoot height, root length, shoot and root dry weight, nodule number and/or dry weight) and five significantly increased at least two aspects, with many common characteristics: six positive for the enzyme 1-aminocyclopropane-1-carboxylic acid deaminase, four positive for siderophore production, and two positive for P solubilization. Results were presented from an in vitro test using bacterial isolates from the Ap horizon of an Appling sandy loam (clayey, kaolinitic, thermic Typic Kanhapludult) soybean field at the University of Georgia Plant Sciences Farm near Watkinsville, GA, and an Ap horizon of a Loring silt loam (fine-silty, mixed, thermic, Oxyaquic Fragiudalf) corn field at the Martin Experiment Station, Martin, TN.

At the Emile A. Lods Research Centre in Montreal, Canada, on a Chicot light sandy loam, co-inoculation of soybean with *B. japonicum* and *Serratia proteamaculans* 1-102 or *S. liquefaciens* 2-68 was shown to increase soybean grain yield by 23 and 29%, respectively (Gray and Smith, 2005). In the previous year, 1993, this experimental field was planted with oat and barley, while in 1992 it was used to produce a crop of green manure alfalfa (*Medicago sativa*).

Plant Growth-Promoting Rhizobacteria

Utilization of bacteria to stimulate plant growth and counteract such negative effects as temperature has been exploited since ancient times. Not all rhizobacteria are helpful; some are inhibitory to plant growth (Zhang et al., 1997) and some are commensals in which the bacteria establish an interaction with the host plant, which exhibits no visible effect on growth or physiology (Bhattacharyya and Jha, 2012). Nevertheless, PGPR depend on the root association for survival (Lucy et al., 2004; Barea et al., 2005). Growth promotion generally results from indirect suppression of soil-borne pathogens and other detrimental microorganisms or direct effects on growth (Hayat et al., 2010), or a combination of multiple mechanisms that are activated simultaneously (Bhattacharyya and Jha, 2012). Sometimes, when plants are growing naturally in soil, it is difficult for one to distinguish whether an apparent growth promotion is caused by stimulated plant growth or suppression of deleterious microorganisms (van Loon, 2007). Plant growth-promoting rhizobacteria are also important with regards to maintenance of root health, nutrient uptake and tolerance to biotic and abiotic environmental stresses (Bhattacharyya and Jha, 2012). Other PGPR benefits to the plant include increases in germination rate, growth of roots, overall yield, Mg, N, and protein content, seedling emergence and vigor, hydraulic activity, drought tolerance and delayed senescence (Bullied et al., 2002; Lucy et al., 2004; Bhattacharyya and Jha, 2012).

Fluorescent *Pseudomonas spp*. are one of the most effective PGPR and have exhibited responsibility for the reduction of disease in natural soils (Pieterse et al., 2003), and may be effective at promoting plant growth basically by changing the entire community structure in the rhizosphere (Bhattacharyya and Jha, 2012). Inoculation of soybean with *Bacillus cereus* strain UW85 resulted in increases in seed emergence and yield, shoot height, and root length (Bullied et al., 2002). Application of PGPR strains in agriculture is a potential method for increasing international demand for food and improving environmental quality.

Plant growth-promoting rhizobacteria can exert a number of positive plant growth effects via direct mechanisms which include solubilization of nutrients such as phosphate, associative biological nitrogen fixation, lowering ethylene levels and production of siderophores and/or growth regulators called phytohormones (Barea et al., 2005; Bhattacharyya and Jha, 2012). Inoculation of rhizobacteria, Rhizobia and Bradyrhizobia for example (Hayat et al., 2010; Bhattacharyya and Jha, 2012), has been shown to increase uptake of nutrients, such as Ca, K, Fe, Cu, Mn and Zn, throughout the growing season (Bhattacharyya and Jha, 2012), even when PGPR numbers decline rapidly in the rhizosphere after inoculation (Lucy et al., 2004). It is presumed that growth promotion effects are seen at the onset of development, which subsequently could translate into greater yields.

Biofertilizer is a recent term whose definition is not exactly clear, but which most commonly refers to the use of soil microbes to increase the availability of nutrients and their successive uptake into plants (Whipps, 2001). A more precise definition is a substance which contains living organisms, which when applied to seed, a plant surface, or soil, begins colonization of the rhizosphere (or the interior of the plant) and promotes growth by increasing supply, availability or access of nutrients to the host plant (Whipps, 2001). This terminology delineates biofertilizer from the broad term organic fertilizer, which contains organic compounds that directly, or indirectly, increase soil fertility.

Fixation of N_2 by *Bradyrhizobium japonicum* is more sensitive to water stress than other physiological processes in soybean, indicative by a greater yield response to N fertilizer under dryland conditions compared with irrigated conditions (King et al., 2014). For example, soybean yields were increased by 16 to 18% in dryland environments, but only by 0 to 8% in irrigated environments (King et al., 2014).

Indirect Effects

Plant growth-promoting rhizobacteria may increase growth indirectly through a number of mechanisms collectively termed biocontrol, such as suppression of well-known soil-borne diseases or reducing the deleterious effects of minor pathogens (i.e., those that reduce plant growth, but do not exhibit obvious symptoms) (Zhang et al., 1997), with a corresponding increase in plant health. Various plant-root colonizing fluorescent *Pseudomonas* spp. have been shown to be potent microbiological control agents (van Loon et al., 1998; Johansson et al., 2004), which can be a result of niche- or colonization-site competition, siderophore-mediated Fe competition or antibiosis through production of inhibitory chemicals, antibiotics, and hydrogen cyanide (Pieterse et al., 2003; Johansson et al., 2004; Compant et al., 2005; Bhattacharyya and Jha, 2012), or some combination of these (van Loon et al., 1998; Barea et al., 2005; Compant et al., 2005). Bacteria may also antagonize pathogenicity through secretion of extracellular lytic enzymes that degrade parasitic fungal cell walls (van Loon, 2007; Bhattacharyya and Jha, 2012), in addition to the extreme densities of bacteria around hyphal cells that may act as a nutrient sink (Dobbelaere et al., 2003), resulting in a weaker fungus. Another method of biocontrol is the activation or induction of systemic resistance in host plants to a spectrum of harmful organisms and/or abiotic stress (Compant et al., 2005; van Loon, 2007; Bhattacharyya and Jha, 2012). For bacteria to be apt for biocontrol, the organisms must not only synthesize and release an antibiotic, but also compete successfully with other microorganisms for nutrients from the root and for niches on the root to deliver the antibiotic (Lugtenberg and Kamilova, 2009). Biocontrol may be increased in the rhizosphere if mixtures or combinations of biocontrol agents are amended, particularly if different or complementary modes of action or their abilities are displayed (Zhang et al., 1997).

Plant Physiology and Root Morphology

Bacterial production of plant hormones, the impact of those hormones on root morphogenesis, the production of root hairs and lateral roots, and subsequent increase of nutrient uptake could explain a significant part of the positive effects of PGPR (Persello-Cartieaux et al., 2003). Improvement of plant growth, development and physiological activities and health have been shown to be due to direct effects of PGPR on overall physiology rather than specific effects on aspects such as N_2-fixation. In addition, bacteria can directly influence the physiology of plants by increasing root cell permeability (Artursson et al., 2006) for example. Treatment of soybean roots with *Azospirillum brasilense* Sp7 caused a 63% increase in root dry weight, more than a six-fold increase in specific root length, expressed as root length per unit root dry weight, and more than a ten-fold increase in total root length (Whipps, 2001). The reporting of specific root length and root length are important because increases in these parameters are more reflective of an increase in the volume of soil explored than which would be expressed only by increases in root weight. With more volume of discovered soil, more nutrients are acquired, and there also exists an improvement in water status of the plant (Steenhoudt and Vanderleyden, 2000). Greater K and Fe uptake are related to thicker roots and greater P uptake to the presence of root hairs (Dobbelaere et al., 2003). *Azospirillum spp*. are N_2-fixers who are considered to be a PGPR because of the production of auxin-type phytohormones that affect root morphology, thereby increasing nutrient uptake (Steenhoudt and Vanderleyden, 2000; Barea et al., 2005).

Antibiotic Production

Phytopathogens may be inhibited by antimicrobial compounds such as antibiotics, hydrogen cyanide (HCN), and/or fungal-cell-wall-degrading enzymes (Barea et al., 2005; Hayat et al., 2010), produced by such organisms as *Pseudomonas spp*. (Gray and Smith, 2005). Bacteria have also been able to synthesize an antifungal compound with a low molecular weight that inhibits production of fungal spores (Dobbelaere et al., 2003). *Pseudomonas fluorescens* CHA0, a PGPR strain with multiple mechanisms of disease suppression, produces several toxic metabolites, including 2,4-

diacetylphloroglucinol, pyoluteorin, and HCN (van Loon et al., 1998). Other PGPR, such as *P. stutzeri*, produce extracellular chitinase and laminarase which digest fungal mycelia (Gray and Smith, 2005). Synthesis of antibiotics is tightly linked to the metabolic status of the cell, which in turn is regulated by availability of nutrients and other outside environmental stimuli (Hayat et al., 2010).

Microbial Antagonism and Competition

Microbial antagonism is an environmentally friendly method of disease suppression. Plant growth-promoting rhizobacteria can be in competition for infection or colonization sites, C and N sources and Fe through production of iron-chelating siderophores in Fe-limiting conditions (Barea et al., 2005; Hayat et al., 2010). Non-pathogenic *Pythium spp*. have been shown to take over and counteract the actions of pathogenic *Pythium spp*. and other deleterious soil microorganisms through microbial antagonism (van Loon, 2007). Plant growth-promoting rhizobacteria such as *Pseudomonas putida* WCS358 produce siderophores (van Loon et al., 1998) to competitively acquire Fe^{3+}, and although there is a difference in abilities of various bacterial siderophores, they deprive pathogenic fungi of essential Fe (Compant et al, 2005). Fungal growth is consequently restricted (Zhang et al., 1997; Dobbelaere et al., 2003), and fungal spore germination and hyphal growth are inhibited (van Loon et al., 1998). During this mechanism, the plant does not appear to suffer from Fe shortage. The dynamics of Fe competition in the rhizosphere are often complex; for example, some siderophores can only be used by the bacteria that produce them, while others can be used by a variety of bacteria. Siderophore quantity is also influenced by various environmental factors (Zhang et al., 1997).

Induced Systemic Resistance

Besides a direct antagonistic effect on pathogens, some PGPR strains are able to reduce disease in above-ground plant parts through a plant-mediated mechanism called induced systemic resistance (ISR), an activation of existing resistance mechanisms in the plant. Induced Systemic Resistance has been demonstrated in many plant species, including soybean, and is effective against a broad spectrum of plant pathogens including bacteria, fungi, and viruses. Induced resistance is not the genesis of resistance where there is none, but the expression of hidden resistance mechanisms that will be utilized in subsequent inoculations of a pathogen (van Loon et al., 1998). Even when the inducing bacterium is shown not to be present at the site of challenge with the pathogen, a metabolite produced by the bacterium could be transported through the plant, inhibiting the pathogen directly. Once induced, ISR is manifested as a reduction in the rate of disease development and is often maintained for the lifetime of the plant, even up to and including senescence (van Loon et al., 1998), implying the inducing agent does not need to be present once the induction occurs, and that the resistance is rather stable (van Loon, 2007). However, no increase in resistance is noted with the increase in dosage of bacteria (van Loon et al., 1998). Plant growth-promoting rhizobacteria-mediated ISR phenotypically resembles classic systemic acquired resistance (SAR), in which non-infected parts of previously infected plants become more resistant to further infection. Both types are effective against a broad spectrum of plant pathogens (van Loon et al., 1998; Compant et al., 2005), including diseases of fungal, bacterial, and viral origin, as well as against several nematodes and insects (van Loon, 2007). However, SAR is pathogen-induced (Pieterse et al., 2003). Systemic acquired resistance is characterized by the accumulation of salicylic acid, whereas ISR does not exhibit this quality (van Loon et al., 1998). Induced system resistance appears to be activated via a pathway involving jasmonic acid and ethylene signals (Compant et al., 2005). In addition, ISR differs from SAR in that the inducing PGPR does not cause visible symptoms on the host plant (Compant et al., 2005). Induction of resistance is dependent on the combination of bacterial strain and host plant (Compant et al., 2005) and colonization of the root system by the inducer in sufficient numbers (van Loon et al., 1998). Therefore, for field usage, application of PGPR is usually accomplished by biopriming (Compant et al., 2005), adding suspensions of bacteria to the soil before sowing, or by coating seeds with large numbers of bacteria. These treatments are designed to give the potentially inducing bacteria a competitive advantage over the indigenous soil bacterial community.

Plant Properties Contributing to High Yields

Effective Filling Period and Seed Growth Rate

Every plant process that affects yield affects total seed growth, either through the seed growth rate (SGR) and/or the effective filling period (EFP) (Egli, 2006), which are traits independent of each other (van Roekel et al., 2015). The EFP is genetically derived, sensitive to stresses, and important in determination of yield of all crops, including soybean (Brevedan and Egli, 2003). The EFP extends from the mid-R5 to the R7 growth stage, increases or decreases based on changes in resource availability or stress statuses, and typically lasts between 22 and 33 d, but can range from 12 to 57 d (van Roekel et al., 2015). A longer EFP is associated with larger seed size, and reports have demonstrated a positive, although inconsistent, relationship between length of the EFP and yield among different soybean genotypes (Board et al., 2003; Cooper, 2003). In a Fayetteville, AR field experiment on a silt-loam soil, a longer EFP in 2003 was associated with an increased seed mass; averaged over a variety of MGs and plant population densities, average seed mass was 162 mg seed^{-1} in 2003 compared with 135 mg seed^{-1} and 115 mg seed^{-1} in 2001 and 2002, respectively (Edwards and Purcell, 2005).

Breeders are able to alter the EFP by either direct selection or inadvertently by selecting for yield (Egli, 2006). Research suggests that most yield differences are a result of differences in EFP, as most cultivars in past studies exhibited similar SGRs, but those with greater yields had longer EFPs (van Roekel et al., 2015). Selection of traits that extend the EFP results in earlier flowering, and not necessarily a delayed maturity, and length of the EFP may be limited by water or temperature stress in some environments (Egli, 2006). During the EFP, after pod and seed number is set, stress in the form of drought, nutrition, high or low temperatures, and photoperiodicity only affects the growth and development of the seed and effectively, seed size, and resultant mass (Egli, 2006; Egli and Bruening, 2004; van Roekel et al., 2015).

In a pot study in 1998, water and N stress that occurred during the EFP shortened the EFP, where R7 occurred 7 d earlier than the control and reduced yield by up to 44% from the control (Brevedan and Egli, 2003). However, water stress would likely occur more slowly in the field. In the same experiment, water stress during the EFP reduced seed size up to 32%, but induction of water stress before this period reduced yield by reduction of the number of seeds per area (Brevedan and Egli, 2003). Furthermore, after a period of stress 3 to 5 d long, re-watering plants did not completely eliminate effects of water stress (Brevedan and Egli, 2003).

Seed growth rate is decided by the number of seeds per area and individual seed characteristics (Egli, 2006). Seed growth rate variations are closely correlated with seed size, wherein larger seeds grow rapidly and smaller seeds grow more slowly. However, there are exceptions to this general trend, where differences in seed size are associated with the same EFP (Egli, 2006). Van Roekel et al. (2015) discovered the SGR is highly correlated ($r = 0.93$) to seed mass. Throughout most of the EFP, the SGR is linear, except at the beginning of seedfill when the SGR increases rapidly and near maturity, when the rate slows to zero (van Roekel et al., 2015). Differences in SGR can be attributed to the number of cotyledonary cells, and are controlled by the seed (i.e., the sink) and not by the supply of raw materials to the seed (i.e., the source) (Egli, 2006).

Seed growth rate is only minimally affected by water stress on the soybean seed, but severe stress may affect SGR through an indirect effect on assimilate supply (Egli, 2006). This is not surprising given that the plant's environment can affect SGR via the supply of raw materials, such as sugars and N, from the mother plant (Egli, 2006).

Yield Predictors and Component Compensation

A seed's total dry matter (TDM) accumulation depends solely upon the supply of raw materials from the mother plant and the seed's ability to convert raw materials into stored materials (Egli and Bruening, 2004). Therefore, identifying TDM predictors for yield optimization may aid farmers by identifying anticipated yields and environmental factors that may limit yields (Board and Modali, 2005). Additionally, failure to achieve certain predictors by certain growth stages, combined with knowledge of stresses, would illustrate to producers if cultural practices may be used to treat specific situations (Board and Modali, 2005).

Studies involving late-planted soybean have linked TDM at R1 with yield. However, yield components are not promising as predictors for final yield due to large variability, the difficulty associated with assessment in large production areas, and the fact that some yield components (e.g., seed size) are formed later in the growing season (Board and Modali, 2005). For example, in Baton Rouge, LA, yield and harvest index were inversely related, but yield was sometimes positively correlated with TDM at R1 and R5, wherein yield showed steep increases with TDM at R5 for low dry matter levels (<300 g m^{-2}), progressively declined at greater TDM at R5 levels, and did not respond to TDM at R5 above 600 g m^{-2} (Board and Modali, 2005). Similar responses occurred with TDM at R1, but the plateau was reached at much smaller TDM levels, around 200 g m^{-2} (Board and Modali, 2005). Also in Baton Rouge, LA, pod number per area ($R^2 = 0.91$) and seed number per area ($R^2 = 0.83$) were closely related to yield, but seed size ($R^2 = 0.27$) and seeds per pod ($R^2 = 0.18$) were not strongly related to yield (Board and Modali, 2005). In 1998 and 1999, 72 to 86% of the yield variability on the phenotypic and genotypic levels were accounted for by seeds per area, and therefore seeds per area could be used as an indirect selector for top-yielding cultivars at late plantings (Board et al., 2003).

Yield component compensation is the phenomena by which a soybean plant can take multiple growth paths, wherein a phenotypic or genotypic increase in one yield component produces a decrease in another yield component, such that the final yield is unaffected (Board et al., 2003; van Roekel et al., 2015). Furthermore, different cultivars utilize different strategies for yield enhancement (Ainsworth et al., 2002). Yield potential is auto-adjusted for the crop first through flower production and subsequent abortions, and thus yield responds to short-term environmental conditions during R1 to R5 (van Roekel et al., 2015). For example, in a meta-analysis conducted by Ainsworth et al. (2002), yield increased by 24% due to a 19% increase in pod number, but was not due to any significant change in seed mass. Additionally, in Baton Rouge, LA in 1998 and 1999, lines with small seeds produced more pods and seeds per plant, but large-seeded plants produced fewer pods and seeds per plant, and increases in seed size or seeds per pod were compensated for by decreases in seeds and pods per area (Board et al., 2003).

Justification

Currently, there is a lack of information examining a multitude of soil characteristics that contribute to high-yielding soybean growth. With careful characterization of soil properties and crop responses in high-yielding areas within fields compared with average-yielding areas in the same or adjacent fields, key differences may be identified that may explain the larger yields in certain areas and offer opportunities to better manage average-yielding areas for larger yields.

Since the world record for soybean yield (10817 kg ha^{-1} or 161 bu ac^{-1}) occurred in Southwest Missouri in 2010 (van Roekel et al., 2015), and Missouri and Arkansas are bordering states, Arkansas soybean growers have the potential to approach or match the current world record. By understanding soil properties that contribute to larger yields in certain fields or areas within fields, producers may be able to determine those fields with the potential for increased productivity given appropriate crop management. In addition, this information may also be valuable in helping producers understand what fields are unlikely to respond to increased management attention and/or resources.

Objectives

The main objective of this study is to evaluate the effects of region and soil depth on soil physical, chemical, and biological properties differences between high- and average-soybean-yielding areas and to determine which soil properties are most related to exceptionally high soybean yields (i.e., > 6719 kg ha^{-1} or 100 bu ac^{-1}). The secondary objective of this study is to identify correlations among aboveground biomass and seed nutrient concentrations from various growth stages and soil properties for high- and average-yielding fields.

Hypotheses

It is hypothesized that soil properties will differ between high- and average-yield area among physiographic regions of Arkansas and with depth, due to natural pedogenic mixing and subsequent stratification. It is hypothesized that soil organic matter, total C and N, soil test P and K, and microbial growth rates and community compositional diversity will be greater in the high-yielding areas compared to the average-yielding areas due to these soil parameters being associated with greater rates of plant growth. In contrast, it is hypothesized that relatively too high and too low soil pH will limit yields in average-yielding areas as a result of soybean growth being retarded at extreme pH values. It is hypothesized that surface textures that are dominantly sandy or clayey will also limit yields as a result of a low water-holding capacity and poor drainage, respectively. It is also hypothesized that a longer seed-filling period will contribute to high-yielding soybean plants as a result of a longer time to incorporate mass into seed, thus increasing yield.

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Chapter 2

Soil Physical, Chemical, and Microbiological Property Differences among High-yield Soybean Areas in Arkansas

Abstract

Soybean [*Glycine max* (L.) Merr] yields greater than 6719 kg ha^{-1} (100 bu ac^{-1}) have only recently and infrequently been achieved, and little is known about the soil physical, chemical, and microbiological environment related to high-yield soybean. Therefore, a greater understanding is needed regarding how soil physical, chemical, and biological properties differ between high- and average-yielding areas within fields. The objectives of this study were to i) evaluate the effects of region and soil depth on soil physical, chemical, and biological property differences between high- and average-yielding areas, ii) assess the effect of region on selected microbiological differences between high- and average-yielding areas, and iii) identify the suite of soil properties that explain the greatest proportion of soybean yield variation in high- and average-yielding areas. Immediately prior to or just after soybean harvest in 2014 and 2015, two locations in each of seven geographical divisions within Arkansas with a high-yield, "Grow for the Green" contest area in close proximity to an average-yield area were soil sampled from the 0- to 10- and 10- to 20-cm depth intervals in each yield area. At the same time, replicate 0- to 10-cm samples were collected for microbiological property determinations. Yields in the average-yield areas ranged from 2687 to 5859 kg ha^{-1} (13 % moisture) and averaged 4633 kg ha^{-1} (69 bu ac^{-1}), while yields in the high-yield area ranged from 2822 to 6760 kg ha^{-1} and averaged 5647 kg ha^{-1} (84 bu ac^{-1}). Averaged across soil depth and years, soil bulk density, clay, pH, carbon (C):nitrogen (N) ratio, and soil organic matter (SOM), extractable soil P, K, Ca, Mg, S, Na, Fe, and B, and total C and total N contents, differed ($P < 0.05$) between high- and average-yield areas within at least one region. Averaged across yield area and years, clay, C:N ratio, and extractable P, Mn, Zn, and Cu differed ($P < 0.05$) between soil depths within at least one region. Averaged across region and years, C:N ratio, total C and N contents, and C (C_{frac}) and N fractions (N_{frac}) of SOM contents differed ($P < 0.05$) between soil depths within yield areas. Multiple regression results showed

that clay content, soil electrical conductivity, extractable soil K, Ca, S, Fe, Zn, and B contents explained 73% of the soybean yield variation for high-yield areas, while of a somewhat different set of soil properties explained only 51 and 50% of the yield variation for the average-yield and combined datasets, respectively. Averaged across yield areas and years, microbial growth rate and Shannon's and Simpson's diversity and evenness were greater ($P < 0.05$) in Region 7 than all other regions. Averaged across regions, Shannon's diversity and evenness were greater ($P < 0.05$) in high-yield areas than in average-yield areas. Principal component analysis demonstrated a variety of carbon substrates were used in high-yield areas, while carbohydrates were predominately used in average-yield areas. Results from this study have the potential to help growers better understand soil properties in their own fields that contribute to or hinder achieving ultra-high soybean yields, but additional properties, beyond those evaluated in this study, may need to be included for a more complete understanding soil environment that is associated with high-yielding soybean.

Introduction

The need to increase the yield of soybean [*Glycine max* (L.) Merr.] and other crops has been recognized in order to keep up with the demand caused by increased world populations and greater individual incomes (Tacarindua et al., 2013). From 1924 to 2012, the average US soybean yield increased annually by 23 kg ha^{-1} yr^{-1}, from 739 kg ha^{-1} to 2661 kg ha^{-1} (Egli, 2008). However, research suggests that continued increases in average yields will depend on decreasing the "yield gap", defined as the difference between current and "potential yield", the yield of a cultivar grown with the best technologies without limitations on nutrient and water availability and biological stresses effectively controlled (Cooper, 2003; Egli and Hatfield, 2014; van Roekel and Purcell, 2014).

Explaining the large "yield gap" that exists between high-yielding areas of some fields and the average field or area within a field on a US farm may require more emphasis on knowledge of agronomics and the production environment, since the average US producer has access to and can grow the same cultivars that are used in large-scale agronomic production and in research plots (Egli and Hatfield, 2014; Specht et al., 1999). Further, in order for a crop production program to be successful, knowledge of the site variables and their interactions is required (Sawchik and Mallarino, 2008).

Legume plants are agriculturally important and have the ability to form symbiotic relationships with bacteria and fungi. The broad range of rhizosphere microbial species in soil, which affect plant-soil interactions and likely contribute at least indirectly to resulting yield, have not been well-characterized. Furthermore, soil microorganism diversity is an important soil microbial parameter, and the EcoPlate™ enables the comparison of the actual overall microbial community function in different samples based on cells being active enough to turn over the specific C sources in the plate (Janniche et al., 2012).

Attempts to improve and/or maximize crop yields have focused on either the plant itself, through breeding, or the environment in which a crop is produced (i.e., management practices such as tillage and crop rotation). However, studying specific soil parameters associated with exceptionally high yields may help to meet the global demand for food, as nations are struggling with food shortages and hunger. Although studies researching soil properties relating to yield have been explored in the upper Midwest (Kravchenko and Bullock, 2000; Anthony et al., 2012) and in the south (Cox et al., 2003), focus to increase yield has been drawn mostly on landscape properties (i.e., slope, elevation, curvature) plus genetics and plant breeding efforts. There is still an enormous of amount of potential information that can be gleaned from better understanding the soil physical, chemical, and microbiological properties associated with exceptionally high crop yields.

Data from yield contests can provide valuable information about crop yield potential. The first soybean yield contest in the US, in 1966, was nation-wide, and two producers achieved yields of 6203 kg ha^{-1} that year, in Chenoa, IL and Hamburg, IA (Cooper, 2003). By the 1968 National Yield Soybean Contest, two plot yields of greater than 6719 kg ha^{-1} (100 bu ac^{-1}) were recorded, when 6890 and 7310 kg ha^{-1} were obtained in Rolling Prairie, IN and Ozark, MO, respectively (Cooper, 2003). Currently, yield contests are conducted in 14 states (van Roekel and Purcell, 2014). The first year of "Grow for the Green", the soybean yield contest in Arkansas, was 1999, when the greatest yield achieved was 5155 kg ha^{-1} (Arkansas Soybean Association, 2015). Finally in 2013, three producers in Arkansas were able to obtain yields greater than 6719 kg ha^{-1} (6771, 7044, and 7232 kg ha^{-1}; Arkansas Soybean Association, 2015).

Identifying willing cooperators who entered portions of fields in state yield contests can provide an important experimental setting for evaluating soil property differences between high- and average-yielding areas within a single field or adjacent fields on similarly mapped soils. Therefore, the objectives of this study were to i) evaluate the effects of region and soil depth on soil physical, chemical, and biological property differences between high- and average-yielding areas, ii) assess the effect of yield area on selected microbiological differences, and iii) identify the suite of soil properties that explain the greatest proportion of soybean yield variation in high- and average-yielding areas. It was hypothesized that soil properties will differ between high- and average-yield area among physiographic regions of Arkansas and with depth, due to natural pedogenic mixing and subsequent stratification. It was hypothesized that soil organic matter, total C and N, and soil-test P and K will be greater in the high-yielding areas compared to the average-yielding areas due to these soil properties being associated with greater rates of plant growth, as well as producers applying organic amendments and fertilizer. In contrast, it was hypothesized that relatively too high and too low soil pH will limit yields in average-yielding areas as a result of soybean growth being retarded at extreme pH values. In addition, it was hypothesized that surface textures that are dominantly sandy or clayey will also limit yields as a result of a low water-holding capacity and poor drainage, respectively. For the microbiological analyses, it was hypothesized microbial growth rates and both Shannon's and Simpson's diversity indices will be greater in the high-yield areas as a result of more intensive management practices.

Materials and Methods

"Grow for the Green" Yield Contest

In 1999, an annual soybean [*Glycine max* (L.) Merr.] yield contest, "Grow for the Green", was initiated by the Arkansas Soybean Promotion Board (ASPB) together with the Arkansas Soybean Association (ASA). In 2011, the ASPB and ASA divided the contest entries into early season, full-season, and double-crop production systems. Another change occurred in 2013, when the state was split into seven geographic regions (Figure 1), and an eighth, statewide, non-genetically-modified-organism category. The seven geographic regions are as follows: 1: Northeast Delta; 2: Northeast; 3: White River Basin; 4: Central and Grand Prairie; 5: East Central Delta; 6: Southeast Delta; 7: Western (Figure 1). Table 1 summarizes the 2007 to 2012 "Grow for the Green" soybean yield contest results, including the 1st- and 10th-place growers and county where the crop was harvested. Table 2 summarizes the agronomic characteristics for the 1st- and 2nd-place finishers in the 2013 yield contest in each of the seven state-wide regions.

Study Area Descriptions

In late summer to early fall 2014, two producers in each of the seven state-wide regions were identified as willing cooperators (Table 3) who had a field entered into the 2014 yield contest as well as an average-yielding area within the same field or in an adjacent field. The average-yielding area was based on each producer's qualitative, historic knowledge of the productivity of their own fields and areas within fields. This process was repeated for the 2015 growing season (Table 4). Seven of the producers identified to cooperate in 2015 were the same producers who were cooperators in 2014. However, different high- and average-yield areas were used each year. The two areas (i.e., the high- and average-yielding areas) per producer within a region were used for subsequent soil sampling purposes in both years. Tables 3 and 4 summarize the county, 2013 contest yield, and soil series and surface texture of the sites sampled in 2014 and 2015, while Table 5 summarizes the Major Land Resource Area (MLRA) and climatic characteristics among the counties in each of the seven state-wide regions sampled in 2014 and 2015. Region 7 includes MLRAs 118A, which consists mainly of Ultisols with 6% of the land area being agricultural, as well as 131C, which consists mainly of Vertisols, Entisols, Alfisols and Inceptisols with 37% of the land area being agricultural (NRCS, 2006;

Table 5). Major Land Resource Areas 131A and 131B have 70% of their land area under agriculture, consist mainly of Alfisols, Vertisols, Inceptisols, and Entisols, and occupy Regions 1, 2, 3, 5, and 6 and Regions 4 and 6, respectively (NRCS, 2006). Nearly 40% of the land area is under agriculture in MLRAs 131D and 134, which consist mainly of Alfisols, Entisols, Inceptisols, and Ultisols, respectively, and occupy Regions 4 and 6 and Regions 2 and 5, respectively (NRCS, 2006; Table 5).

The amount of annual precipitation varies slightly across the state (Table 5), with annual values in counties sampled ranging from 1225 mm in Craighead and Cross counties in the northern part of Arkansas (Figure 1) to 1363 mm in Chicot and Desha counties, in the southern portion of the state. Similar to precipitation, average temperatures vary across the state, but only slightly (Table 5). The lowest average January temperature (2.1°C), as well as the lowest average annual temperature (15.1°C), are both in Craighead county (Table 5). The highest average July temperature of counties sampled (28.1°C) is in Philips, Chicot, and Desha counties, but the highest annual temperature (17.7°C) is in Miller county, in the southwestern part of the state (Figure 1).

Soil Physical and Chemical Sample Collection and Processing

In 2014 and 2015, in each high- and average-yielding area and immediately before or just after soybean had been harvested, five sample points were established in a diamond formation, with three points in the same row approximately 62 m apart from one another, and two points perpendicular to the middle row approximately 38 m in the opposite direction from the mid-point of the middle row. At each point, soil samples were collected from the 0- to 10- and 10- to 20-cm depth intervals using a 4.7-cm diameter, stainless steel core chamber that was beveled to the outside to reduce compaction while sampling. Samples were oven-dried at 70°C for 48 hr and weighed for bulk density (BD) determinations. Samples were then ground to pass a 2-mm mesh sieve for particle-size analyses using a modified 12-hr hydrometer method (Gee and Or, 2002) and subsequent chemical analyses.

Soil pH and electrical conductivity (EC) were determined potentiometrically using a 1:2 soil mass:water volume mixture. Mehlich-3 extractable nutrient concentrations (i.e., P, K, Ca, Mg, S, Na, Fe, Mn, Zn, B, and Cu) were determined using a 1:10 soil volume:extractant solution volume ratio (Tucker, 1992) and analyzed by inductively coupled argon-plasma spectrometry (ICAP, Spectro Analytical Instruments, Spectro Arcos ICP, Kleve, Germany). Soil OM (SOM) concentration was determined by weight-loss-on-ignition at 360°C for 2 h (Schulte and Hopkins, 1996). Total C (TC) and N (TN) concentrations were determined by high-temperature combustion using a VarioMax CN analyzer (Elementar Americas Inc., Mt. Laurel, NJ). Using measured soil concentrations, C:N ratio, and C (C_{frac}) and N (N_{frac}) fractions of SOM were calculated. In addition, measured bulk densities and elemental concentrations (mg kg^{-1}) for each soil depth were used to calculate elemental contents (kg ha^{-1}), where elemental contents were used for subsequent statistical analyses.

Soil Microbiological Sample Collection and Processing

In 2014 and 2015, immediately before or just after soybean had been harvested in each high- and average-yielding area, three sample points were established in a row approximately 62 m apart from one another. One set of 10 soil samples were collected from the 0- to 10-cm depth interval using a 2-cm diameter push probe and mixed for one composite soil sample per sampling point from within 0.5 m in both directions from the three sample points. Samples were immediately put on ice and stored for approximately 5 to 8 months in a refrigerator at 4ºC for biological property determinations.

A series of dilutions were prepared for each soil sample and were chemically flocculated with 0.85% sodium chloride (NaCl) to remove suspended clays. An aliquot of 150 µL of the 10^{-3} dilutions were dispensed by pipette into each of 96 wells of Biolog EcoPlates™ (Biolog, Inc., Hayward, CA), similar to procedures in Yu et al. (2015) and plates were incubated in the dark at 20°C for 6 d. The EcoPlate™ is a system of three replications of wells, where each well contains one of 31 of the most utilized carbon (C) sources for soil microbial, primarily bacterial, community analysis (Table 6). A Synergy HT microplate reader (Biotek Instruments, Inc., Winooski, VT), set to a wavelength of 590 nm, read the plates immediately after incubation and at hourly intervals of 24, 36, 48, 60, 72, 96, 120, 144 h after incubation. Similar to Yu et al. (2015), average well-color development (AWCD) was determined for the purposes of normalization, and results were used to calculate microbial growth rates (Eq. 1), and Shannon's diversity (Eq. 2) and evenness (Eq. 3) and Simpson's diversity (Eq. 4) and evenness (Eq. 5) at 72 h, which was based on the majority of the growth rates' inflection points. The three parameter logistic equation for growth rate was:

$$AWCD = (\theta_1) / (1 + \theta_2 * e \wedge (\theta_3 * X)) \quad (1)$$

where θ_1 was the asymptote, θ_2 was the growth rate, θ_3 was the inflection point of the curve, and X was the hour of measurement. The equation for Shannon's diversity (*H*) was:

$$H = - \Sigma\, p_i \ln(p_i) \quad (2)$$

where p_i was the proportion of species *i* relative to the total number of species (i.e., substrates, 31) (Shannon, 1948; Beals et al., 2000), while the equation for Shannon's evenness (E_H) was:

$$E_H = H / 31 \quad (3)$$

where 31 is the number of substrates on Ecoplates™. The equation for Simpson's diversity (D) was:

$$D = 1 / \Sigma p_i^2 \qquad (4)$$

where p_i was the proportion of species i relative to the total number of species (Simpson, 1949; Beals et al., 2000), and the equation for Simpson's evenness (E_D) was:

$$E_D = D / 31 \qquad (5)$$

Statistical Analyses

Soil Physical and Chemical Properties

A three-factor analysis of variance (ANOVA), assuming a completely random design, was conducted using SAS (version 9.3, SAS Institute, Inc., Cary, NC) to evaluate the effects of region (i.e., seven different regions), yield area (i.e., high- and average-yielding areas), soil depth (i.e., 0- to 10- and 10- to 20-cm depth intervals), and their interactions on near-surface soil properties (i.e., bulk density, sand, silt, and clay, pH, EC, and SOM, TC, TN, P, K, Ca, Mg, S, Na, Fe, Mn, Zn, B, and Cu contents, as well as calculated C:N ratio, C_{frac}, and N_{frac}). Furthermore, a one-factor ANOVA was conducted using SAS to evaluate the effect of yield area on yield. For the purpose of these analyses, year (i.e., 2014 or 2015) was treated as a random effect. Significance was judged at $P < 0.05$. When appropriate, means were separated by least significant difference at $\alpha = 0.05$.

Combining data across years, multiple regression analyses were also conducted similar to that performed in other studies (Brye et al., 2016; McMullen et al., 2014; Smith et al., 2014), using a backwards stepwise approach, to evaluate relationships among soybean yield and the suite of measured soil properties (i.e., BD, sand, clay, SOM, pH, EC, TC, TN, P, K, Ca, Mg, S, Na, Fe, Mn, Zn, B, and Cu contents, and growth rate and Shannon's diversity) for the combined data set and for the high- and average-yielding areas separately. Initial multiple regression analyses were performed in Minitab (version 13.1, Minitab, Inc., State College, PA) and regression parameter estimates and 95% confidence intervals subsequently were obtained from JMP (version 12 Pro, SAS Institute, Inc., Cary, NC). Parameter significance was judged at $P < 0.1$ for inclusion in the final model, while overall final model significance was judged at $P < 0.05$.

Soil Microbiological Properties

A two-factor ANOVA, assuming a completely random design, was conducted using SAS (version 9.3, SAS Institute, Inc., Cary, NC) to evaluate the effects of region (i.e., seven different regions) and yield area (i.e., high- and average-yielding areas), and their interaction on growth rate, H, E_H, D, and E_D based on measured color development in EcoPlates™. For the purpose of these analyses, year (i.e., 2014 or 2015) was treated as a random effect. Significance was judged at $P < 0.05$), and when appropriate, means were separated by least significant difference at $\alpha = 0.05$. Color development in wells of the EcoPlates™ was used to perform principal component analysis (PCA) using JMP (version 12 Pro, SAS Institute, Inc., Cary, NC), where high- and average-yield areas were evaluated separately in order to elucidate differences in substrate utilization patterns.

Results and Discussion

General Yield and Soil Property Variations

For the fields sampled in the 2014 and 2015 "Grow for the Green" yield contest, soybean yields in the average-yield areas ranged from a low of 2687 kg ha^{-1} in Region 2 (Table 7) to a high of

5859 kg ha^{-1} in Region 6. The mean yield for all average-yield areas was 4701 kg ha^{-1}, which was 1409 kg ha^{-1} greater than the Arkansas state average from 2015, and 804 kg ha^{-1} greater than the state average from Nebraska, the most productive soybean state in the United States, in 2015 (NASS, 2016). For 2014 and 2015, soybean yields in the high-yield areas of fields sampled ranged from a low of 2822 kg ha^{-1} (Table 7) in Region 2 to a high of 6760 kg ha^{-1} in Region 6, while the mean yield for all high-yield areas was 5498 kg ha^{-1}, which was different ($P < 0.001$) than the mean yield for all-average yield areas. Regions 2 and 6 of the yield contest both lie along the Mississippi River Delta (Figure 1); however, Region 2 is mostly alluvial soils, while the soils in Region 6 are a mix of terrace and lower-elevation alluvial soils. Region 6 is also further south, and therefore has a slightly warmer climate (Table 3; Table 4; NRCS, 2014b). In 2014 and 2015, yield increases from each average-yield area in a field to the high-yield area within a field ranged from 5% in Region 2 to 88% in Region 5 (Table 7). The mean yield increase from the average- to high-yield areas within fields averaged 24%. Region 5 of the "Grow for the Green" yield contest is in the middle portion of the Mississippi River Delta within Arkansas, and consists mostly of alluvial soils with some loess-covered areas (NRCS, 2014b).

Across all regions and yield areas, soil properties measured during the 2014 and 2015 soybean growing seasons in the top 10 cm (Table 8) and in the 10- to 20-cm depth (Table 9) varied in scale and magnitude. For both yield areas, in the top 10 cm, soil BD ranged from a low of 0.87 g cm^{-3} in Region 1 (Table 8) to a high of 1.48 g cm^{-3} in Regions 3 and 7, while sand ranged from 0.01 g g^{-1} in Region 2 (Table 8) to 0.79 g g^{-1} in Region 7. Soil organic matter (SOM) in the top 10 cm ranged from 10.8 Mg ha^{-1} in Region 6 (Table 8) to 47.3 Mg ha^{-1} in Region 7. Extractable soil P and K contents in the top 10 cm of both yield areas for each region ranged from 15 and 51 kg ha^{-1}, respectively, in Region 7 and 1, respectively (Table 8), to 262 and 524 kg ha^{-1}, respectively, in Region 4 and 1, respectively.

In the 10 to 20-cm depth, soil BD ranged from 1.16 g cm^{-3} in Region 2 (Table 9) to 1.61 g cm^{-3} in Region 3, while, similar to that in the top 10 cm, sand ranged from 0.01 g g^{-1} in Region 2 to 0.77 in Region 7 (Table 9). The extremes in the 10- to 20-cm depth for SOM (6.8 and 82.9 Mg ha^{-1}) were both measured in Region 7. Extractable soil P contents extremes in the 10- to 20-cm depth ranged from 6 to 197 kg ha^{-1} in Region 4 (Table 9), while extractable soil K contents ranged from 32 kg ha^{-1} in Region 3 to 401 kg ha^{-1} in Region 7.

Treatment Effects

Since the boundaries of the seven regions of the "Grow for the Green" yield contest are not only somewhat arbitrary, but are also highly variable among and within regions (i.e., differences in soil parent material, climate, topography, etc.), the scope of this study focuses on evaluating differences between and among yield areas and soil depths within regions, not across regions. Therefore, this study does not aim to elucidate regional differences, but merely differences that may help to explain soybean yield within the seven regions and to identify any potential consistencies across regions. However, since no previous studies have examined the "Grow for the Green" yield contest regions for any purpose, this study will contribute to characterizing the major soybean-yield-influencing soil properties within these regions of Arkansas.

Combined Effects of Region, Yield Area, and Depth

All soil properties measured in the top 20 cm were affected ($P < 0\ .05$) by one or more treatments (Table 10). Across the 2014 and 2015 soybean growing seasons, measured sand and silt differed between yield area/soil depth treatment combinations within regions ($P < 0.05$; Table 10). Sand ranged from 0.09 g g^{-1} in the 10 to 20-cm depth of the high-yield areas in Region 2 to 0.48 g g^{-1}

in the top 10 cm of the high-yield areas in Region 1 (Table 11). Within Region 1, the numerically greatest sand content (0.48 g g^{-1}) was in the top 10 cm of the high-yield areas, which did not differ *(P* > 0.05) from that in the average-yield areas (0.43 g g^{-1}), while the numerically smallest sand content was measured in the 10- to 20-cm depth of the high-yield (0.28 g g^{-1}), which did not differ ($P < 0.05$) from that in the average-yield areas (0.32 g g^{-1}). Within Region 2, sand content was 126% greater ($P <$ 0.05) in the top 10 cm of the average- and high-yield areas, which did not differ and averaged 0.21 g g^{-1}, than that in the 10- to 20-cm depth of both the average- and high-yield areas, which did not differ and averaged 0.09 g g^{-1}. Within Region 3, sand content was 0.06 g g^{-1} less ($P < 0.05$) in the top 10 cm of the high-yield areas than in all other yield area/soil depth combinations, which did not differ and averaged 0.35 g g^{-1}. Similar to Region 2, within Region 4, the sand content in the top 10 cm for both yield areas, which did not differ and averaged 0.37 g g^{-1}, was 56% greater ($P < 0.05$) than that in the 10- to 20-cm depth of both yield areas, which did not differ and averaged 0.24 g g^{-1}. Region 5 was the opposite of Region 3, where sand content was 0.21 g g^{-1} greater ($P < 0.05$) in the top 10 cm of the high-yield areas than in all other depth/yield area combinations, which did not differ and averaged 0.16 g g^{-1}. Within Regions 6 and 7, the numerically greatest sand contents were in the top 10 cm of the average-yield areas (0.42 and 0.32 g g^{-1}, respectively), but did not differ from that in the high-yield areas (0.31 and 0.23 g g^{-1}, respectively). Additionally, the smallest sand contents within Regions 6 and 7 were in the 10- to 20-cm depth of both yield areas (0.25 and 0.19 g g^{-1}, respectively), which also did not differ from that in the top 10 cm of the high-yield areas (Table 11).

Silt content behaved somewhat the opposite of sand, where the numerically lowest silt content (0.33 g g^{-1}) was in the top 10 cm of the high-yield areas of Region 1 and the numerically largest (0.71 g g^{-1}) occurred in the 10- to 20-cm depth of the high-yield areas in Region 2 (Table 11). Within Regions 1 and 2, silt content was 35% greater ($P < 0.05$) in the 10- to 20-cm depth of both yield areas, which did not differ and averaged 0.52 and 0.71 g g^{-1}, respectively, than that in the top 10 cm of both yield areas, which did not differ and averaged 0.33 and 0.62 g g^{-1}, respectively. Within Region 3, silt was numerically greatest in the top 10 cm of the high-yield areas (0.58 g g^{-1}), but did not differ ($P > 0.05$) from that in the average-yield areas (0.54 g g^{-1}), which also did not differ from silt in the 10- to 20-cm depth of both yield areas, which did not differ and averaged 0.47 g g^{-1}. The numerically greatest silt content in Region 4 was in the 10- to 20-cm depth of the high yield areas (0.62 g g^{-1}), which did not differ ($P > 0.05$) from that in the average-yield areas (0.59 g g^{-1}), while the numerically smallest silt content in Region 4 was in the top 10 cm of the average-yield areas (0.44 g g^{-1}), which also did not differ from that in the high-yield areas (0.50 g g^{-1}). Region 5 was similar to Region 4, where the numerically greatest silt was in the 10- to 20-cm depth of the high-yield areas (0.63 g g^{-1}); however, the silt was 0.07 g g^{-1} greater ($P < 0.05$) in the 10- to 20-cm depth of the high-yield areas than in all other yield area/soil depth treatment combinations, which did not differ and averaged 0.55 g g^{-1}. Within Region 6, the numerically greatest silt content was in the 10- to 20-cm depth of the high-yield areas, which did not differ ($P > 0.05$) from that in the average-yield areas or that in the top 10 cm of the high- yield areas, while the numerically smallest silt content was in the top 10 cm of the average-yield areas (0.44 g g^{-1}), which also did not differ from that in the high-yield areas (0.54 g g^{-1}). Similar to Region 6, within Region 7 the numerically greatest silt was in the 10- to 20-cm depth of the high-yield areas (0.55 g g^{-1}), which did not differ from that in the top 10 cm of the high-yield areas (0.48 g g^{-1}) or that in the 10- to 20-cm depth of the average-yield areas (0.47 g g^{-1}), both of which did not differ from that in the top 10 cm of the average yield areas (0.44 g g^{-1}; Table 11).

The measured variations in sand and silt within regions in this study may be significant contributors to soybean yield variations. Areas with greater sand are usually associated with a low water-holding capacity due to the greater abundance of macropores and a greater hydraulic conductivity compared to more finer-textured soils (NRCS, 2014d). In Mississippi, Cox et al. (2003) investigated soil texture and its relationship to soybean yield, and results showed that sand content was both positively and negatively correlated (r = -0.41, -0.50, and 0.11) with yield in three different fields, all of which were a Brooksville silty clay loam (fine, smectitic, thermic, Aquic Hapluderts). Similarly, Cox et al. (2003) also reported positive and negative correlations (r = 0.28, -0.81, and -0.47) between silt content and yield. However, this study was conducted on two fields with at least five years of continuous soybean and one field with a 25-yr continuous fescue (*Festuca arundinacea* Schreb.) operation before planting soybean (Cox et al., 2003).

Combined Effects of Region and Yield Area, Region and Soil Depth, and Yield Area and Soil Depth

Averaged across soil depth, soil BD, clay, and SOM, TC, and TN contents differed ($P < 0.05$; Table 10) between yield areas within at least one region across the 2014 and 2015 soybean growing seasons. Soil BD differed ($P < 0.05$) between yield areas only in Region 7, where BD was 0.09 g cm^{-3} greater in the high-yield (1.41 g cm^{-3}) than in the average-yield area (1.32 g cm^{-3}) (Figure 2). Since Region 7 encompasses the entire western portion of the state of Arkansas, it can be expected that there are varied soil conditions and differing bulk densities due to different soil parent materials, climates, and topographies. Overall, soil BD in the top 20 cm was numerically greater in the high-yield area in three of the seven regions, while soil BD was greater in the average-yield area in only one of the seven regions (Region 4). Bulk density did not differ between yield areas by more than 0.01 g cm^{-3} in Regions 2, 3, and 6. Although BD is an indicator of soil quality and compaction, none of the soils measured in this study exceeded the formal criteria for inhibition of plant root growth (i.e., > 1.47 g cm^{-3} for clayey soils or > 1.80 g cm^{-3} for sandy soils; NRCS, 2014c). Furthermore, soil BD is a dynamic property that was likely affected by differences in the agricultural practices used (e.g., tillage, residue levels, and organic soil amendment applications) among the various locations sampled in this study (NRCS, 2014c). Similar to BD, clay differed ($P < 0.05$) in the top 20 cm between yield areas only in Region 5, in which the average-yield area had 71% greater clay (0.29 g g^{-1}) than that in the high-yield area (0.17 g g^{-1}) (Figure 2). Overall, as expected, the average-yield areas had numerically greater clay in the top 20 cm than in the high-yield areas in all other regions except for in Regions 2 and 4. Since areas with greater clay are generally associated with poor internal drainage due to the greater abundance of micropores and lower hydraulic conductivity compared to more coarse-textured soils (NRCS, 2014d), it was expected that average-yield areas would have somewhat greater clay compared to the high-yield areas. Similar to clay, SOM content differed ($P < 0.05$) between yield areas only in Region 5, where SOM was 38.5% greater in the average-yield (27.3 Mg ha^{-1}) than the high-yield area (19.7 Mg ha^{-1}) (Figure 2). Overall, SOM was numerically greater in the average-yield areas in all regions expect for in Region 2.

The SOM content result was somewhat unexpected, since SOM benefits crops in a variety of ways, including acting as a nutrient reserve, retaining moisture, and contributing to soil aggregate stability (NRCS, 2014e). However, SOM may be greater in areas with greater clay contents, since SOM decomposes slower in wet to saturated soils compared to well-drained soils (NRCS, 2014e). Nevertheless, based on a study conducted in Illinois and Iowa, Kravchenko and Bullock (2000) stated that SOM was more important at influencing yield in soils with low SOM than in soils with a greater SOM content. Compared to soils in the upper mid-west, many soils in the mid-southern US have substantially lower SOM contents due to more rapid decomposition from increased air and soil temperatures.

As sub-fractions of SOM, soil TC and TN contents in the top 20 cm differed ($P < 0.05$) between yield areas within four and three of the seven regions, respectively (Figure 3). Soil TC content was at least 20.2% greater in the high- than in the average-yield area in three regions (i.e., Regions 2, 4, and 7), plus soil TC content was numerically greater in the high- than in the average-yield area in two additional regions (i.e., Regions 1 and 3). In contrast, TC content was 24% greater in average- than in the high-yield area in Region 6, and was also numerically greater in the average- than in the high-yield area in Region 5 (Figure 3). Soil TN content was at least 10.6% greater in the high- than in the average-yield areas in Regions 4 and 7, and was also numerically greater in Regions 1, 2, and 3. Similar to TC, TN content was 6.6% greater in the average- than in the high-yield area in Region 5, and was also numerically greater in Region 6. In contrast to TC and TN contents, averaged across soil depth, the soil C:N ratio in the top 20 cm did not differ between yield areas within the same region for any of the seven regions (Figure 3).

Similar to soil BD, clay, SOM, TC, and TN, averaged across soil depth, extractable soil P and B contents differed ($P < 0.05$; Table 10) between yield areas within at least one region across the 2014 and 2015 soybean growing seasons. Extractable soil P content was, on average, 19.4 kg ha^{-1} greater in high- than in average-yield areas in three of the seven regions (Regions 2, 5, and 7; Figure 4). In addition, two other regions had numerically greater extractable soil P in the high- than in the average-yield areas. Differences in extractable soil P content between yield areas may be a result of differing applications of nutrients in high- than in average-yield areas in order to achieve greater yields for contest purposes. However, Anthony et al. (2012) stated soybean yield was unrelated to levels of P-fertilizer applications in slightly acid to neutral soils in Minnesota. Additionally, Cox et al. (2003) suggested that fields with low soil-test-P concentrations may still achieve greater yields compared to fields with greater soil-test-P concentrations if other potentially yield-limiting factors are overcome. Similar to clay and SOM, extractable soil B content was nearly two times greater in the average- (1.33 kg ha^{-1}) than the high-yield area (0.76 kg ha^{-1}) in Region 5, and did not differ ($P > 0.05$) between yield areas within any other region (Figure 4). Extractable soil B content was also numerically greater in the average- than in high-yield area in three of the other six regions. Boron deficiency in soybean is not considered widespread, but is the most common micronutrient deficiency in Arkansas (UACES, 2014). Moreover, B toxicity can also occur; since measured extractable soil B in this study ranged from a rating of deficient (i.e., < 0.5 mg kg^{-1}) to toxic (i.e., > 2.5 mg kg^{-1}; UACES, 2014), yields may have been reduced in either scenario. However, similar to soil BD, extractable soil B did not differ between yield areas by more than 0.02 kg ha^{-1} within Regions 2, 3, and 6.

Averaged across soil depth, soil pH and extractable soil K, Ca, Mg, S, Na, and Fe contents did not differ ($P > 0.05$) between yield areas within any region (Figures 4, 5, 6). However, soil pH and extractable soil K, Ca, Mg, S, and Na contents were numerically greater in average- than in high-yield areas in three or more of the seven regions. For example, extractable soil K, Ca, Mg, S, Na, and B contents were numerically greater in average- than in high-yield areas in Region 5, while soil pH and extractable soil K, Ca, Mg, Na, and B contents were numerically greater in average- than in high-yield areas in Region 4.

Across the 2014 and 2015 soybean growing seasons, averaged across yield area, clay content, C:N ratio, and P, Mn, Zn, and Cu contents differed ($P < 0.05$; Table 10) between soil depths within at least one region. Clay content in the top 10 cm ranged from 0.11 g g^{-1} in Region 3 to 0.28 g g^{-1} in Region 7 (Figure 7). Additionally, clay content in the 10- to 20-cm depth increment ranged from 0.14 g g^{-1} in Region 6 to 0.30 g g^{-1} in Region 7. Averaged across yield area, clay content differed ($P < 0.05$) between soil depths within four of seven regions. As expected, clay content was greater ($P < 0.05$) in the 10- to 20-cm depth than in the top 10 cm in Regions 3 and 5, and was numerically greater in Regions 2, 4, and 7. Since clay is a mobile component in soils, downward movement occurs with water percolation, thus often increasing clay contents with depth (Miller and White, 2008).

Soil C:N ratio in the top 10 cm ranged from 7.5 in Region 3 to a 9.1 in Region 7 (Figure 7), while soil C:N ratio ranged from 6.3 in Region 1 to 7.9 in Region 7 in the 10- to 20-cm depth. Averaged across yield area, soil C:N ratio was greater ($P < 0.05$) in the top 10 cm in all regions except Region 6, where soil C:N ratio was only numerically greater in the top 10 cm than the 10- to 20-cm depth. Total C and TN, which were used to calculate soil C:N ratio, are determined by a dynamic balance of C and N inputs from plant production, as well as outputs from plant production and microbial decomposition (Yang et al., 2010). Similar to soil C:N ratio, extractable soil P was at least numerically greater in the top 10 cm in all regions (Figure 7). Averaged across yield area, extractable soil P content was 23.3 kg ha^{-1} greater, on average, in the top 10 cm within all regions. Cox et al. (2003) observed double the yield from fields with sub-optimal compared to fields with optimal P and K concentrations. Extractable soil Mn content was greater ($P < 0.05$) in the 10- to 20 cm depth than in the top 10 cm in Regions 2, 3, and 4, and was numerically greater in Regions 1 and 6 (Figure 8). Extractable soil Mn content was numerically greater in the top 10 cm than in the 10- to 20-cm depth in Regions 5 and 7. Some fields in eastern Arkansas that have soil-test Mn levels less than 10 mg kg^{-1} have responded to Mn fertilization (UACES, 2014), but none of the soil samples collected in this study had extractable soil Mn concentrations lower than 22 mg kg^{-1}.

Extractable soil Zn was greater ($P < 0.05$) in the 10- to 20-cm depth in Region 4 (Figure 8); however, Zn was, on average, 25% numerically greater ($P > 0.05$) in the top 10 cm than in the 10- to 20-cm depth in all other regions. Similar to Zn, extractable soil Cu differed ($P < 0.05$) between soil depths in only one region (Figure 8), where extractable soil Cu content was greater in the top 10 cm than in the 10- to 20-cm depth in Region 6, and was numerically greater in the top 10 cm in Regions 3, 4, 5, and 7. However, extractable soil Cu content did not differ between depths by more than 0.3 kg ha^{-}

^{1} within any region, excluding Region 6. Extractable soil Zn and Cu deficiencies have not been recognized as yield-limiting soil factors in Arkansas (UACES, 2014).

Averaged across regions, soil TC and TN contents, C:N ratio, C and N fractions of SOM (C_{frac} and N_{frac}, respectively) differed ($P < 0.05$; Table 10) between yield areas and soil depths across the 2014 and 2015 soybean growing seasons. Total C content was 0.3 Mg ha^{-1} greater ($P < 0.05$) in the top 10 cm in the average-yield areas and both depths in the high-yield areas than that in the 10- to 20-cm depth of the average-yield areas (Figure 9). Similar to TC, TN content was 17% greater ($P < 0.05$) in the 10- to 20-cm depth in the average-yield areas and in the top 10 cm of the high-yield areas than that in the 10- to 20-cm depth in the high-yield areas (Figure 9). However, TN content in the top 10 cm in the average-yield areas did not differ ($P > 0.05$) from any other yield area/soil depth treatment combination. Soil C:N ratio was at least 15% greater ($P < 0.05$) in the top 10 cm of both yield areas than in the 10- to 20-cm depth, and was also greater ($P < 0.05$) in the high- than in the average-yield area in the 10- to 20-cm depth (Figure 9). The soil C fraction of SOM in the 10- to 20-cm depth of the high-yield areas (0.63 g g^{-1}) was greater ($P < 0.05$) than in all other yield area/soil depth treatment combinations (Figure 9). The soil C fraction of SOM was also greater ($P < 0.05$) in the top 10 cm than the 10- to 20-cm depth in the average-yield areas, but did not differ ($P > 0.05$) from that in the top 10 cm of the high-yield areas. Similar to C_{frac}, the soil N fraction of SOM was greater ($P < 0.05$) in the 10- to 20-cm depth in the high-yield areas (0.08 g g^{-1}) than in all other yield area/soil depth treatment combinations, which did not differ (Figure 9).

Soil C and N are dependent on the amount of plant residues deposited or removed, the C and N concentrations in plant residues, and the rate of C and N mineralized in soil (Wang and Sainju, 2014). Previous crop, which varied in this study as either corn (*Zea mays*, L.), rice (*Oryza sativa* L.), soybean, and fallow, affects the quantity and quality (i.e., C:N ratio) of residues returned to the soil and, therefore, resulting soil C and N levels. Furthermore, different C and N forms can be considered part of active or inactive soil fractions; for example, SOC and TN are thought to be non-labile, while potentially mineralizable C and N and microbial biomass C and N are more dynamic and can change seasonally, and are small portions of total SOM (Wang and Sainju, 2014).

Independent Effects of Region and Soil Depth

Averaged across soil depth and yield area, soil EC, C_{frac}, and N_{frac} differed ($P < 0.05$; Table 10) among regions. Across the 2014 and 2015 soybean growing seasons, soil EC in the top 20 cm ranged from 0.08 dS m^{-1} in Region 5 to 0.16 dS m^{-1} in Region 2 (Figure 10). However, soil EC was greater ($P < 0.05$) in Region 2 than that in all other regions. Furthermore, soil EC was greater in Regions 4 and 6, which did not differ, than in Regions 1 and 7, which also did not differ, while soil EC in Regions 3 and 5, which did not differ, was lowest among all regions. Soil EC values measured in this study would all be considered as non-saline (i.e., soil EC < 1.1 dS m^{-1}) and, therefore, were lower than the threshold for any expected yield reduction in a variety of crops across all soil textures due to an excessive salt concentration (NRCS, 2014f). Soil C_{frac} in the top 20 cm ranged from 0.44 g g^{-1} in Region 7 to 0.56 g g^{-1} in Region 6. Soil C_{frac} was greatest ($P < 0.05$) in Regions 1, 3, 5 and 6, which did not differ, and was lowest ($P < 0.05$) in Regions 2, 4, and 7, which did not differ (Figure 10). Soil N_{frac} in the top 20 cm ranged from 0.05 g g^{-1} in Region 7 to 0.08 g g^{-1} in Region 1. Soil N_{frac} was greatest ($P < 0.05$) in Regions 1, 3, and 6 (Figure 10). Additionally, soil N_{frac} was greater ($P < 0.05$) in Region 5 than in Regions 2 and 7, but did not differ from that in Region 4.

For the 2014 and 2015 soybean growing seasons, averaged across region and yield area, soil BD, pH, EC, and SOM, K, Ca, Mg, and Na contents differed ($P < 0.05$; Table 10) between soil depths. As would be expected, BD, pH, and Ca, Mg, and Na contents were greater ($P < 0.05$) in the 10- to 20-

cm depth than the top 10 cm (Figures 11, 12). Bulk density was 10% greater in the 10- to 20-cm depth than in the top 10 cm. Soil BD is known to increase with depth as a result of a reduction in SOM, aggregation, root presence, and less pore space (NRCS, 2014c). Averaged across region and yield area, soil pH (Figure 11) and Ca, Mg, and Na contents (Figure 12) were, on average, 13% greater in the 10- to 20-cm depth than the top 10 cm. Soil pH and Ca, Mg, and Na contents would be expected to be lower close to the soil surface, where a greater amount of leaching occurs as rainfall and/or irrigation water infiltrates. In areas with large amounts of rainfall, such as Arkansas, soluble salts can accumulate in the subsoil, as opposed to near the surface, as a result of leaching (NRCS, 2014f). As expected, averaged across region and yield area, SOM content was greater ($P < 0.05$; Figure 11) in the top 10 cm (24.6 Mg ha^{-1}) than in the 10- to 20-cm depth (20.4 Mg ha^{-1}). Although the long history of cultivated agriculture in eastern Arkansas has resulted in generally low SOM concentrations in the top 10 to 15 cm of most cultivated agricultural soils (Amuri et al., 2008), fields would still generally have a greater SOM content in the upper part of the soil profile due to the repeated addition of residues and increased root concentration near the soil surface. Furthermore, SOM generally increases where biomass production is greater and where organic material additions occur (NRCS, 2014e). Soil EC (Figure 11) and extractable soil K (Figure 12) were also greater ($P < 0.05$) in the top 10 cm than in the 10- to 20-cm depth. Since EC is a measure of soluble salts, and K, in addition to Ca, Mg, and Na, are soluble salts, it was expected that soil EC and extractable soil K would be greater deeper in the profile. However, in soils with a restrictive layer, such as a plow pan or claypan, both of which are frequently present in agricultural fields in Arkansas, salts may accumulate near the surface since leaching from the root zone is limited (NRCS, 2014f).

Multiple Regression Analyses

Similar to results presented above, parameter inputs (i.e., elemental contents) for multiple regression analyses were inherently related to measured soil BD. Therefore, regression analyses were performed with and without BD, whereby results did not change. Therefore, the results presented below reflect multiple regression analyses including soil BD as a predictor variable in the original model before parameter reduction. Furthermore, in order to avoid collinearity with sand and clay, silt content was excluded as a model predictor. Soil C:N ratio and C_{frac} and N_{frac} were also excluded as initial model predictors since each was derived from one or more predictor variables already included in the initial analysis before parameter reduction.

Although studies have been conducted using regression analyses to relate row spacing and plant population to yield (De Bruin and Pedersen, 2008), as well as to relate weather variables and general historical technological innovations to yield (Tannura et al., 2008), there have been no studies that have examined a suite of soil properties in order to explain soybean yield variations in the mid-southern US. Across the 2014 and 2015 soybean growing seasons, and averaged across soil depths and all five replicate soil sample points, soil EC, extractable soil Mg and S, and TC contents, and Shannon's diversity (Div) were significant ($P < 0.1$) in the final model and collectively explained 50% of the variation in soybean yield for the dataset combined across yield areas ($P < 0.0001$; Table 12). Extractable soil Mg explained more than twice the proportion of the model sum of squares (38%) than the other significant model parameters (Table 12). There was no pattern in the residuals that would suggest a trend which may be indicative of the existence of a better model.

Combined across years and averaged across both soil depths and all five replicate soil sample points, extractable soil P, Mg, and Fe, and TC contents were significant ($P < 0.1$) in the final model for the average-yield areas only ($P = 0.0017$; Table 12) and collectively explained 51% of the variation in soybean yield. Extractable soil Mg and Fe explained a similar proportion of the model sum of squares (20 and 21%, respectively) than the other significant model parameters (Table 12). Similar to the combined model, no pattern was obvious in the residuals that would have invalidated the model. When the model for the combined dataset was applied to the average-yield dataset, the overall model was significant (P = 0.0183; R^2 = 0.44), but soil EC and Div were not significant (P > 0.1) in the model.

Combined across years and averaged across both soil depths and all five replicate soil sample points, clay, EC, and extractable soil K, Ca, S, Fe, Zn, and B contents were significant (P < 0.1) in the final model for the high-yield areas only (P = 0.0004; Table 12) and collectively explained 73% of the variation in soybean yield. Extractable soil Ca explained the greatest proportion of the model sum of squares (37%) than the other significant model parameters (Table 12). Similar to the combined and average-yield-area regression equations, there was no pattern in the residuals. When the model for the combined dataset was applied to the high-yield-area dataset, similar to that for the average-yield area, the overall model was significant (P = 0.0005; R^2 = 0.61), but soil TC content and Div were not significant (P > 0.1) in the model.

There was some parameter estimate overlap among regression equations for the three datasets. The parameter estimate for extractable soil Mg for the combined dataset fell within the 95% confidence interval (CI) for that for the average-yield dataset (Table 12). Similar to soil Mg, the parameter estimate for TC for the average-yield dataset fell within the 95% CI for that for the combined dataset (Table 12). The parameter estimate for extractable soil Fe for the high-yield dataset fell within the 95% CI for that for the average-yield dataset (Table 12). Additionally, the parameter estimates for the intercept for the average- and high-yield datasets fell within the 95% CI for the combined datasets (Table 12).

Though there was some parameter estimate overlap among dataset equations, average soil predictor variables in the top 20 cm common to each of the three derived multiple regression models were inconsistent. No soil property evaluated in this field study was significant in the final model for all three datasets investigated (Table 12). Clay, as the only soil physical property, was positive and significant in the final model of only one of the three datasets (i.e., the high-yield area dataset; Table 12). Similarly, extractable soil P (positive), K (negative), Ca (negative), Zn (negative), and B (positive) contents, as soil chemical properties, and Div (positive), as the only soil biological property, were significant in the final model of only one of the three datasets (Table 12). Extractable soil Mg (negative) and TC (positive) contents were significant in the final models for both the combined and average-yield-area datasets, while soil EC (positive) and extractable soil S (negative) content were significant in the final models for both the combined and high-yield-area datasets (Table 12). Of the essential plant macro-nutrients that were significant in any dataset's model (i.e., P, K, Ca, and Mg), only extractable soil P was directly related to yield, which would be expected, while extractable soil K, Ca, and Mg were inversely related to yield, which was somewhat unexpected, indicating as these nutrient contents increased, soybean yield decreased. In contrast to extractable soil K, Ca, and Mg, and as might be expected, both TC and Div were both directly related to yield, indicating that as TC and Div increased, soybean yield increased as well. Extractable soil Fe (negative) was significant in the final models for both the average- and high-yield-area datasets (Table 12), which is somewhat counter-intuitive since Fe is generally considered ubiquitous in the Alfisols and highly weathered Ultisols of the mid-southern and southern US. However, the negative correlation between extractable soil Fe and yield suggests that reducing conditions from wetter soil may indicate fewer moisture limitations on plant growth and productivity. Individually, soil BD was weakly correlated (0.08, 0.15, and -0.04 for the combined, average, and high-yield areas, respectively) with yield across the 2014 and 2015 soybean growing seasons.

Based on the results of multiple regression analyses, it appears that the combined model would be insufficient to even reasonably predict soybean yield from a series of soil chemical and biological soil properties. In addition, it appears that there are other factors (i.e., soil, agronomic, and/or environmental) that would have to be included before a general model, one that does not need to account for yield history, would be useful. However, it is clear that a suite of soil properties, including physical and chemical, but not biological parameters, is more than reasonably adequate ($R^2 = 0.73$) to predict soybean yield across high-yielding soybean environments, such as those submitted to Arkansas' "Grow for the Green" soybean yield contest.

Microbiological Results

General Property Variations

Functional diversity on EcoPlates™ is based on the carbon substrate utilization pattern (Preston-Mafham et al., 2002), and across all regions and yield areas, soil microbiological properties measured on EcoPlates™ from samples collected from the top 10 cm during the 2014 and 2015 soybean growing seasons varied in range and magnitude (Table 13). For both yield areas, growth rate ranged from a low of 0.023 Abs d^{-1} (Table 13) to a high of 0.082 Abs d^{-1}, which were both measured from samples collected in Region 7. Shannon's diversity ranged from a low of 2.21, which corresponded to an E_H of 0.64, to a high of 3.25, which corresponded to an E_H of 0.95, which were both measured from samples collected in Region 5. These H values are below those reported by Yu et al. (2015), where H averaged 3.5 across treatments in mulberry (*Morus* spp.) production on a clay-loam soil in China. However, H measured across treatments by Janniche et al. (2012) in agriculturally affected groundwater (2.97 to 3.04) was within the range measured in this study. Simpson's diversity ranged from a low of 6.22 (Table 13), which corresponded to an E_D of 0.20, measured in Region 4 to a high of 20.1, which corresponded to an E_D of 0.65, measured in Region 7. While the calculation for Shannon's diversity index weights rare species (i.e., substrate utilization) more than common ones, the Simpson's diversity calculation weights common species more and rarer species relatively less (Janniche et al., 2012). Furthermore, functional diversity on EcoPlates™ is based on the carbon substrate utilization pattern (Preston-Mafham et al., 2002).

Treatment Effects on Microbiological Properties

For the 2014 and 2015 soybean growing seasons, averaged across yield areas, growth rate, and H, E_H, D, and E_D differed ($P < 0.05$; Table 14; Figure 13) among regions. Growth rate was greatest in Region 7, which did not differ ($P > 0.05$) from the growth rate measured in Region 4. Averaged across yield area, growth rate in Region 4 also did not differ ($P > 0.05$; Figure 13) from the growth rate measured in Regions 1, 2, and 6, which did not differ ($P > 0.05$) from the growth rate in Regions 3 and 5. Region 7 encompasses the entire western portion of Arkansas (Figure 1). Deng et al. (2011) reported that enhanced levels of soil nutrients, as well as rhizosphere secretions, may result in greater growth rates of plants, which leads to increased nutrient cycling rates. In addition, these growth rates are not measures of "growth" per se, but rather AWCD development is linked to cellular respiration of the specific carbon substrates on the EcoPlate™ (Preston-Mafham et al., 2002).

Averaged across yield area, H and E_H were greater ($P < 0.05$; Figure 13) in Region 7 than in all other regions. Shannon's diversity and E_H were greater ($P < 0.05$) in Regions 1, 5, and 6 than in Region 2, which did not differ ($P > 0.05$; Figure 13) from H and E_H in Regions 3 and 4. Similar to H and E_H, D and E_D were greater ($P < 0.05$) in Region 7 than in all other regions. Simpson's diversity and E_D were greater ($P < 0.05$) in Region 6 than in Region 2, but did not differ ($P > 0.05$; Figure 13) from D and E_D in Regions 1, 3, 4, and 5. Since both E_H and E_D are simple calculations based on their respective diversities, it was expected that the same differences that occurred among regions with diversity would occur for evenness as well. The boundaries of the regions of the "Grow for the Green" yield contest are somewhat arbitrary and contain large variations in soil-forming factors (i.e., differences in soil parent material, climate, topography, etc.) within and across regions. Therefore, regional differences may be random, and perhaps do not reflect consistencies within and among regions. Notwithstanding, as no previous studies have evaluated differences among regions in the "Grow for the Green" yield contest, these results may provide a framework for characterizing the major soybean-yield-influencing soil microbial parameters across regions in Arkansas.

As hypothesized, across the 2014 and 2015 soybean growing seasons and averaged across regions of the "Grow for the Green" yield contest, H and E_H were greater ($P < 0.05$; Table 14; Figure 14) in high- than in average-yield areas. Similar to differences among regions, it was expected that the same differences that occurred between yield areas with diversity would also occur for evenness. Since it can be assumed that management for contest purposes included application of additional fertilizer, this may explain the greater diversity in high-yield areas. Soil microbial diversity and community structure are affected by different management practices (Girvan et al., 2003), and the influence of fertilizer applications on diversity is complex, perhaps related to fertilizer type, application rate and placement, and soil texture (Yu et al., 2015). Studying mulberry growth in a clay-loam soil in China, Yu et al. (2015) stated that the soil physio-chemical characteristics (e.g., SOM, soil nutrient content, and pH) were responsible for governing microbial functional diversity. Yu et al. (2015) also cited studies that reported appropriate fertilizer management, including the application timing, type, and quantity, can increase microbial functional diversity; subsequently, functional diversity may induce changes in resulting substrate utilization. However, Girvan et al. (2003) reported biodiversity can be depleted by excessive application of fertilizer and pesticide use, and that community compositions are determined primarily by the soil environment rather than different management practices.

Multiple potential reasons may explain the lack of differences ($P > 0.05$) in growth rate between yield areas. One explanation is that the growth rates measured in this study are culture-based; thus, the organisms are extracted from their natural environment and may not be culturable or are inactive (Girvan et al., 2003; Muniz et al., 2014). Furthermore, growth rates are tested under well-defined conditions that do not mimic in-situ conditions (Preston-Mafham et al., 2002), and collection to processing times were different for samples collected in 2014 and 2015. Additionally, the growth rates measured in this study are "community" growth rates based on all substrates on EcoPlates™, and some species may antagonize or synergistically interact with each other (Muniz et al., 2014; Preston-Mafham et al., 2002). Some specific substrates may be more informative than others, and the combination of several approaches (i.e., other ways to evaluate the data such as principal component analysis; PCA) may be necessary (Girvan et al., 2003; Preston-Mafham et al., 2002; Yu et al., 2015).

Principal Component Analysis

For samples collected in high-yield areas in 2014 and 2015, principal components (PC) 1 and 2 explained 19.4 and 8.1% (Table 15), respectively, of the variation in the Ecoplate™ results, which corresponded to eigenvalues of 6.01 and 2.53, respectively. The greatest eigenvector (0.2899; Table 15), which is a measure of PC loading, or the contribution of each factor, for PC1 was α-D-lactose, a carbohydrate. Other substrates that had eigenvectors greater than 0.26 for PC1 were the amino acid glycl-L-glutamic acid, the carbohydrate D-xylose, the carboxylic and ketonic acids α-ketobutyric acid and γ-hydroxybutyric acid, and the phenolic compound 2-hydroxy benzoic acid. For PC2, the greatest eigenvector (0.3350; Table 15) was the ketonic pyruvic acid methyl ester, while other eigenvectors greater than 0.27 were the carbohydrates D-cellobiose, N-acetyl-D-glucosamine, glucose-1-phosphate, and glycogen, a polymer. Every compound group represented (Tables 6 and 15) on Ecoplates^{TM}, except the amines and amides, contributed to the PCs that explained the most variation in substrate utilization for high-yield areas.

In average-yield areas in 2014 and 2015, 22.2 and 7.6% (Table 16) of the variation in substrate utilization on Ecoplates^{TM} were explained by PCs 1 and 2, respectively, which corresponded to eigenvalues of 6.89 and 2.37, respectively. D-xylose, a carboyhydrate, had the greatest eigenvector (0.3089) for PC1, and carbohydrates α-D-lactose and i-erythritol, amino acids L-threonine and glycl-L-glutamic acid, the polymer α-cyclodextrin, and the phenol 2-hydroxy benzoic acid all had eigenvectors greater than 0.26 (Table 16). The greatest eigenvector for PC2 (0.4162; Table 16) was D-cellobiose, a carbohydrate, while other eigenvectors greater than 0.25 were the carbohydrates D-mannitol, glucose-1-phosphate, β-methyl-D-glucoside, and the polymer Tween® 80. In contrast to the factors contributing to PCs 1 and 2 in the high-yield areas, the greatest factors contributing to PCs 1 and 2 in the average-yield areas were mainly carbohydrates, except for two amino acids (i.e., L-threonine and glycl-L-glutamic acid), one phenolic (2-hydroxy benzoic acid), and two polymers (α-cyclodextrin and Tween® 80; Table 16). The average-yield areas did not have a large proportion of variation on Ecoplates^{TM} explained by carboxylic and ketonic acids, and similar to the high-yield areas, amines and amides.

Although carbohydrates are the most represented substrate group on Ecoplates^{TM} (i.e., 10 of 31), only two (D,L-α-glycerol phosphate and D-galactonic acid γ-lactone) did not have eigenvectors greater than 0.25 for PCs 1 and 2 for high- and average-yield areas. Furthermore, both of the amines and amides, half of the carboxylic and ketonic acids (D-galacturonic acid, itaconic acid, and D-malic acid), one of two phenolics (4-hydroxy benzoic acid), one polymer (Tween® 40), and four of six amino acids (L-arginine, L-asparagine, L-phenylalanine, and L-serine) did not have eigenvectors greater than 0.25 for PCs 1 and 2 for high- and average-yield areas. Factors with eigenvectors greater than 0.25 in common to PCs 1 and 2 for high- and average-yield areas (Tables 15 and 16) were α-D-lactose, glycl-L-glutamic acid, D-xylose, 2-hydroxy benzoic acid, D-cellobiose, and glucose-1-phosphate. However, factors with eigenvectors greater than 0.25 present only in PCs 1 or 2 for high-yield areas (Tables 6 and 15) included one carbohydrate, three carboxylic and ketonic acids, and one polymer, while those factors present only in PCs 1 or 2 for average-yield areas (Tables 6 and 16) included three carbohydrates, one amino acid, and two polymers.

The carbohydrate with a large eigenvector (i.e., > 0.25) in PC 2 of only high-yield areas was N-acetyl-D-glucosamine, a carbohydrate that polymerizes into chitin, which exists in many fungi and in the exoskeleton of many invertebrates (Paul and Clark, 1996). The ketonic acid that had a large eigenvector in PC 1 of high-yield areas was α-ketobutyric acid, one of the products of the catabolism of threonine, an amino acid that is another substrate on Ecoplates™ (Froliks et al., 2010). Another pathway for α-ketobutyric acid is eventually entering the citric acid cycle (Froliks et al., 2010). One carboxlyic acid that had a large contribution to PC 1 of high-yield areas was γ-hydroxybutyric acid, a derivative of butyric acid, also known as butanoic acid or BTA, and a product of anaerobic fermentation (Bach et al., 2009). The other carboxylic acid that had a large contribution to PC 2 of high-yield areas was pyruvic acid methyl ester, the ester of pyruvic acid, also an intermediate in the citric acid cycle (Froliks et al., 2010). The polymer that had a large eigenvector in PC 2 of high-yield areas was glycogen, a polysaccharide of glucose and main storage entity of glucose in fungi (Berg et al., 2002).

Carbohydrates that had a large eigenvector appearing only in PCs 1 or 2 in average-yield areas were α-D-lactose, D-mannitol, and β-methyl-D-glucoside. The disaccharide of glucose and galactose is α-D-lactose, while D-mannitol is the sugar alcohol of the simple sugar D-mannose (Froliks et al., 2010). One variant of methyl glucoside, β-methyl-D-glucoside, is a monosaccharide and a variation of the product of the reaction of glucose and methanol (Helferich and Schafer, 1926). The amino acid that had a large eigenvector in PC 1 in average-yield areas was L-threonine, used in the synthesis of proteins and also synthesized from *Escherichia coli* (Rais et al., 2001). The polymers that had a large eigenvector occurring only in PCs 1 or 2 in average-yield areas were α-cyclodextrin, an oligosaccharide (Kurkov and Loftsson, 2013) and Tween® 80, also known as polysorbate 80, a polymer of ethylene oxide (Chou et al., 2005).

Results indicated that soil microbial communities in high-yield areas were able to utilize a greater variety of substrate types, while communities in average-yield areas utilized mostly carbohydrates. Greater levels of versatility indicate that soil microbial communities are more able to capitalize on various natural and anthropogenic compounds present in soil (Lyons and Dobbs, 2012), and thus are potentially more active in high-yield areas. Although results of the growth rate analysis did not illuminate differences between yield areas, results of PCA, combined with the diversity results, demonstrate that perhaps a greater abundance and relative proportion of certain bacterial and fungal individuals within soil microbial communities may contribute to greater yields. Additional analysis of the mechanisms underlying plant interactions with various soil microbes during growth in the field would perhaps further characterize the communities that contribute to greater soybean growth and resulting yield in the field.

Conclusions and Implications

Averaged across the 2014 and 2015 soybean growing seasons, measured soil properties differed between high- and average-yield areas and between soil depths among soybean-growing regions of Arkansas. However, soil OM was unexpectedly greater in average-yield areas, but only in one region, and did not differ between yield areas in other regions. Total soil C and N content differences were inconsistent, as contents were greater in some high-yield areas than in average-yield areas in some regions, but the opposite also occurred in other regions. Extractable soil P was greater in the high-yielding areas compared to the average-yielding areas in at least three regions. Unexpectedly, there were no differences between yield areas for extractable soil K and soil pH. It was hypothesized that yield would be limited by surface textures that are dominantly sandy or clayey, but sand content was greater in high-yield areas in one region and, similar to SOM, was not different in other regions. However, as expected, the average-yield areas had a greater clay content than high-yield areas in one region, but similar to SOM and sand, clay content did not differ between yield areas in other regions.

Based on multiple regression analyses, numerous soil physical, chemical, and biological properties in the top 20 cm were significantly related to soybean yield. However, little soil property consistency existed in final multiple regression models when the high- and average-yield-area datasets were analyzed separately or when the two datasets were combined. Results showed that soybean yield variations were most explained for the high-yield-area dataset and less explained for the average-yield-area and the combined datasets.

Based on EcoPlate™ substrate utilization, averaged across yield areas, microbial growth rate, and H, E_H, D, and E_D differed among regions. Additionally, averaged across regions, H and E_H were greater in high- than in average-yield areas. Results of PCA demonstrated a variety of C substrates contributed to the variation in overall substrate utilization, but amines and amides did not greatly contribute to the use in either yield area. In high-yield areas, a greater variety of C types was used, but in average-yield areas the greatest contributors were mostly carbohydrates.

Efforts to continually increase yields are important for not only matters regarding global population increases and subsequent intensification of food production, but are necessary to mitigate crop production expansion onto poorer quality soils, the use of which may decrease subsequent land capability and threaten environmental sustainability (Egli, 2008). Further, producers who understand the causes of spatial and temporal soybean yield variations within or across their fields may be better able to actualize site-specific management practices (Kaspar et al., 2004). The results of this study demonstrated that the soil environment plays a critical role in attainment of high soybean yields and that specific management of certain soil properties may unlock the key to achieving above-average soybean yields, with more frequent surpassing of the 6719 kg ha^{-1} (100 bu ac^{-1}) mark. Nevertheless, additional properties and factors, beyond those evaluated in this study, may need to be included for a more complete understanding of the soil environment that is associated with high-yielding soybean production.

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Table 1. Summary of the 2007 to 2012 "Grow for the Green" soybean yield contest results including the 1st- and 10th-place growers and county where the crop was harvested. For years 2011 and 2012, the contest was divided into three soybean-production categories: early season, full season, and double-cropped. Production system, variety, seeding rate, planting date, fertilizer, and soil texture data were provided by the grower. Rank and final yield were verified by the Arkansas Soybean Association (2015).

Year	**Rank**	**County**	**Production System**	**Variety**	**Seeding Rate/ha**†	**Planting date**	**Fertilizer**	**Soil Surface Texture**	**Final Yield (kg ha^{-1})**
2007	1st	Craighead	NA	Pioneer 94B73	395360	4/20	10-60-20	NA	6197
	10th	Desha	NA	Armor 47-F8	NA	NA	NA	NA	5026
2008	1st	Phillips	NA	USB 74B88	345940	5/27	NA	Silt loam	6300
	10th	Lonoke	NA	Armor 47-F8	350882	5/28	0-46-100	Silt loam	4275
2009	1st	Phillips	NA	Asgrow 4703	333585	4/29	NA	Silt loam	5887
	10th	Craighead	NA	Armor 47-F8	NA	5/19	NA	Silt loam	4125
2010	1st	Phillips	NA	Asgrow 4907	345940	4/1	40.9 kg K	Silt loam	6030
	10th	Phillips	NA	Pioneer 94M80	333585	4/5	27.2 kg K	Silt loam	4762
2011	1st	Poinsett	Early season	Pioneer 94Y70	336056	4/9	0-40-60 in fall; 45-40-40 in spring	Silt loam	6313
	10th	Clay	Full season	Pioneer 94Y70	442541	5/18	4540 kg poultry litter	Sandy loam	5383
2012	1st	Desha	Early season	Armor 4744	343469	4/1	112 kg ha^{-1} potash; 56 kg ha^{-1} urea	Buckshot	6376
	10th	Chicot	Early season	Pioneer 94Y70	395360	4/15	112 kg ha^{-1} potash	Loam	5986

† NA indicates not available.

Table 2. Summary of the 2013 "Grow for the Green" soybean yield contest data including the 1st- and 2nd-placed growers for each region and county where crop was harvested. 2013 was the first year the contest was broken into geographical regions. Variety, seeding rate, planting date, fertilizer, and soil texture data were provided by the grower. Rank and final yield verified by the Arkansas Soybean Association (2015).

Region	Rank	County	Variety	Seeding Rate/ha	Planting Date	Fertilizer	Soil Surface Texture	Final Yield (kg ha^{-1})
1	1st	Craighead	Pioneer 94Y70	370650	4/8	224 kg ha^{-1} potash	Fine sandy loam	5772
	2nd	Craighead	Pioneer 46T21	395360	4/20	NA	Silt loam	5634
2	1st	Clay	Pioneer 47T36	390418	5/25	0-30-90; 2 kg B	Fine sandy loam	5938
	2nd	Randolph	Pioneer 47T36	383005	5/25	69 kg ha^{-1} 0-46-0; 90 kg ha^{-1} 0-0-60; 91 kg poultry litter	Silt loam	5758
3	1st	Jackson	Pioneer 94Y23	383005	4/15	907 kg litter, potash	Sandy loam	6108
	2nd	Woodruff	Asgrow 4632	345940	5/18	0-36-72	Silt loam	6022
4	1st	Lonoke	Pioneer 94Y70	395360	4/25	336 kg ha^{-1} 0-18-36; 1814 kg poultry litter; 224 kg ha^{-1} urea	Silt loam	6339
	2nd	Arkansas	Asgrow 4633	316288	5/15	907 kg poultry litter	NA	6192
5	1st	Phillips	Asgrow 4533	296520	4/23	90 kg ha^{-1} potash	Silt loam	6262
	2nd	Phillips	Asgrow 4232	358295	4/17	NA	Silt loam	6152
6	1st	Desha	Asgrow 4632	420070	4/23	1361 kg poultry litter	NA	7232†‡
	2nd	Drew	Pioneer 93Y92	358295	4/24	112 kg ha^{-1} urea	Silt loam	6771†
7	1st	Pope	Pioneer 94Y70	370650	5/13	18-46-0, 1814 kg poultry litter	Silt loam	7044†
	2nd	Pope	Pioneer 94Y70	370650	5/13	10-46-0	Silt loam	6597

† Top 3 for the state. ‡ State record. § NA indicates not available.

Table 3. Summary of growers participating in the 2014 “Grow for the Green” yield contest sponsored by the Arkansas Soybean Promotion Board whose fields were soil sampled in fall 2014.

Region*	County	Site	Contest participant before 2014?	2013 Contest-reported Yield (kg ha^{-1})	Dominant Soil Series (Taxonomic Description) in High-yielding Area†	Soil Surface Texture
1	Craighead	1	Yes	5772	Dundee (Typic Endoaqualfs)	Fine sandy loam
	Poinsett	2	Yes	5324	Dundee (Typic Endoaqualfs)	Silt loam
2	Cross	1	Yes	5664	Arkabutla (Fluventic Endoaquepts)	Silt loam
	Cross	2	No	-	Crowley (Typic Albaqualfs)	Silt loam
3	Jackson	1	Yes	5773	Bosket (Mollic Hapludalfs)	Fine sandy loam
	Woodruff	2	Yes	6022	Wiville (Ultic Hapludalfs)	Fine sandy loam
4	Lonoke	1	No	-	Hebert (Aeric Epiaqualfs)	Silt loam
	Lonoke	2	Yes	6339	Rilla (Typic Hapludalfs)	Silt loam
5	Phillips	1	Yes	6011	Commerce (Fluvaquentic Endoaquepts)	Silt loam
	Monroe	2	Yes	6152	Dubbs (Typic Hapludalfs)	Silt loam
6	Drew	1	Yes	6771	Rilla (Typic Hapludalfs)	Silt loam
	Desha	2	Yes	7232	Hebert (Aeric Epiaqualfs)	Silt loam
7	Conway	1	No	-	Gallion (Typic Hapludalfs)	Silt loam
	Miller	2	No	-	Bossier (Aeric Epiaquerts)	Clay

† Data obtained from Official Soil Series Descriptions (2014) and Web Soil Survey (2014).

* The regions are as follows Region 1: Northeast Delta; Region 2: Northeast; Region 3: White River Basin; Region 4: Central and Grand Prairie; Region 5: East Central Delta; Region 6: Southeast Delta; Region 7: Western.

Table 4. Summary of growers participating in the 2015 "Grow for the Green" yield contest sponsored by the Arkansas Soybean Promotion Board whose fields were soil sampled in fall 2015.

Region*	County	Site	Contest participant before 2015?	2014 Contest-reported Yield (kg ha^{-1})	Dominant Soil Series in (Taxonomic Description) in High-yielding Area†	Soil Surface Texture
1	Craighead	1	Yes	6508	Dubbs (Typic Hapludalfs)	Silt loam
	Craighead	2	Yes	6564	Dundee (Typic Endoaqualfs)	Silt loam
2	Cross	1	Yes	5169	Arkabutla (Fluventic Endoaquepts)	Silt loam
	Cross	2	Yes	4465	Crowley (Typic Albaqualfs)	Silt loam
3	Jackson	1	No	-	Bosket (Mollic Hapludalfs)	Fine sandy loam
	Woodruff	2	Yes	6694	Wiville (Ultic Hapludalfs)	Fine sandy loam
4	Arkansas	1	No	-	Portland (Chromic Epiaquerts)	Silty clay
	Lonoke	2	Yes	6355	Rilla (Typic Hapludalfs)	Silt loam
5	Phillips	1	Yes	6456	Henry (Typic Fragiaqualfs)	Silt loam
	Phillips	2	No	-	Dundee (Typic Endoaqualfs)	Silt loam
6	Chicot	1	Yes	7526	Dundee (Typic Endoaqualfs)	Silt loam
	Desha	2	Yes	6760	Hebert (Aeric Epiaqualfs)	Silt loam
7	Conway	1	Yes	5053	Gallion (Typic Hapludalfs)	Silt loam
	Conway	2	No	-	Roxana (Aeric Epiaquerts)	Silt loam

† Data obtained from Official Soil Series Descriptions (2014) and Web Soil Survey (2014).

* The regions are as follows Region 1: Northeast Delta; Region 2: Northeast; Region 3: White River Basin; Region 4: Central and Grand Prairie; Region 5: East Central Delta; Region 6: Southeast Delta; Region 7: Western.

Table 5. Climate and geographical data for the Arkansas counties represented in the 2014 and 2015 soil sampling. Climate data is provided by the SRCC (2015) and are normals.

Year	Region*	County	MLRA[†]	Annual Precipitation (mm)	Air Temperature		
					July (°C)	January (°C)	Annual (°C)
2014	1	Craighead	131A	1225	26.8	2.1	15.1
		Poinsett	131A	1288	26.8	2.6	15.3
	2	Cross	131A, 134	1225	26.9	3.1	15.6
	3	Jackson	131A	1256	27.3	2.7	15.6
		Woodruff	131A	1251	27.7	2.6	16.0
	4	Lonoke	131B, 131D	1234	27.3	5.2	16.9
	5	Phillips	131A, 134	1291	28.1	4.7	17.0
		Monroe	131A, 134	1230	27.3	3.8	16.1
	6	Drew	131B, 131D	1358	27.8	6.3	17.6
		Desha	131B	1363	28.1	5.8	17.2
	7	Conway	118A	1267	27.0	3.4	15.5
		Miller	131C	1261	27.9	6.6	17.7
2015	1	Craighead	131A	1225	26.8	2.1	15.1
	2	Cross	131A,134	1225	26.9	3.1	15.6
	3	Jackson	131A	1256	27.3	2.7	15.6
		Woodruff	131A	1251	27.7	2.6	16.0
	4	Arkansas	131B	1268	27.5	4.3	16.5
		Lonoke	131B, 131D	1234	27.3	5.2	16.9
			131A, 134				
	5	Phillips	131A	1291	28.1	4.7	17.0
	6	Chicot	131B	1363	28.1	5.8	17.2
		Desha	118A	1363	28.1	5.8	17.2
	7	Conway		1267	27.0	3.4	15.5

[†] Major Land Resource Area (2014): 118A: Arkansas Valley and Ridges, Eastern Part; 131A: Southern Mississippi River Alluvium; 131B: Arkansas River Alluvium; 131C: Red River Alluvium; 131D: Southern Mississippi River Terraces; 134: Southern Mississippi Valley Loess.

* The regions are as follows Region 1: Northeast Delta; Region 2: Northeast; Region 3: White River Basin; Region 4: Central and Grand Prairie; Region 5: East Central Delta; Region 6: Southeast Delta; Region 7: Western.

Table 6. Carbon substrates, replicated three times, on Ecoplates™ (Zak et al., 1994; Biolog, 2007).

Well #	Compound type	Compound
7	Carbohydrates	D-cellobiose
8		α-D-lactose
9		β-methyl-D-glucoside
10		D-xylose
11		i-erythritol
12		D-mannitol
13		N-acetyl-D-glucosamine
15		Glucose-1-phosphate
16		D,L-α-glycerol phosphate
17		D-galactonic acid γ-lactone
31	Amines and amides	Phenylethylamine
32		Putrescine
2	Carboxylic and	Pyruvic acid methyl ester
18	ketonic Acids	D-galacturonic acid
21		γ-hydroxybutyric acid
22		Itaconic acid
23		α-ketobutyric acid
24		D-malic acid
19	Phenolics	2-hydroxy benzoic acid
20		4-hydroxy benzoic acid
3	Polymers	Tween 40
4		Tween 80
5		α-cyclodextrin
6		Glycogen
25	Amino acids	L-arginine
26		L-asparagine
27		L-phenylalanine
28		L-serine
29		L-threonine
30		Glycl-L-glutamic acid

Table 7. Summary of minimum, maximum, and mean yields for average-yield and high-yield areas soil sampled from the seven regions in the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Values are kg ha^{-1} and are rounded.

	Region						
Yield Area	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Average-yield							
Minimum	4938	2688	3360	3359	3024	3837	3024
Maximum	5859	5106	5174	5174	5039	6585	4031
Mean	5505	4216	4603	4300	3959	5511	3779
High-yield							
Minimum	5375	2822	5241	4166	3359	5416	4435
Maximum	6508	5711	6355	6328	6070	7324	5053
Mean	6063	4663	5926	5378	5243	6386	4749

Table 8. Summary of minimum and maximum values for soil properties measured from the 0 to 10 cm depth from high- and average-yield areas for the seven regions in the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Values are rounded.

Soil Property†	Region						
	1	2	3	4	5	6	7
BD	0.87-1.42	0.92-1.34	1.17-1.48	0.82-1.38	0.96-1.41	1.08-1.34	1.13-1.48
Sand	0.05-0.68	0.01-0.61	0.09-0.57	0.11-0.74	0.10-0.78	0.13-0.78	0.03-0.79
Silt	0.14-0.58	0.24-0.81	0.27-0.82	0.17-0.73	0.13-0.78	0.13-0.72	0.16-0.58
Clay	0.05-0.49	0.08-0.43	0.08-0.18	0.09-0.25	0.08-0.40	0.06-0.29	0.05-0.60
pH	5.5-7.5	5.5-8.2	5.2-7.8	5.4-7.1	5.0-7.3	5.2-7.8	4.7-8.3
EC	0.07-0.16	0.07-0.44	0.05-0.18	0.09-0.27	0.07-0.21	0.05-0.22	0.06-0.19
SOM	14.8-27.8	17.3-42.0	11.3-28.0	14.8-29.4	12.4-46.6	10.8-36.6	11.7-47.3
P	17-121	15-191	24-176	16-262	44-180	29-247	15-238
K	51-524	55-293	52-354	90-254	60-431	61-258	82-450
Ca	0.6-2.1	0.7-3.2	0.4-1.4	0.8-3.7	0.7-3.8	0.7-2.9	0.4-5.4
Mg	73-275	137-294	54-216	81-610	95-644	98-513	112-1132
S	5-19	10-98	6-20	8-60	6-30	84-29	7-33
Na	8-59	12-98	5-22	9-130	8-81	16-55	10-110
Fe	159-388	165-638	118-363	128-638	181-521	161-472	153-514
Mn	37-287	48-285	51-543	35-401	80-500	43-324	34-180
Zn	2-16	1-15	2-7	1-188	2-336	2-182	2-15
Cu	0.6-2.0	0.7-2.6	1.1-3.9	0.5-3.7	1.2-8.6	1.3-13.6	0.7-5.8
B	<0.1-0.8	<0.1-1.6	<0.1-0.5	0.1-2.9	0.1-3.3	0.2-2.9	0.1-2.6
TC	6.3-19.3	3.7-15.3	5.8-16.3	5.3-13.1	3.7-23.5	3.6-16.2	5.1-20.7
TN	0.8-2.0	0.6-1.7	0.9-1.8	0.7-1.6	0.6-2.3	0.5-2.2	0.8-2.0
C:N	3.8-12.4	4.5-11.2	4.6-9.7	6.0-9.3	6.1-11.2	5.4-10.7	4.7-12.1
C_{frac}	0.35-0.97	0.14-0.64	0.31-0.90	0.22-0.68	0.17-1.10	0.17-0.85	0.18-0.60
N_{frac}	0.05-0.11	0.02-0.07	0.05-0.11	0.03-0.08	0.03-0.11	0.03-0.09	0.02-0.10

†Units and abbreviations are as follows: BD (bulk density), g cm^{-3}; Sand, Silt, Clay, C_{frac} (C fraction in organic matter), N_{frac} (N fraction in organic matter), g g^{-1}; EC (electrical conductivity), dS m^{-1}; SOM (organic matter), Ca, TC (total C), TN (total N), Mg ha^{-1}; P, K, Mg, S, Na, Fe, Mn, Zn, Cu, B, kg ha^{-1}.

Table 9. Summary of minimum and maximum values for soil properties measured from the 10 to 20 cm depth from high- and average-yield areas for the seven regions in the “Grow for the Green” yield contest across Arkansas in 2014 and 2015. Values are rounded.

Soil	**Region**						
Property[†]	**1**	**2**	**3**	**4**	**5**	**6**	**7**
BD	1.24-1.58	1.16-1.49	1.23-1.61	1.15-1.50	1.20-1.51	1.19-1.50	1.17-1.59
Sand	0.01-0.65	0.01-0.29	0.06-0.59	0.09-0.40	0.01-0.31	0.10-0.41	0.02-0.77
Silt	0.14-0.77	0.56-0.80	0.25-0.73	0.49-0.75	0.49-0.78	0.49-0.70	0.15-0.72
Clay	0.07-0.34	0.14-0.25	0.09-0.35	0.02-0.28	0.09-0.49	0.03-0.33	0.06-0.59
pH	5.8-7.4	5.3-8.1	5.4-7.5	5.2-7.6	4.8-7.5	4.9-7.6	4.9-8.1
EC	0.06-0.18	0.06-0.46	0.03-0.13	0.08-0.23	0.04-0.18	0.03-0.42	0.03-0.25
SOM	11.7-26.4	8.8-36.5	9.6-27.2	12.7-31.7	7.2-35.0	11.1-30.1	6.8-82.9
P	9-118	9-195	13-134	6-197	18-132	13-99	5-83
K	41-341	38-193	32-245	54-220	61-374	56-237	65-401
Ca	0.7-2.2	0.9-3.2	0.4-1.5	1.0-4.3	0.9-4.3	0.9-2.4	0.3-8.1
Mg	87-347	158-337	30-184	111-742	86-777	101-819	86-1252
S	5-31	9-145	7-17	7-40	4-30	6-326	6-8
Na	7-50	15-136	6-26	16-156	9-100	20-121	8-163
Fe	147-430	205-658	117-368	127-592	194-627	154-629	164-535
Mn	31-341	52-370	61-568	27-423	64-471	38-341	34-231
Zn	1-8	<1-20	<1-6	<1-556	<1-160	<1-162	<1-7
Cu	0.7-2.7	0.7-4.7	0.7-4.7	0.4-3.4	1.4-5.7	1.0-5.4	0.7-5.8
B	<0.1-0.6	<0.1-1.1	<0.1-0.4	<0.1-2.5	<0.1-4.9	<0.1-1.6	<0.1-2.1
TC	4.2-17.1	4.4-25.7	3.4-20.4	2.4-15.1	4.0-19.4	6.3-16.8	2.8-23.8
TN	0.9-1.9	0.7-2.3	0.6-2.0	0.6-1.6	0.7-2.0	0.8-2.0	10-2.2
C:N	2.6-9.7	5.5-11.0	3.7-10.5	3.9-10.2	3.8-10.1	4.2-12.4	2.9-10.6
C_{frac}	0.24-1.05	0.18-1.28	0.21-1.27	0.15-0.93	0.20-2.03	0.29-1.33	0.06-1.40
N_{frac}	0.04-0.16	0.03-0.14	0.04-0.14	0.04-0.11	0.03-0.20	0.04-0.12	0.01-0.14

[†]Units and abbreviations are as follows: BD (bulk density), g cm^{-3}; Sand, Silt, Clay, C_{frac} (C fraction in organic matter), N_{frac} (N fraction in organic matter), g g^{-1}; EC (electrical conductivity), dS m^{-1}; SOM (organic matter), Ca, TC (total C), TN (total N), Mg ha^{-1}; P, K, Mg, S, Na, Fe, Mn, Zn, Cu, B, kg ha^{-1}.

Table 10. Analysis of variance summary of the effects of region (R), yield area (YA), soil depth (D), and their interactions on selected soil physical and chemical properties measured across Arkansas in 2014 and 2015.

Soil Property†	Source of Variation						
	R	YA	D	R*D	R*YA	YA*D	R*YA*D
	P						
BD	<0.01	0.01	<0.01	NS	<0.01	NS	NS
Sand	<0.01	NS‡	<0.01	<0.01	<0.01	NS	<0.01
Silt	<0.01	<0.01	<0.01	<0.01	<0.01	NS	<0.01
Clay	<0.01	<0.01	<0.01	<0.01	<0.01	NS	NS
pH	<0.01	NS	<0.01	NS	<0.01	NS	NS
EC	<0.01	NS	<0.01	NS	NS	NS	NS
SOM	<0.01	<0.01	<0.01	NS	<0.01	NS	NS
P	<0.01	0.04	<0.01	0.01	<0.01	NS	NS
K	<0.01	NS	<0.01	NS	<0.01	NS	NS
Ca	<0.01	<0.01	<0.01	NS	<0.01	NS	NS
Mg	<0.01	<0.01	<0.01	NS	<0.01	NS	NS
S	<0.01	0.04	NS	NS	<0.01	NS	NS
Na	<0.01	NS	<0.01	NS	<0.01	NS	NS
Fe	<0.01	NS	NS	NS	<0.01	NS	NS
Mn	<0.01	NS	<0.01	<0.01	NS	NS	NS
Zn	<0.01	NS	NS	<0.01	NS	NS	NS
Cu	<0.01	NS	NS	<0.01	NS	NS	NS
B	<0.01	<0.01	NS	NS	<0.01	NS	NS
TC	<0.01	0.03	<0.01	NS	<0.01	<0.01	NS
TN	0.02	NS	NS	NS	0.03	<0.01	NS
C:N	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NS
C_{frac}	<0.01	<0.01	NS	NS	NS	<0.01	NS
N_{frac}	<0.01	<0.01	<0.01	NS	NS	<0.01	NS

†Units and abbreviations are as follows: BD (bulk density), g cm^{-3}; Sand, Silt, Clay, C_{frac} (C fraction in organic matter), N_{frac} (N fraction in organic matter), g g^{-1}; EC (electrical conductivity), dS m^{-1}; SOM (organic matter), Ca, TC (total C), TN (total N), Mg ha^{-1}; P, K, Mg, S, Na, Fe, Mn, Zn, Cu, B, kg ha^{-1}.
‡Effects and interactions that are not significant at the 0.05 level are represented by NS (i.e., $P > 0.05$).

Table 11. Summary of sand and silt contents measured within regions in high- (HY) and average-yield areas (AY) at the 0 to 10 and 10 to 20-cm depth increments across Arkansas during the 2014 and 2015 soybean growing seasons.

		Depth/ Yield Area			
		0-10 cm		10-20 cm	
Soil Property	**Region**	**HY**	**AY**	**HY**	**AY**
Sand ($g\ g^{-1}$)	1	0.480 a†	0.433 ab	0.278 c	0.320 bc
	2	0.195 a	0.218 a	0.089 b	0.093 b
	3	0.301 b	0.355 a	0.367 a	0.350 a
	4	0.356 a	0.393 a	0.238 b	0.242 b
	5	0.359 a	0.193 b	0.155 b	0.103 b
	6	0.312 ab	0.425 a	0.249 b	0.247 b
	7	0.235 ab	0.316 a	0.158 b	0.219 b
Silt ($g\ g^{-1}$)	1	0.327 b	0.337 b	0.536 a	0.495 a
	2	0.608 b	0.635 b	0.711 a	0.711 a
	3	0.583 a	0.537 ab	0.469 b	0.475 b
	4	0.501 bc	0.442 c	0.617 a	0.591 ab
	5	0.522 b	0.563 b	0.627 a	0.566 b
	6	0.542 abc	0.438 c	0.625 a	0.602 ab
	7	0.483 ab	0.405 b	0.553 a	0.474 ab

†Means for a soil property with different letters within a region are significantly different at $\alpha = 0.05$.

Table 12. Summary of multiple regression coefficient estimates (Estimate), associated 95% confidence intervals (Lower, Upper), and percent sum of squares explained (%SS) in average-yield and high-yield areas, and all areas combined for soybean fields soil sampled across Arkansas in fall 2014 and 2015. Bolded values lie within the confidence interval for another regression equation. All models are significant at $P < 0.05$ and all variables within a model are significant at $P < 0.10$.

Variable	**Combined**†				**Average**‡				**High**‡			
in model	**Estimate**	**Lower**	**Upper**	**%SS**	**Estimate**	**Lower**	**Upper**	**%SS**	**Estimate**	**Lower**	**Upper**	**%SS**
Clay§	-	-	-	-	-	-	-	-	5982	378	11687	7
EC	9642	-421.8	19706	4	-	-	-	-	34340	16279	52402	22
P	-	-	-	-	13.9	2.23	25.6	13	-	-	-	-
K	-	-	-	-	-	-	-	-	-6.09	-11.3	-0.89	9
Ca	-	-	-	-	-	-	-	-	-1323	-1862	-783	37
Mg	**-3.81**	-5.06	-2.57	38	-2.28	-3.81	-0.76	20	-	-	-	-
S	-59.2	-94.8	-23.7	11	-	-	-	-	-122	-177	-67.2	31
Fe	-	-	-	-	-6.52	-10.8	-2.21	21	**-2.84**	-5.73	0.05	6
Zn	-	-	-	-	-	-	-	-	-22.0	-37.6	-6.44	12
B	-	-	-	-	-	-	-	-	1993	699	3286	15
TC	180	74.0	286	12	**162**	35.6	290	15	-	-	-	-
Div	2891	623	5158	7	-	-	-	-	-	-	-	-
Intercept	-4059	-10670	2550		**4839**	3174	6504		**5786**	4210	7361	
R^2		.50				.51				.73		

† $n = 56$

‡ $n = 28$

§ Units are as follows: Clay, g g^{-1}; EC (electrical conductivity), dS m^{-1}; P, K, Mg, S, Fe, Zn, B, kg ha^{-1}; Ca, TC (total C), Mg ha^{-1}; Div (Shannon's diversity).

Table 13. Summary of minimum and maximum values for soil microbiological properties measured on Ecoplates™ (Biolog, 2007) from high- and average-yield areas for the seven regions in the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Values are rounded.

	Region						
Property†	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Rate	0.036-0.061	0.042-0.061	0.039-0.063	0.033-0.070	0.037-0.065	0.042-0.062	0.023-0.082
Shannon's diversity	2.37-2.99	2.42-2.97	2.35-2.94	2.22-3.02	2.21-3.25	2.65-2.92	2.49-3.14
Shannon's evenness	0.69-0.87	0.70-0.86	0.68-0.85	0.65-0.88	0.64-0.95	0.77-0.85	0.73-0.92
Simpson's diversity	6.66-17.1	6.43-16.2	6.87-16.0	6.22-18.9	7.52-21.5	11.1-15.6	6.79-20.1
Simpson's evenness	0.21-0.55	0.21-0.52	0.22-0.52	0.20-0.61	0.24-0.69	0.36-0.50	0.22-0.65

† Units and abbreviations are as follows: Rate (Abs d^{-1}).

Table 14. Analysis of variance summary of the effects of region (i.e., 1 through 7 of the "Grow for the Green" yield contest), yield area (i.e., high- and average-yield), and their interaction on microbiological growth rate and Shannon's and Simpson's diversities measured on EcoPlates™ (Biolog, 2007) from samples collected across Arkansas in 2014 and 2015.

Variable	Region	Yield Area	R*YA
Growth rate†	< 0.001	NS‡	NS
Shannon's diversity	0.043	0.004	NS
Simpson's diversity	0.036	NS	NS

† Abs d^{-1}.

‡ Effects and interactions that are not significant at the 0.05 level are represented by NS (i.e., $P > 0.05$).

Table 15. Principal components (PC) 1 and 2, their respective eigenvalues (including percentage of variation explained), substrates loaded in each PC, substrate type, where C is carbohydrates, A is amino acids, K is carboxylic and ketonic acids, P is phenolics, and O is polymers, and respective eigenvector for substrate in each PC derived from measurements on Ecoplates™ (Biolog, 2007) from high-yield areas across Arkansas in 2014 and 2015. Values are rounded. Only substrates with an eigenvector > 0.26 for PC1 and > 0.27 for PC 2 are reported.

Component	Eigenvalue	Substrate	Type	Eigenvector
PC 1	6.01 (19.4%)	α-D-lactose	C	0.2899
		Glycl-L-glutamic acid	A	0.2747
		D-xylose	C	0.2688
		α-ketobutyric acid	K	0.2675
		2-hydroxy benzoic acid	P	0.2660
		γ-hydroxybutyric acid	K	0.2632
PC 2	2.53 (8.1%)	Pyruvic acid methyl ester	K	0.3350
		D-cellobiose	C	0.3208
		N-acetyl-D-glucosamine	C	0.3004
		Glucose-1-phosphate	C	0.2898
		Glycogen	O	0.2790

Table 16. Principal components (PC) 1 and 2, their respective eigenvalues (including percentage of variation explained), substrates loaded in each PC, substrate type, where C is carbohydrates, A is amino acids, O is polymers, and P is phenolics, and respective absolute value eigenvector for substrate in each PC derived from measurements on Ecoplates™ (Biolog, 2007) from average-yield areas across Arkansas in 2014 and 2015. Values are rounded. Only substrates with an eigenvector > 0.26 for PC1 and > 0.25 for PC 2 are reported.

Component	Eigenvalue	Substrate	Type	Eigenvector
PC 1	6.89 (22.2%)	D-xylose	C	0.3089
		α-D-lactose	C	0.3052
		L-threonine	A	0.2921
		i-erythritol	C	0.2829
		α-cyclodextrin	O	0.2676
		Glycl-L-glutamic acid	A	0.2667
		2-hydroxy benzoic acid	P	0.2648
PC 2	2.37 (7.6%)	D-cellobiose	C	0.4162
		D-mannitol	C	0.3680
		Glucose-1-phosphate	C	0.3353
		β-methyl-D-glucoside	C	0.3110
		Tween 80	O	0.2557

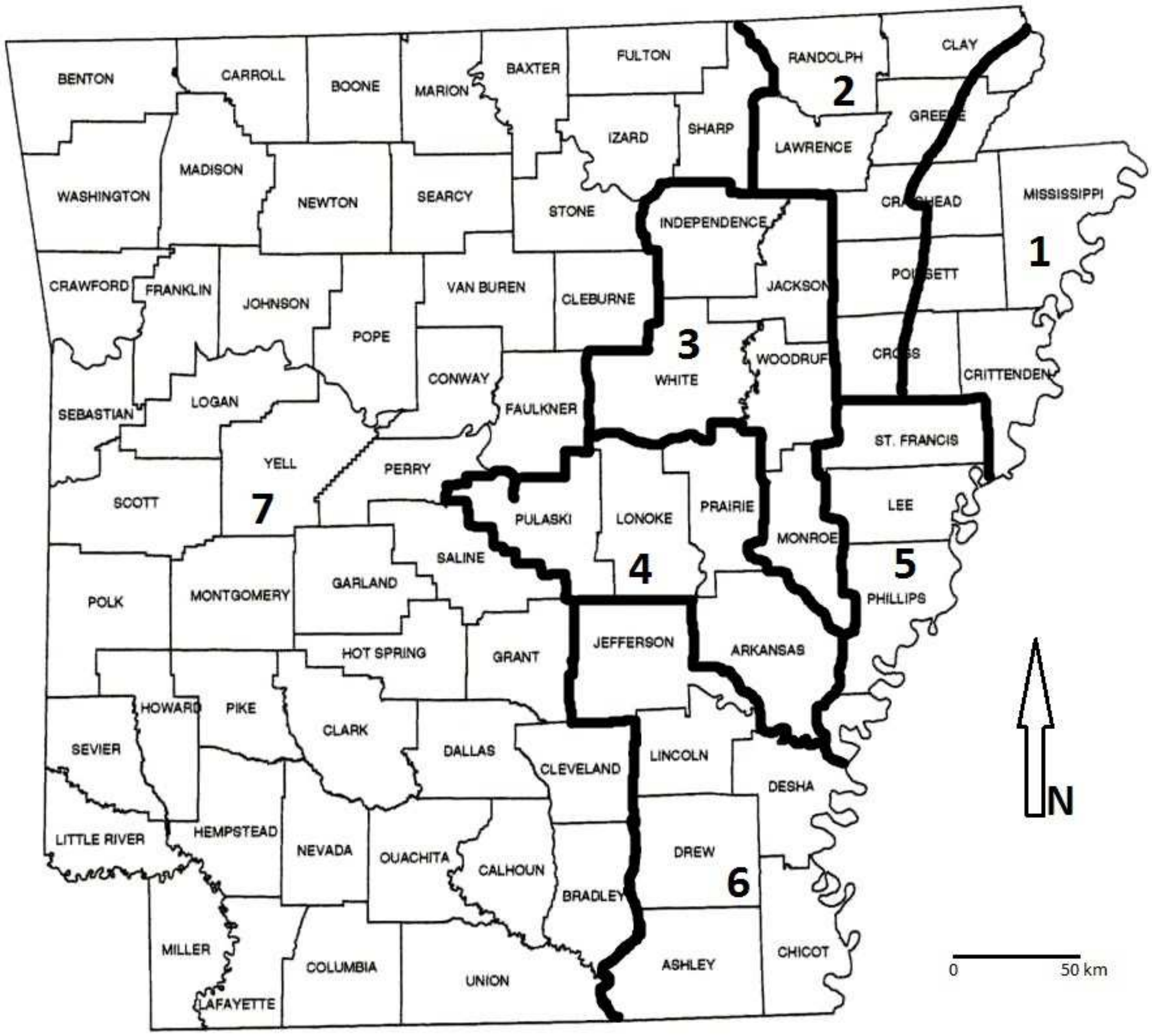

Figure 1. Seven regions for the “Grow for the Green” contest sponsored by the Arkansas Soybean Promotion Board together with the Arkansas Soybean Association. Division 1: Northeast Delta; Division 2: Northeast; Division 3: White River Basin; Division 4: Central and Grand Prairie; Division 5: East Central Delta; Division 6: Southeast Delta; Division 7: Western.

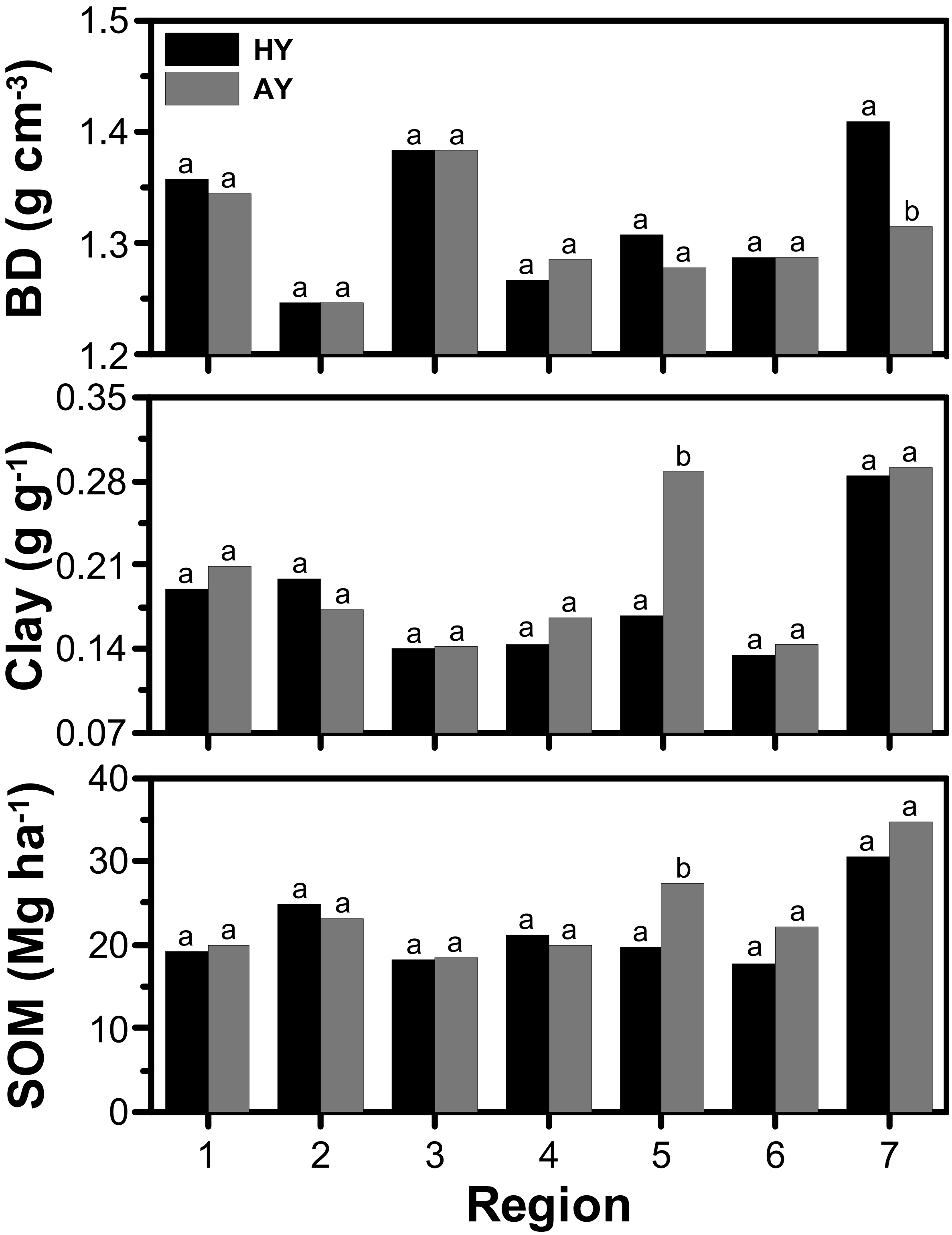

Figure 2. Bulk density (BD), clay content, and soil organic matter (SOM), averaged across the 0 to 10-cm and 10 to 20-cm depth, measured in high-yield (HY) and average-yield (AY) areas in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each region are not significantly different at α=0.05.

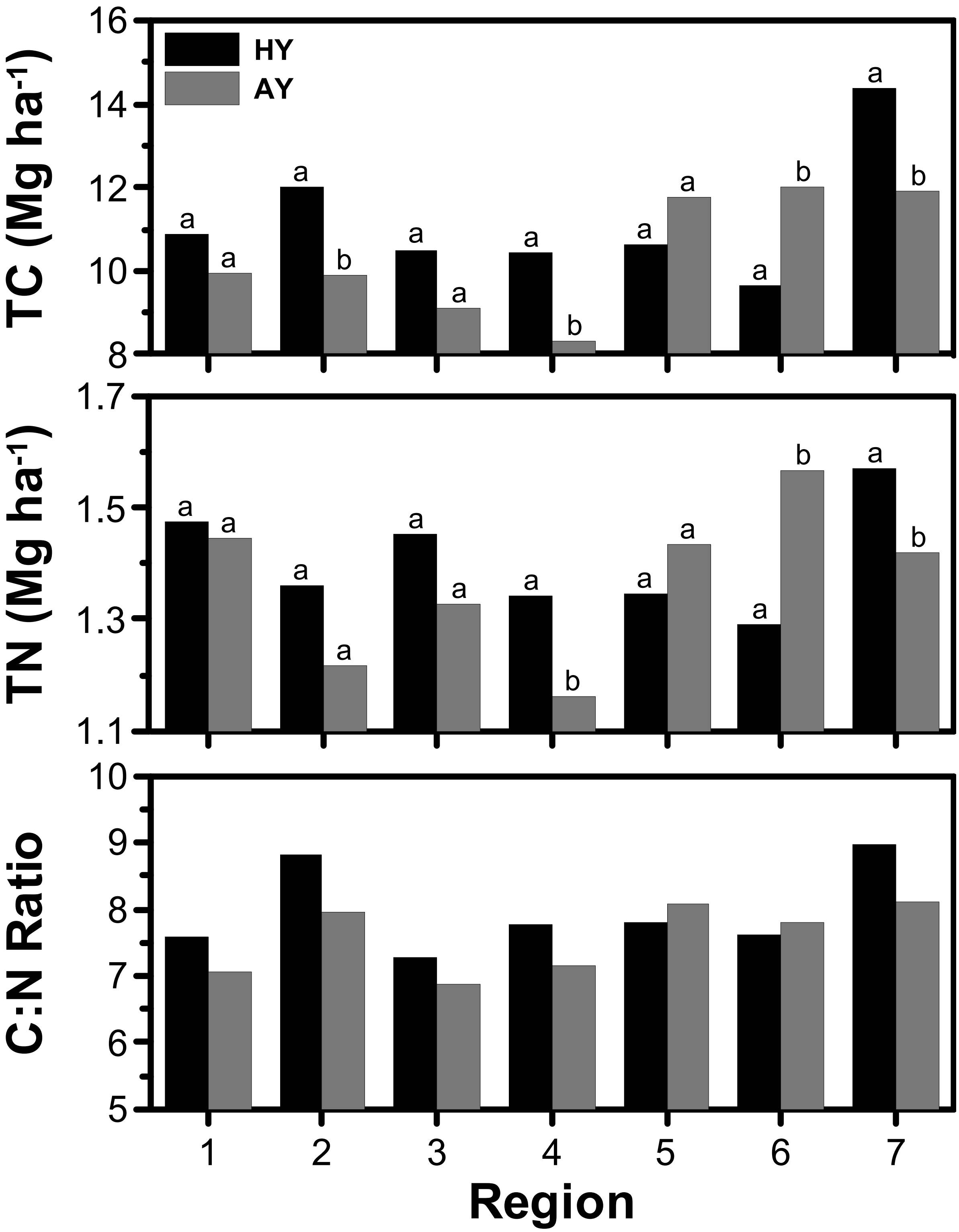

Figure 3. Soil total C (TC), total N (TN), and soil C:N ratio, averaged across the 0 to 10-cm and 10 to 20-cm depth, measured in high-yield (HY) and average-yield (AY) areas in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each region are not significantly different at α=0.05.

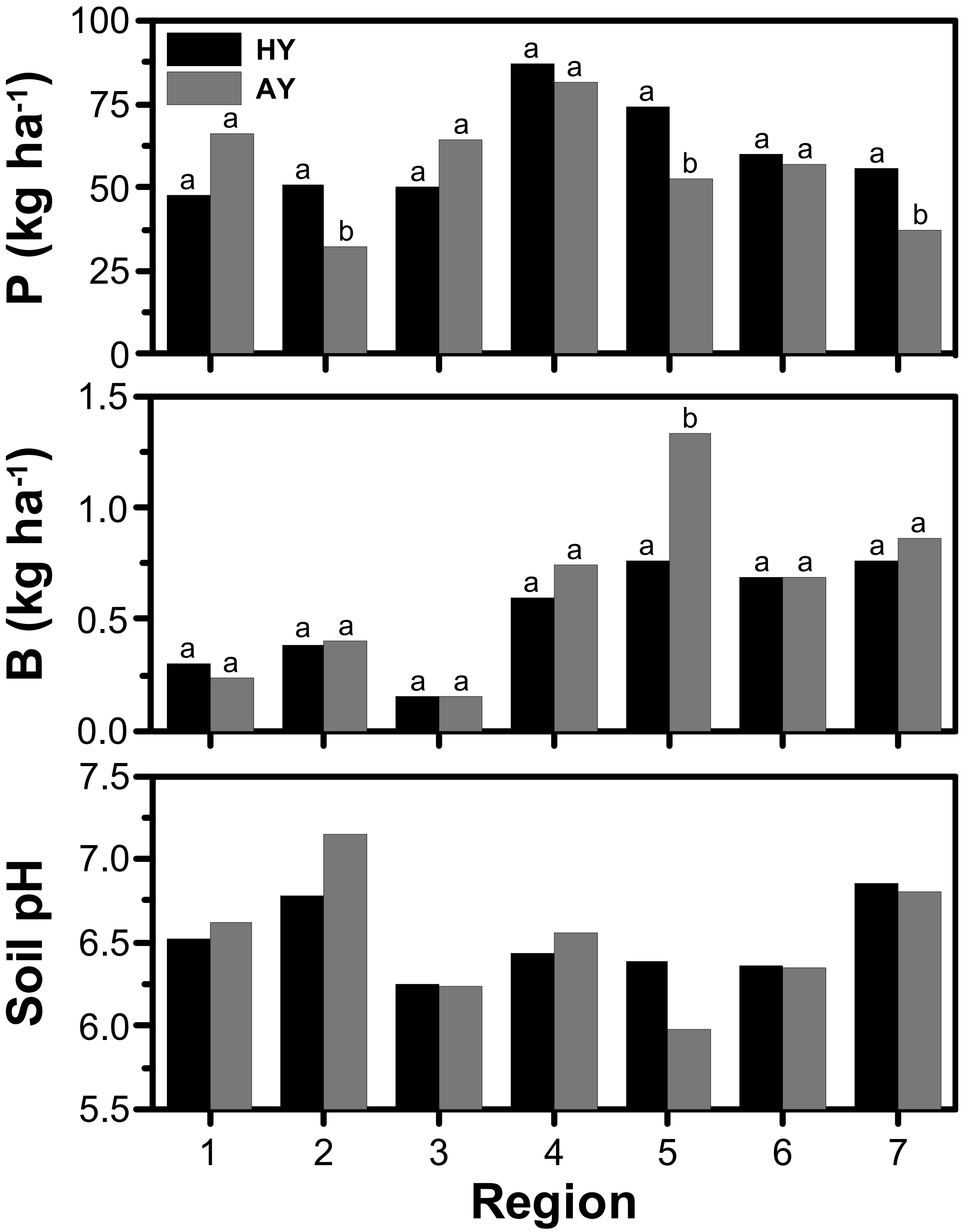

Figure 4. Extractable soil P and B, and soil pH, averaged across the 0 to 10-cm and 10 to 20-cm depth, measured in high-yield (HY) and average-yield (AY) areas in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each region are not significantly different at α=0.05.

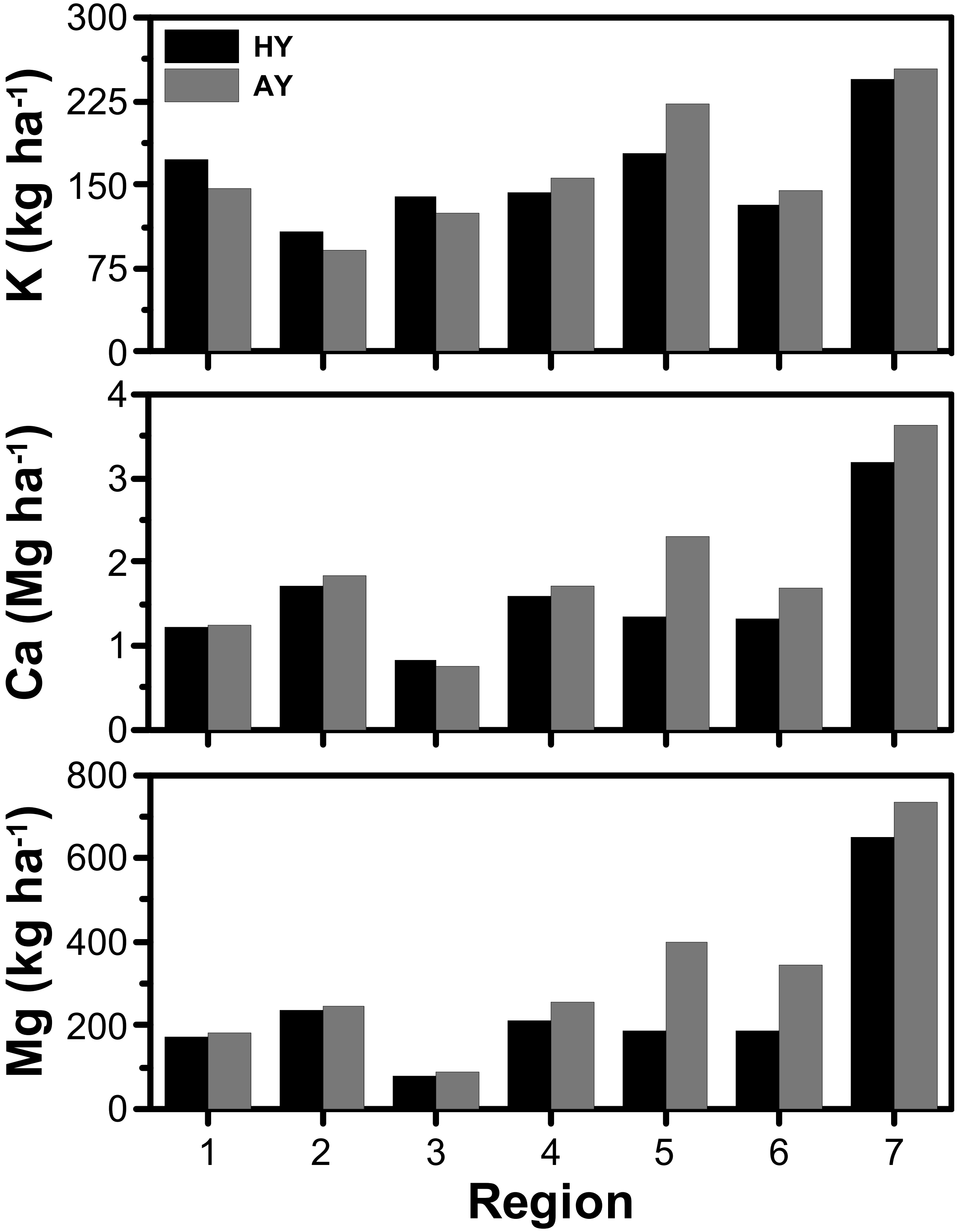

Figure 5. Extractable soil K, Ca, and Mg, averaged across the 0 to 10-cm and 10 to 20-cm depth, measured in high-yield (HY) and average-yield (AY) areas in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015.

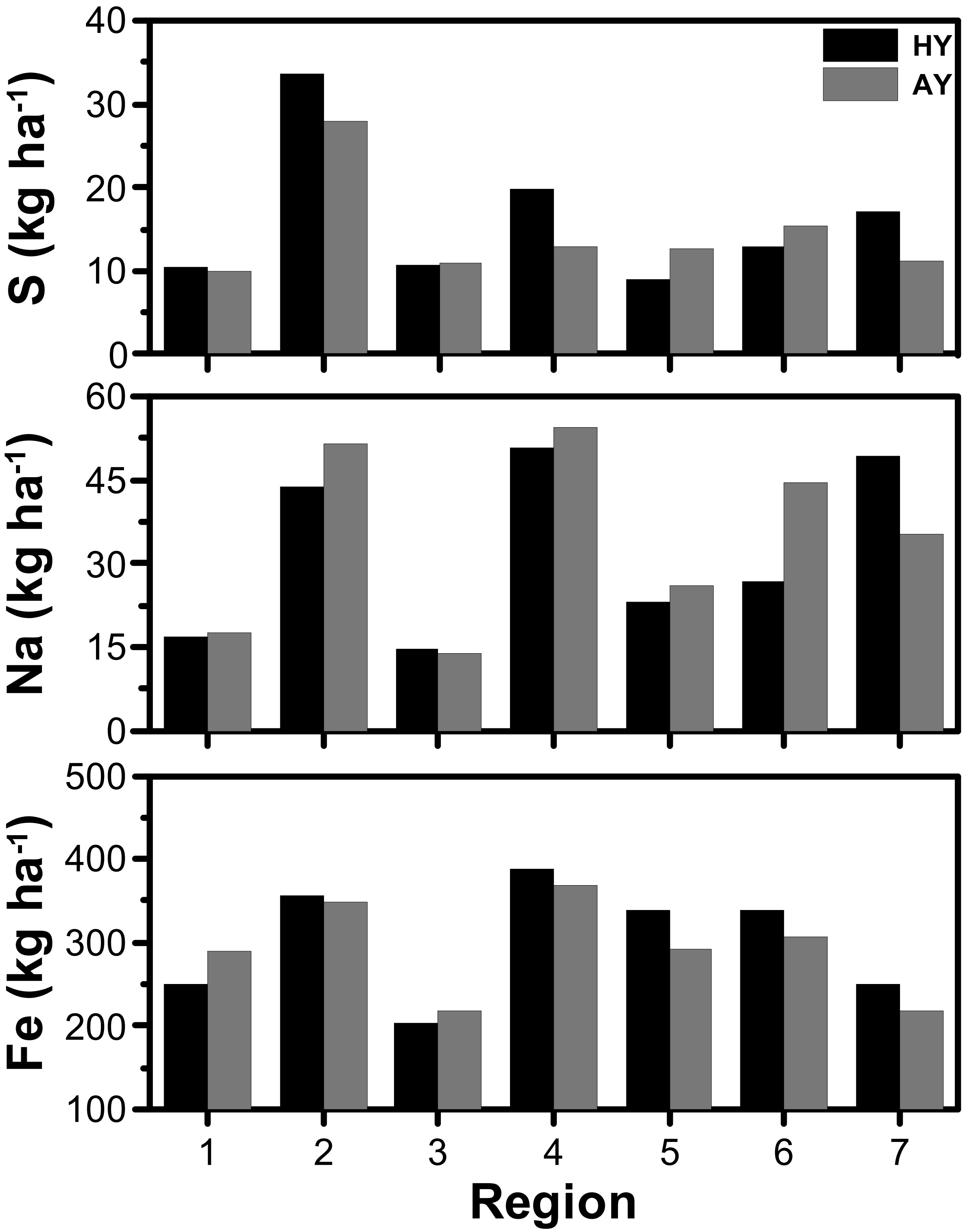

Figure 6. Extractable soil S, Na, and Fe, averaged across the 0 to 10-cm and 10 to 20-cm depth, measured in high-yield (HY) and average-yield (AY) areas in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015.

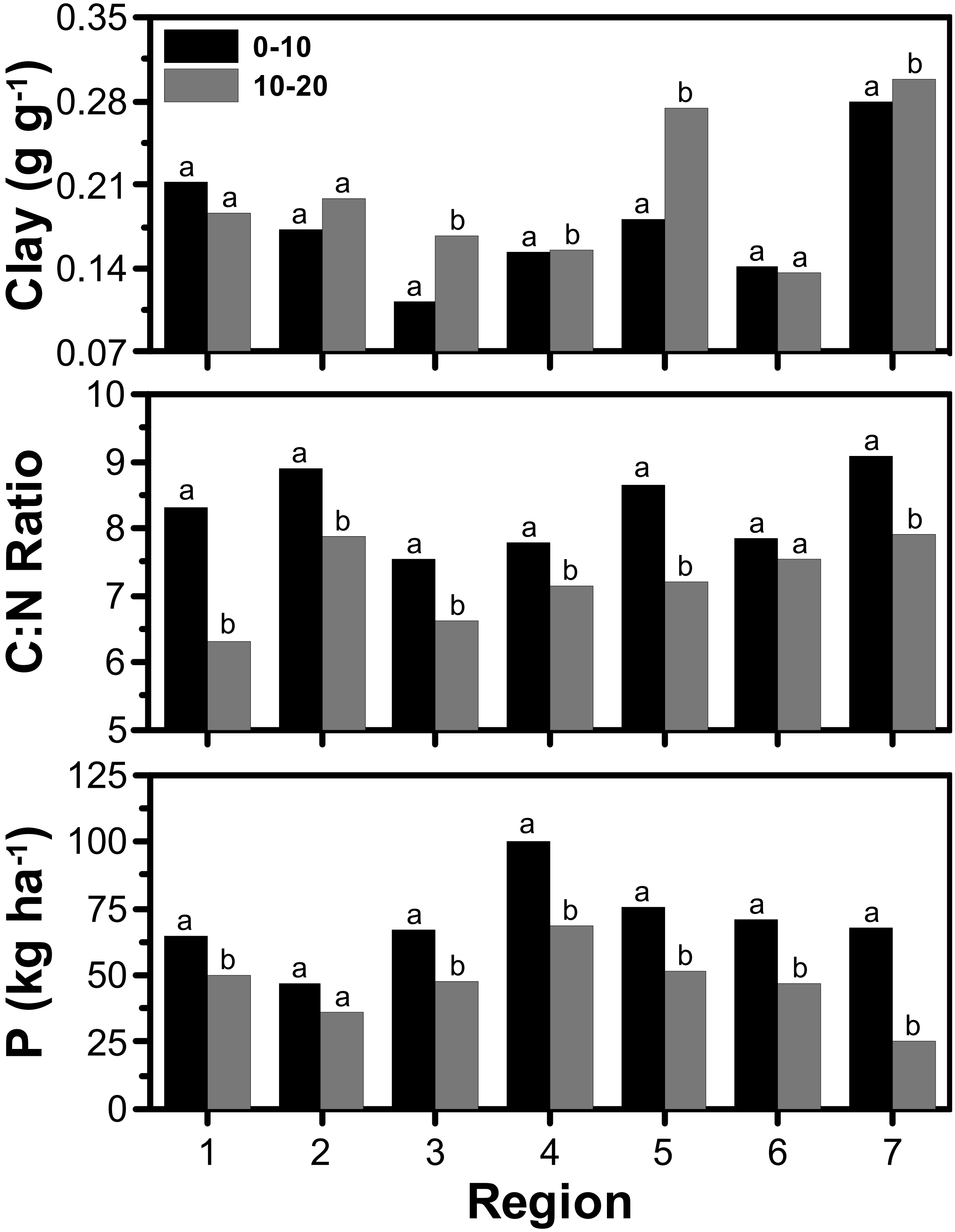

Figure 7. Clay content, soil C:N ratio, and extractable soil P, averaged across yield areas, measured in the 0 to 10-cm and 10 to 20-cm depths in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each region are not significantly different at α=0.05.

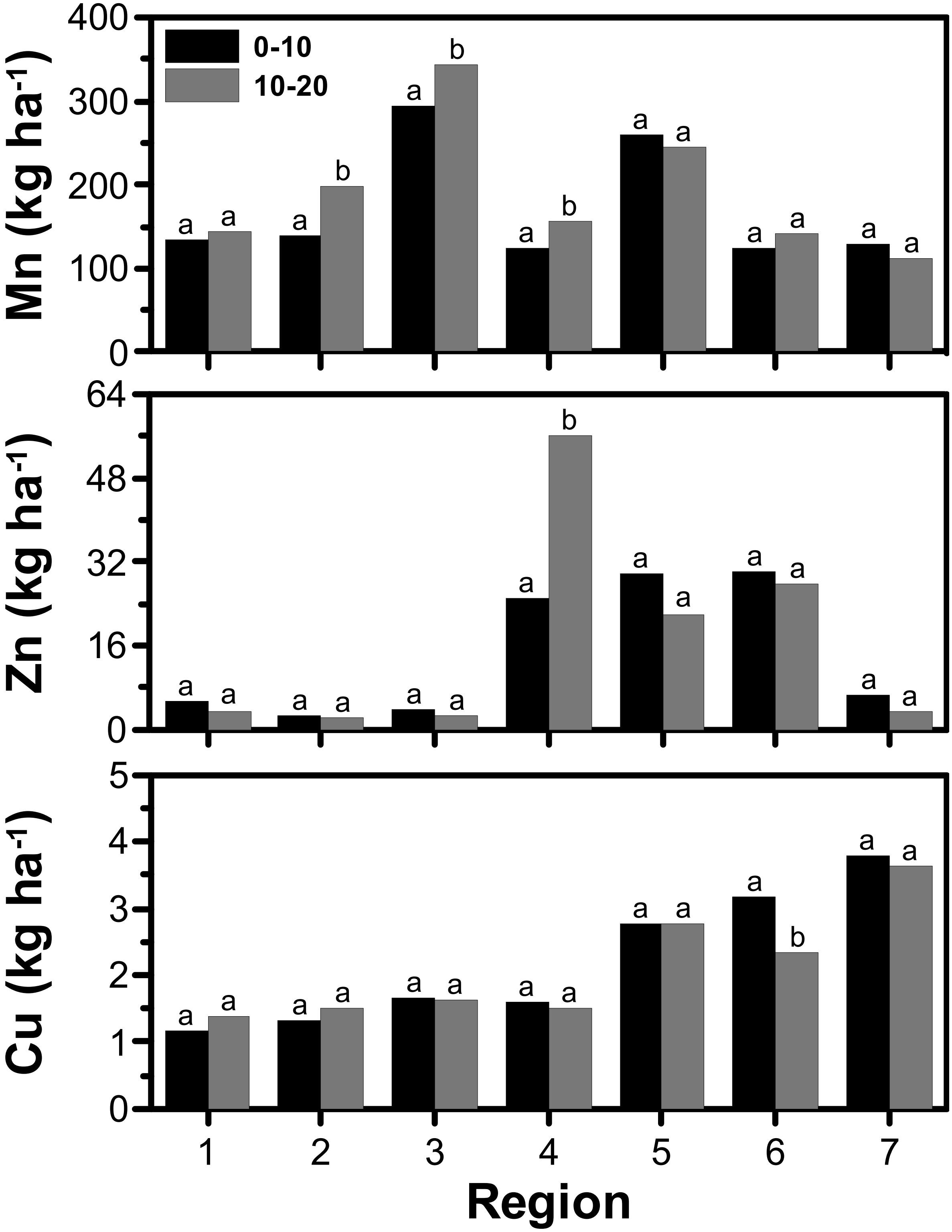

Figure 8. Extractable soil Mn, Zn, and Cu, averaged across yield areas, measured in the 0 to 10-cm and 10 to 20-cm depths in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each region are not significantly different at α=0.05.

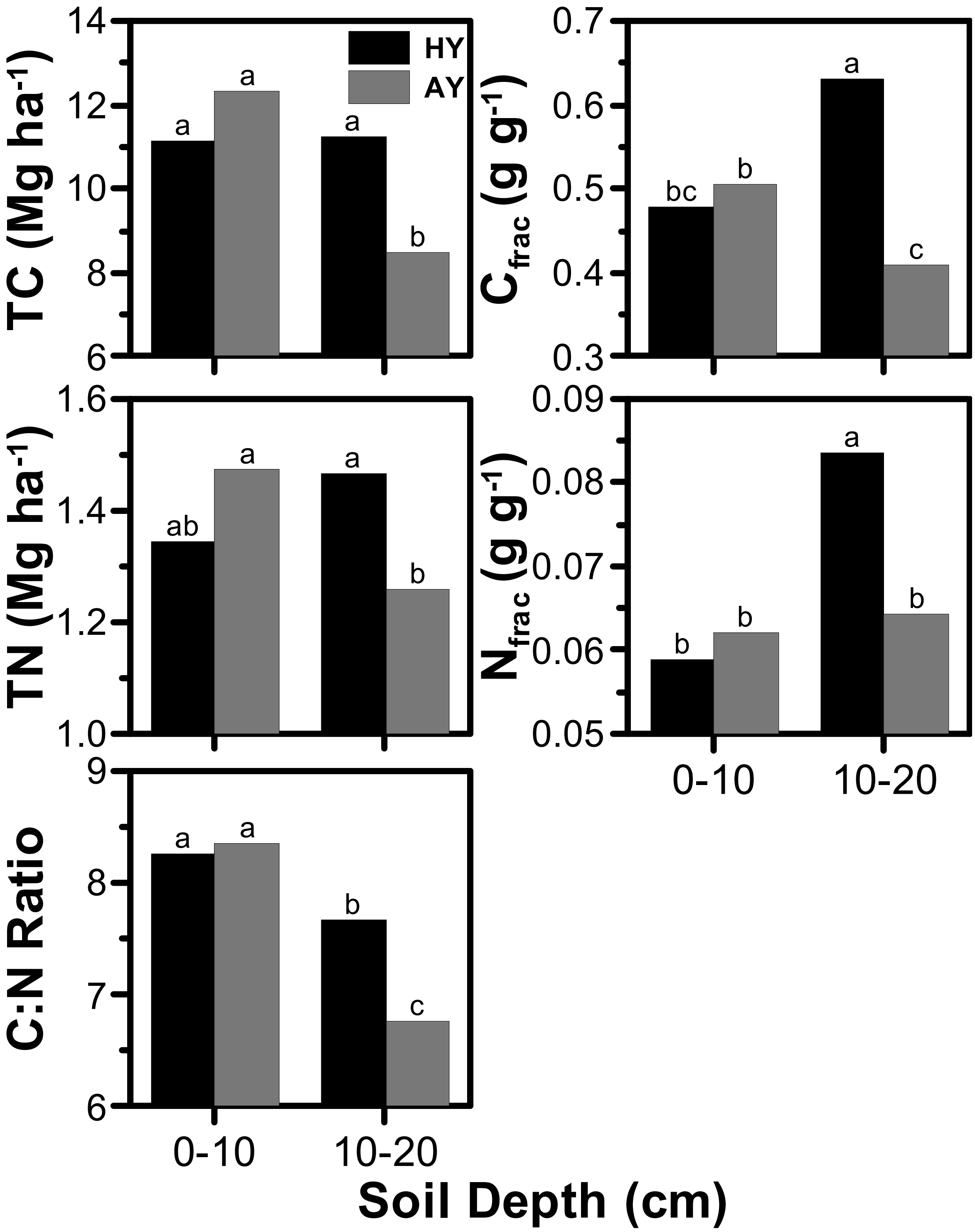

Figure 9. Soil total C (TC), total N (TN), C:N ratio, and C (C_{frac}) and N (N_{frac}) fractions of soil organic matter, averaged across regions, measured in the 0 to 10-cm and 10 to 20-cm depths in the average-yield (AY) and high-yield (HY) areas of the "Grow for the Green" yield contest cross Arkansas in 2014 and 2015. Means with the same letter across depths are not significantly different at α=0.05.

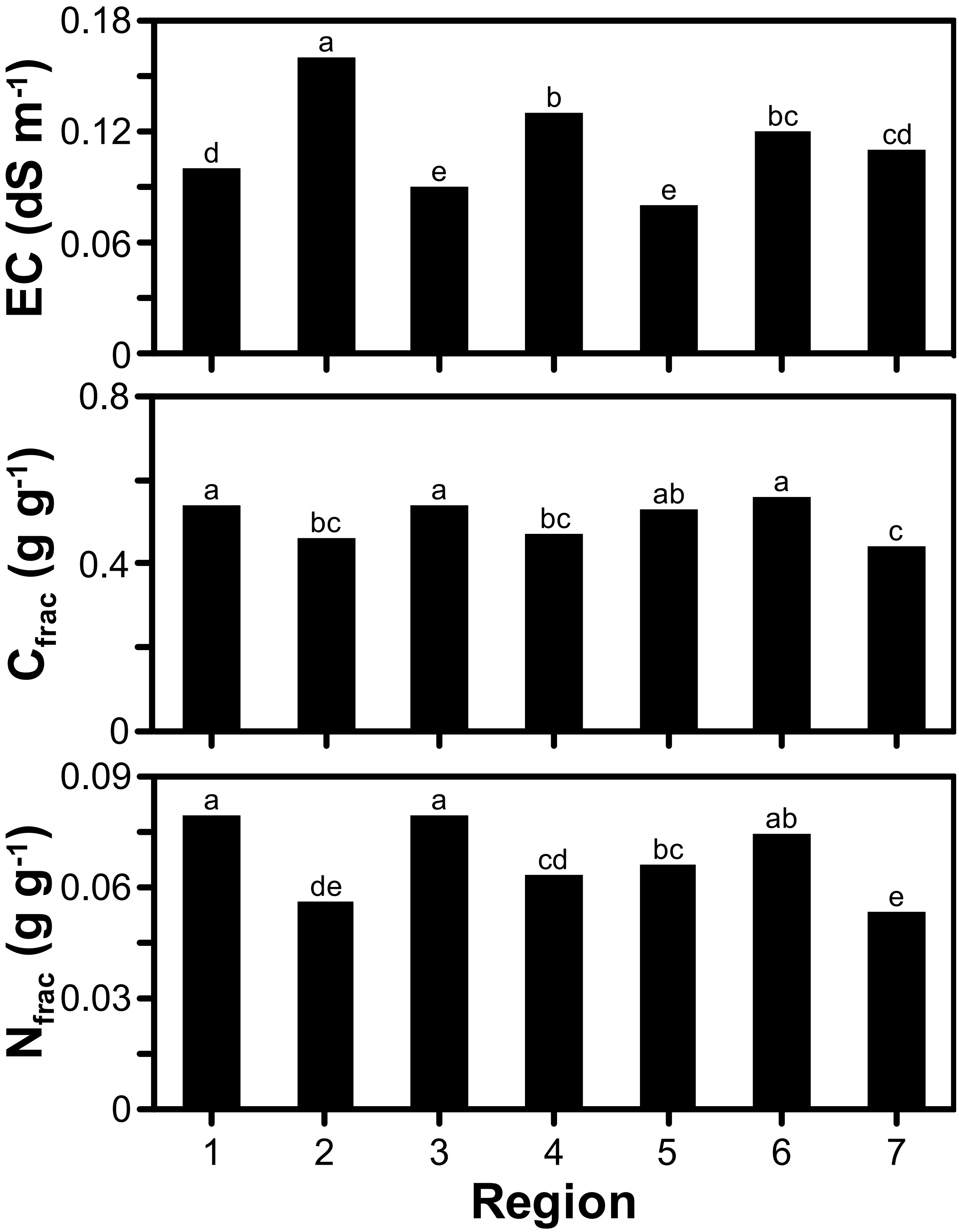

Figure 10. Soil electrical conductivity (EC), and C (C_{frac}) and N (N_{frac}) fractions of soil organic matter, averaged across yield areas and soil depths, measured in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter across regions are not significantly different at α=0.05.

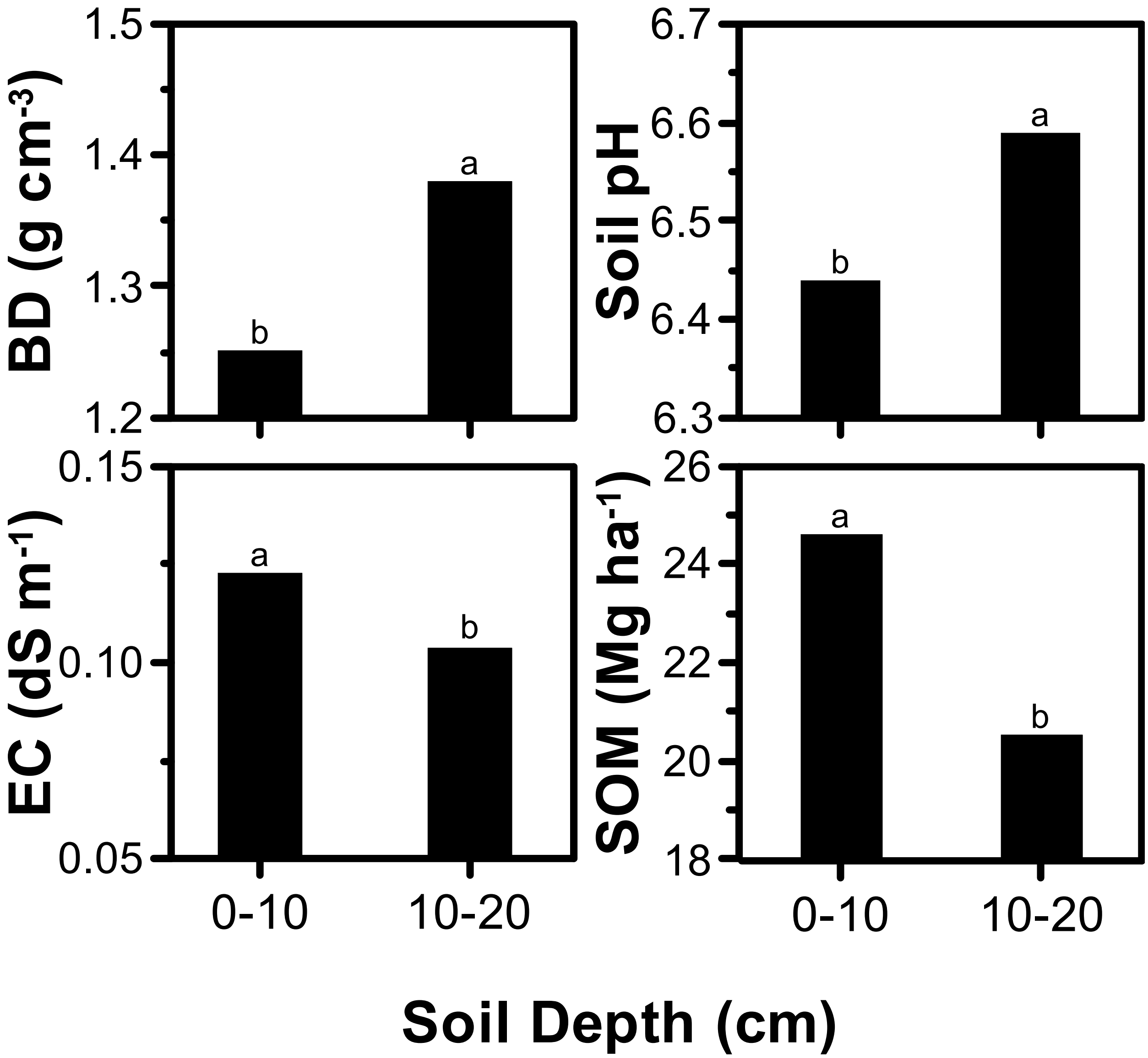

Figure 11. Soil bulk density (BD), electrical conductivity (EC), pH, and organic matter (SOM), averaged across yield areas and regions, measured in the 0 to 10-cm and 10 to 20-cm depths of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each soil property are not significantly different at α=0.05.

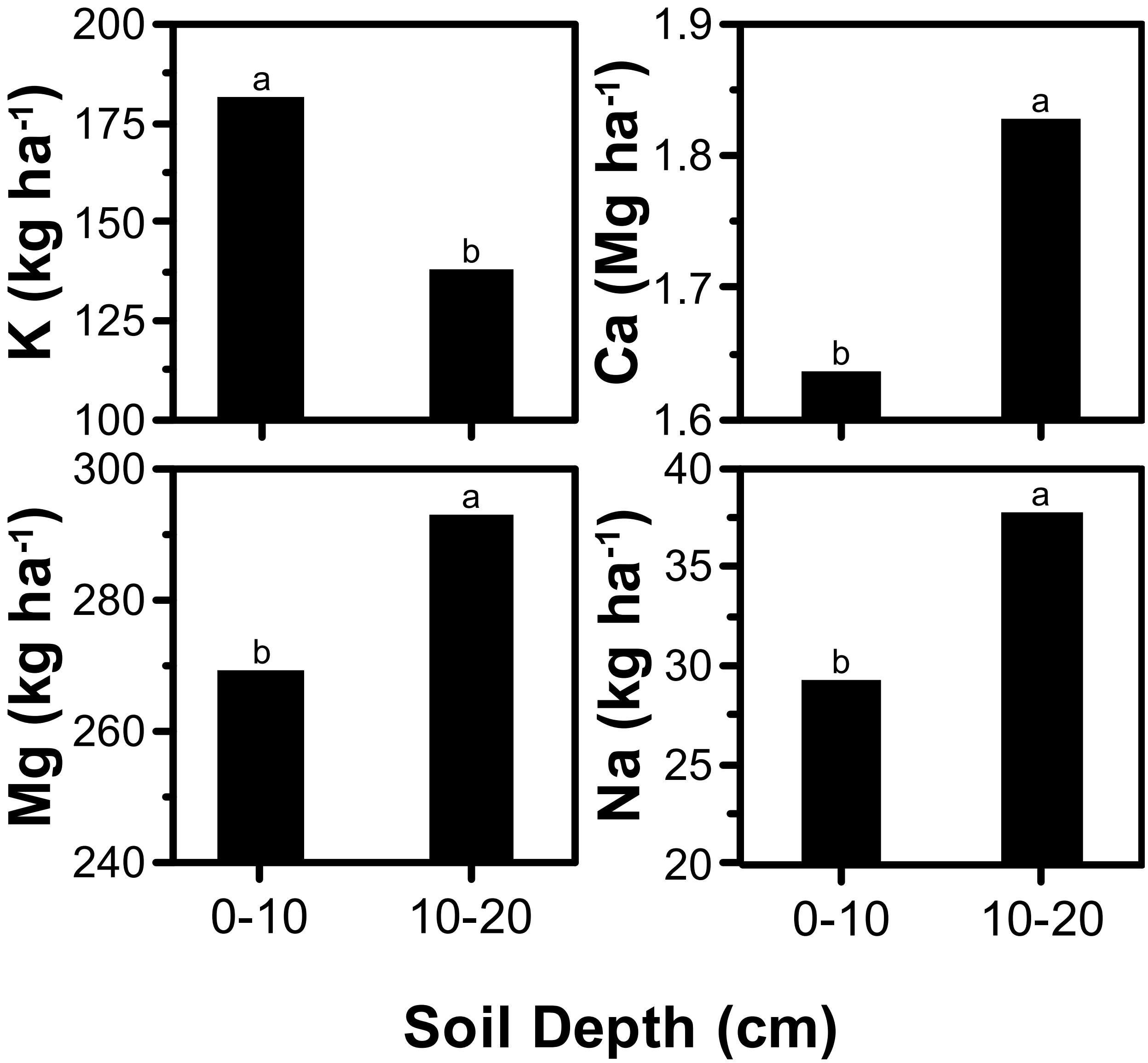

Figure 12. Extractable soil K, Mg, Ca, and Na, averaged across yield areas and regions, measured in the 0 to 10-cm and 10 to 20-cm depths of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter within each soil property are not significantly different at α=0.05.

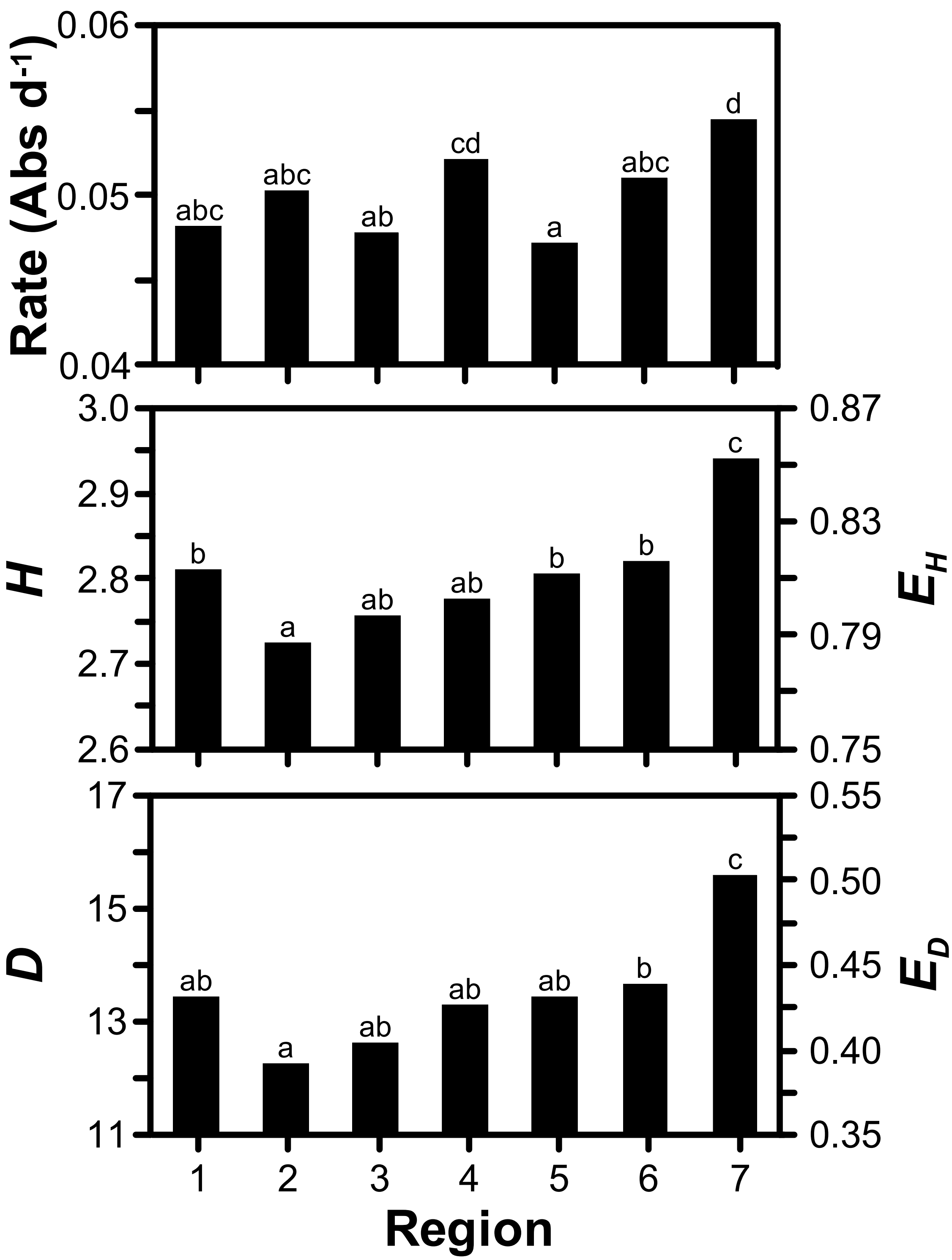

Figure 13. Microbial growth rate, Shannon's diversity (*H*) and evenness (E_H), and Simpson's diversity (*D*) and evenness (E_D), averaged across yield areas, measured in the seven regions of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter across regions are not significantly different at $\alpha = 0.05$.

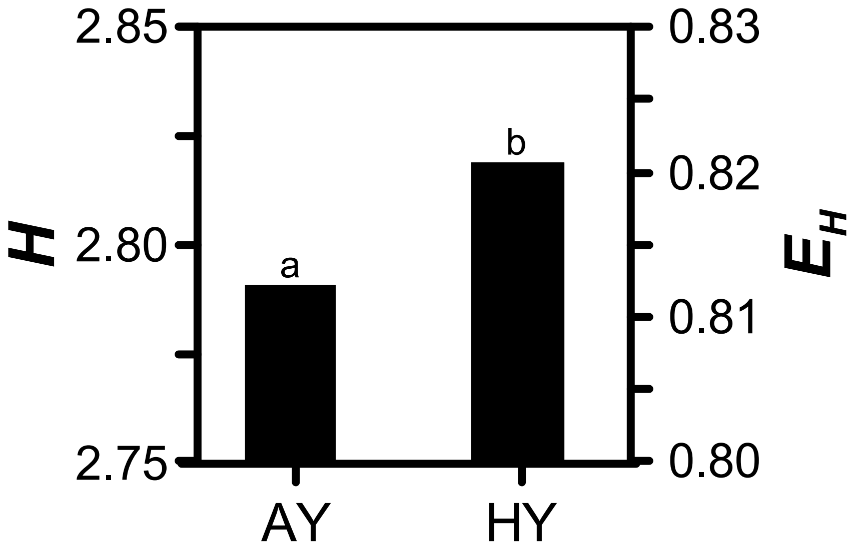

Figure 14. Shannon's diversity (*H*) and evenness (E_H), averaged across regions, measured in the average- (AY) and high-yield (HY) areas of the "Grow for the Green" yield contest across Arkansas in 2014 and 2015. Means with the same letter across regions are not significantly different at $\alpha = 0.05$.

Chapter 3

Plant Property Differences among High-yield Soybean Areas in Arkansas

Abstract

Continued increases in average soybean [*Glycine max* (L.) Merr.] yield will depend on decreasing the yield gap, defined as the difference between current and potential yield, which is the yield of a cultivar grown with the best technologies without limitations on nutrient and water availability and biological stresses effectively controlled. Therefore, understanding the main factors influencing yield in soybean can provide key insights for making management decisions to increase yield. The objective of this study was to i) to assess plant property and seed concentration differences between high- and average-yield areas and across soybean growth stages and ii) evaluate relationships among plant properties and yield. In each of seven regions of the "Grow for the Green" yield contest in Arkansas, one contest-entered, high-yield area (HY) in close proximity to one average-yield area (AY) were plant-sampled at mid-R5, mid-R6, and harvest maturity (HM). Grain yields in AY areas ranged from 2688 to 6585 kg ha^{-1} (13% moisture) and averaged 4664 kg ha^{-1} (69 bu ac^{-1}), while yields in HY areas ranged from 2822 to 7324 kg ha^{-1} and averaged 5647 kg ha^{-1} (82 bu ac^{-1}). Across growth stages and between yield areas, harvest index (HI) and final average seed weight (FASW) were greater ($P < 0.05$) in both yield areas at HM across regions, while seed number was greatest ($P < 0.05$) in HY areas at HM and seed K concentration was greatest ($P < 0.05$) in HY areas at mid-R5 across regions. Averaged across growth stage, aboveground dry matter (ADM) and seed B concentration was greater ($P < 0.05$) in high-yield areas, while seed C concentration was greater ($P < 0.05$) in AY areas across regions. Averaged across yield area, seed P, Ca, Fe, Mn, Zn, Cu, and B concentrations were greatest ($P < 0.05$) at mid-R5, while seed N concentration was greatest ($P < 0.05$) at HM. Yield, seed growth rate, effective filling period, dry matter allocation coefficient (DMAC), HI, effective filling period 2 (derived from DMAC), seed N concentration, final average seed weight, and planting day of year (PDOY) were correlated ($P < 0.05$; $r > 0.24$) with at least one other measured or calculated variable.

The strongest correlation for yield was with PDOY ($P < 0.001$; $r = -0.62$). Encompassing a wide variety of landscapes and soybean management systems across Arkansas, results of this study validate the importance of PDOY to yield. However, additional factors (i.e., genetic, agronomic and/or environmental) may need to be evaluated in order to discover stronger relationships with yield in order to continue working towards minimizing the yield gap.

Introduction

From 1924 to 2012, the average US soybean yield increased annually by 23 kg ha^{-1} yr^{-1}, from 739 kg ha^{-1} to 2661 kg ha^{-1} (Egli, 2008). However, soybean yields greater than 6719 kg ha^{-1} (100 bu ac^{-1}) have been reported in yield contests in multiple states within at least the past 3 years. Until recently, research focusing on managing soybean for high-yield production has concentrated on maximizing light interception and crop growth rate before mid-R5 (Fehr et al., 1971) to provide the maximum level of photosynthate for translocation to seeds (Westgate, 2001). Although choosing the correct row spacing, plant population, variety, and planting day of year perhaps achieves the greatest amount of photosynthate, the resulting correct combination is dependent on achieving the greatest efficiency for seed formation and resulting final yield (Westgate, 2001). Better understanding of the physiological framework for grain yield determination in soybean provides a guide for understanding the effect of management practices and growing conditions on final yield.

Yield is determined by the final seed number and the final average seed weight (FASW), and of the two, seed number has the greatest impact on final soybean yield. Seed number is a function of the plants per unit area, pods per plant, and seeds per pod, which are determined by genetics and planting practices (Egli, 1998). As such, it becomes difficult to focus on just one component of seed number, and it is better to think of seed number instead as the total number of seeds or pods per unit area. Physiologically, a soybean crop will adjust its yield potential to match the growing conditions. Thus, seed number (per hectare) determination can be simply viewed as the crop setting the number of seeds it can support (Westgate, 2001). More specifically, seed number determination is closely related to photosynthate production from R1 to R5 (van Roekel et al., 2015). The following seed-fill period from R6 to R7 will have a major impact on seed weight, which will also influence yield. This understanding of how yield is determined in soybean is the crucial first step in making management decisions for sustainable yield increases over time. However, given equal photosynthetic rates and reproductive partitioning, a large-seeded variety can still produce the same amount of final grain weight as a smaller-seeded variety; the plant will just have fewer seeds per unit area (Egli, 1998).

Prior to flowering, stresses do not have a large impact on final yield, provided that the stress did not severely stunt the plants (Egli, 1998); therefore, maximizing yield depends upon alleviating all stresses throughout the entirety of reproductive development. Both too much and not enough water can have a large impact on photosynthesis and crop growth, while soil fertility and pH must also allow for optimal crop growth rates. Soil fertility and pH, as well as irrigation practices, should be managed according to soil and plant analyses in conjunction with the yield goal and calculated crop demands.

Yield-contest data provide alternative information about achieving maximum crop yield. For example, in 1966, the first soybean yield contest in the US was held nationwide when two producers achieved yields of 6203 kg ha^{-1} in Chenoa, IL and Hamburg, IA (Cooper, 2003). Yields of greater than 6719 kg ha^{-1} were recorded during the 1968 National Yield Soybean Contest, when 6890 and 7310 kg ha^{-1} were harvested in Rolling Prairie, IN and Ozark, MO, respectively (Cooper, 2003). Nationwide, yield contests are currently conducted in 14 states, including Arkansas (van Roekel and Purcell, 2014). The first year of the soybean yield contest in Arkansas, “Grow for the Green”, was 1999, when the greatest yield achieved was 5155 kg ha^{-1} (ASA, 2015). The 6719 kg ha^{-1} yield barrier was finally broken in 2013, when three producers in Arkansas were able to obtain yields of 6771, 7044, and 7232 kg ha^{-1} (ASA, 2015).

Conducting research in producers’ fields that produce high-yield soybean in Arkansas may provide relevant information for other producers in the state who are striving to achieve soybean yields equal to or greater than the current world record (10817 kg ha^{-1} or 161 bu ac^{-1}), which was harvested in southwest Missouri in 2010 (van Roekel et al., 2015). Since Missouri and Arkansas are bordering states and are both in the upper mid-southern soybean production region, Arkansas soybean growers perhaps have the potential to approach, match, or even exceed the world record. Additionally, through characterization of plant property and mechanism differences that occur in contest-/high-yield management areas as well as in average-yield areas in the same or adjacent fields, consistencies and patterns in soybean physiology may be observed that explain large yields occurring under similar and/or different management practices. Therefore, the main objective of this study was to evaluate plant-property and seed-concentration differences between high- and average-yield areas and across soybean growth stages [i.e., mid-R5, mid-R6, and harvest maturity (HM)] as well as to determine which properties are most related to high soybean yields. The secondary objective of this study was to identify correlations among plant properties and soybean grain yield. It was hypothesized that a longer effective filling period (EFP) will contribute to high-yielding soybean plants due to the longer time the plant has to incorporate mass into seed. Additionally, it was hypothesized that earlier planting will also contribute to high yields as a result of a longer growing season and the advantage of avoiding late-summer droughts. Harvest index and final average seed weight (FASW) were hypothesized to be greater at HM than at mid-R5 and mid-R6 because seeds continue to gain mass from inception until after mid-R6.

Materials and Methods

"Grow for the Green" Yield Contest

An annual soybean [*Glycine max* (L.) Merr.] yield contest, "Grow for the Green", was initiated by the Arkansas Soybean Promotion Board (ASPB) together with the Arkansas Soybean Association (ASA) in 1999. In 2011, the ASPB and ASA divided the contest entries into three production systems: early season, full-season, and double-crop. Another change occurred in 2013, when Arkansas was split into seven geographic regions (Figure 1), and an eighth, statewide, non-genetically-modified-organism category. The seven geographic regions for the yield contest are as follows: 1: Northeast Delta; 2: Northeast; 3: White River Basin; 4: Central and Grand Prairie; 5: East Central Delta; 6: Southeast Delta; 7: Western (Figure 1). Table 1 summarizes the 2007 to 2012 "Grow for the Green" soybean yield contest results, including the 1st- and 10th-place growers and the county where the crop was harvested, while Table 2 summarizes the agronomic characteristics for the 1st- and 2nd-place finishers in the 2013 yield contest in each of the seven regions.

Study Area Description

In late spring to early summer 2015, one producer in each of the seven regions was identified as a willing cooperator who had a field area entered into the 2015 yield contest, as well as an average-yielding area within the same field or in an adjacent field. The average-yielding area identified was based on each producer's qualitative, historic knowledge of the productivity of their own fields and areas within fields.

Annual precipitation varied slightly across the seven regions (Table 3), with annual precipitation in counties sampled ranging from 1225 mm in Craighead and Cross Counties in the northern portion of Arkansas (Figure 1) to 1363 mm in Desha County, in the southern part of the state. As with precipitation, average monthly air temperatures varied across the state, but only slightly (Table 3). The lowest average January air temperature (2.1°C), as well as the lowest average annual air temperature (15.1°C), both occurred in Craighead County (Table 3). Similar to the low air temperatures, the largest average July air temperature of counties sampled (28.1°C) occurred in Philips and Desha Counties, and the largest annual temperature (17.2°C) occurred in Desha County.

Sample Collection and Processing

During the 2015 growing season, sample points were established in a five-point diamond formation within each high- and average-yielding areas in each of the seven state-wide yield contest regions. Three of the five points were in the same row approximately 62 m apart from one another, and the other two points were perpendicular to the middle row approximately 38 m in the opposite direction from the mid-point of the middle row. At each point, above-ground plant material was collected from 5 plants within a row at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and also at HM. For all three growth stages, the total above-ground plant material was dried at ~ 55^{o}C for 7 d and weighed to determine above-ground dry matter (ADM), then seeds were removed, counted, and weighed. A subsample of the seed material was ground in a coffee grinder to pass a 1-mm mesh sieve, and N and C concentrations were determined by high-temperature combustion using a VarioMax CN analyzer (Elementar Americas Inc., Mt. Laurel, NJ). For determination of elemental seed-tissue concentrations (i.e., P, K, Ca, Mg, S, Na, Fe, Mn, Zn, Cu, and B), seeds were digested using concentrated HNO_3 and analyzed by inductively coupled, argon-plasma spectrometry (ICAP, Spectro Analytical Instruments, Spectro Arcos ICP, Kleve, Germany).

For processing of soybean seed from the mid-R5 and mid-R6 sample dates, pods were removed from stems and vigorously shaken in plastic jars with rubber stoppers to remove seeds from pods. Seeds were then placed on a series of sieves to remove any pod material remaining from samples. Samples were next laid out on trays and the smallest seed material was eliminated by lightly orally blowing across the surface of the tray. This process effectively removed seed that was still in the lag phase of growth, before the linear period between the mid-R5 and mid-R6 growth stages.

Seed-weight increases from the R5 to R6 sample dates were used to determine the seed growth rate (SGR). The final average seed weight (FASW) divided by the SGR was then used as an estimate of the duration of the effective seed-filling period (EFP). Harvest index (HI), the mass proportion of the vegetative plant that is seed, was used to calculate the dry matter allocation coefficient (DMAC; Salado-Navarro et al., 1985), defined as the rate of increase in HI from the R5 to R6 sample dates. Similar to EFP, EFP2 was then calculated by dividing the HI at HM by the DMAC.

Statistical Analyses

Using 2015 plant data, a two-factor analysis of variance (ANOVA), assuming a completely random design, was conducted using SAS (version 9.3, SAS Institute, Inc., Cary, NC) to evaluate the effects of yield area (i.e., high- and average-yielding areas) and growth stage (i.e., mid-R5, mid-R6, and HM) and their interactions on measured and calculated plant properties (i.e., ADM, FASW, seed number, HI, and seed N, C, P, K, Ca, Mg, S, Na, Fe, Mn, Zn, Cu, and B concentrations). In addition, a one-factor ANOVA was conducted using SAS to evaluate the effect of yield area on yield, SGR, EFP, DMAC, and EFP2. Significance was judged at $P < 0.05$. When appropriate, means were separated by least significant difference at $\alpha = 0.05$.

Linear correlation analyses were conducted to evaluate the relationships among selected plant properties (i.e., seed N concentrations, SGR, FASW, EFP, HI, DMAC, EFP2, and planting day of year) with yield combined across both yield areas. All correlations were performed in JMP (version 12 Pro, SAS Institute, Inc., Cary, NC). For the purposes of these analyses, region was treated as a random variable, as there was no replication within a region. Therefore, results apply to combined data across all regions.

Results and Discussion

General Yield and Plant Property Variations

For the fields sampled in the 2015 "Grow for the Green" yield contest, soybean yield in the average-yield areas ranged from a low of 2688 kg ha^{-1} in Region 2 (Table 4; Figure 1) to a high of 6585 kg ha^{-1} in Region 6. The mean yield for all average-yield areas was 4664 kg ha^{-1}, which was 1372 kg ha^{-1} greater than the Arkansas state average from 2015, and 767 kg ha^{-1} greater than the state average from Nebraska, the most productive soybean state in the United States in 2015 (NASS, 2016). Soybean yield in the high-yield areas of fields sampled ranged from a low of 2822 kg ha^{-1} (Table 4) in Region 2 to a high of 7324 kg ha^{-1} in Regions 3 and 6, while the mean yield for all high-yield areas was 5537 kg ha^{-1}. Regions 2, 3, and 6 of the yield contest are all in the eastern portion of the state (Figure 1); however, Region 2 has alluvial and loess soils, while the soils in Region 3 were derived from a mix of alluvial and eolian parent materials (Table 4; NRCS, 2014b). Region 6 consists of terraces and lower-elevation alluvial sediments, and is also further south, and therefore has a slightly warmer climate (Table 3; NRCS, 2014b). In 2015, yield increase from each average-yield area in a field to the high-yield area within a field ranged from 5% in Region 2 to 63% in Region 1 (Table 4). The mean yield increase from the average- to high-yield areas within fields was 19%. Region 1 of the "Grow for the Green" yield contest is as far north as Region 2 (Figure 1), and similar to Region 2, the soils of Region 1 were derived from a mix of alluvial and loess parent materials (NRCS, 2014b).

Soybean varieties planted were the same in average- and high-yield areas within Regions 1, 2, and 4 (Table 4), but the variety planted differed between average- and high-yield areas in the other four regions (i.e., Regions 3, 5, 6, and 7). However, for all regions, both varieties planted within a region were in the same maturity group (Table 4).

Across regions and yield areas, plant properties measured and calculated during the 2015 soybean growing season (Table 5) varied in scale and magnitude. For both yield areas, SGR from the mid-R5 to the mid-R6 sample dates ranged from a low of 0.9 mg $seed^{-1}$ d^{-1} in Region 2 (Table 5) to a high of 5.2 mg seed^{-1} d^{-1} in Region 6, and consequently EFP ranged from 23 d in Region 6 (Table 5) to 99 d in Region 2. The unusually low SGR observed in Region 2, which coincided with the abnormally long EFP also observed in Region 2, was outside the values of SGR and EFP previously reported in the literature, which range from 2.2 to 13.0 mg seed^{-1} d^{-1} and from 13 to 57 d, respectively (van Roekel et al., 2015). An potential explanation for the atypical values is that the procedure used for separating seeds (i.e., gently blowing of mid-R5 seed) perhaps eliminated seed that would have been a component for final yield, but were too small after drying to be retained. Similar to SGR, the FASW for all average- and high-yield areas was lowest in Region 2 (78 mg; Table 5); however, the greatest FASW (162 mg) occurred in Region 4. Harvest index of both yield areas for each region ranged from 0.37 g g^{-1} in Region 3 to a high of 0.72 g g^{-1} in Region 6, while seed N concentration ranged from 5.2 % in Region 7 (Table 5) to 6.2 % in Region 5.

Treatment Effects

Combined Effect of Yield Area and Growth Stage

Across regions, soybean HI, seed number, FASW, and seed K concentration differed ($P < 0.05$; Table 6) between yield areas among growth stages for the 2015 growing season. Soybean HI was, on average, 77% greater at HM than at mid-R6 in both yield areas (Figure 2), and was, on average, 275% greater at mid-R6 than at mid-R5 (Figure 2). This result was expected, as HI is a measure of the mass of seed relative to the mass of the entire plant, and seeds gain mass from mid-R5 to HM (UACES, 2014). Seed number was greater at HM in high-yield areas (816 seeds; Figure 2) than in all other growth stage/yield area treatment combinations. Seed number did not differ ($P > 0.05$; Figure 2) between the mid-R6 growth stage in the high-yield areas (652 seeds) and at HM in the average-yield areas (670 seeds), which were both greater ($P < 0.05$) than seed number at mid-R6 in average-yield areas (559 seeds). Additionally, seed number did not differ between yield areas at mid-R5, and was, on average, 103% less ($P < 0.05$; Figure 2) than the average seed number at mid-R6 for both yield areas. It was expected that seed number would be different between yield areas, as any stress that occurs throughout the season, which is more likely to occur in average- than in contest and/or high-yield areas, would likely decrease seed number and yield (van Roekel et al., 2015). Furthermore, increased soil N fertility, which was likely to occur in contest fields, likely contributed to increased seed number and yield (van Roekel et al., 2015). However, it was unexpected that seed number differ across growth stage, as stress after mid-R5 generally decreases FASW without affecting seed number (UACES, 2014). Another explanation for the increase in seed number from mid-R5 to mid-R6 is again related to the method used for separating seeds from pods, which perhaps eliminated small seed from analysis. However, this explanation does not apply to the greater seed number at HM than at mid-R6. Another explanation for the differences in seed number across growth stage relate to the sampling time, which was perhaps too early or too late and was not collected at the exact mid-R5 and mid-R6 growth stage. Growth stages were estimated based on planting day and maturity group, so it was possible samples were collected at incorrect times. Similar to HI, FASW in both yield areas, which did not differ (Figure 3), was 29% greater at HM than FASW in both yield areas at mid-R6, which did not differ. Furthermore, FASW in the average-yield areas at mid-R6 (96 mg; Figure 3) was greater ($P < 0.05$) than FASW in average-yield areas at mid-R5 (42 mg), which subsequently was greater ($P < 0.05$) than FASW in high-yield areas at mid-R5 (31 mg). Similar to HI, it was expected that FASW would increase from mid-R5 to HM. Although seeds continue to gain mass from formation until HM, FASW may decrease either before cell division by decreasing cell number and SGR or after cell division through shortening the EFP (van Roekel et al., 2015). In contrast to HI, seed number, and FASW, seed K concentration were greater ($P < 0.05$; Figure 3) in high-yield areas at mid-R5 (19.5 g kg^{-1}) than in all other growth stage/yield area treatment combinations. Seed K concentration was also greater ($P < 0.05$; Figure 3) in average-yield areas at mid-R5 (17.6 g kg^{-1}) than in both yield areas at mid-R6 and HM. Seed K concentration did not differ ($P > 0.05$; Figure 3) between yield areas at mid-R6 and HM. Seed K concentrations at HM observed in this study were well below those reported previously by Parjev et al. (2015) under low-soil-K-fertility conditions across Arkansas, but greater than those reported by Farmaha et al. (2011) in Illinois averaged over soil-K fertility levels.

Effect of Yield Area

For the 2015 soybean growing season, across regions, yield differed ($P = 0.010$; Table 6; Figure 4) between high- (5537 kg ha^{-1}) and average-yield (4664 kg ha^{-1}) areas. This result was expected, as high-yield areas located in yield-contest fields areas were managed more closely than average-yield areas for maximum productivity for contest purposes.

Across regions and averaged across growth stage, ADM and seed C and B concentrations differed ($P < 0.05$) between yield areas (Figure 4). Similar to yield, ADM and seed B concentration were greater in high-yield areas. On average, ADM was 23% greater in high-yield areas, while seed B concentration was 10% greater in high-yield areas (Figure 4). As with yield, it was expected that ADM would be greater in high-yield areas due to the increased management by producers. However, Board and Modali (2005) reported that yield components such as ADM are not promising as predictors for final yield due to large variability and the difficulty associated with assessment in large production areas. For example, near Baton Rouge, LA, yield was sometimes positively correlated with ADM at R5, wherein yield showed steep increases with ADM at R5 for low dry matter levels (< 300 g m^{-2}), progressively declined at greater ADM at R5 levels, and did not respond to ADM at R5 above 600 g m^{-2} (Board and Modali, 2005). In contrast to yield, ADM, and seed B, C concentrations were greater in average- than in high-yield areas (Figure 4). However, the difference in seed C concentration was negligible, at only 0.7%. Across regions, SGR, EFP, DMAC, and EFP2 did not differ ($P > 0.05$; Table 6) between yield areas, while FASW and seed N, P, Ca, Mg, S, Na, Fe, Mn, Zn, and Cu concentrations also did not differ ($P > 0.05$; Table 6) between yield areas across regions and averaged across growth stages.

Effect of Growth Stage

For the 2015 soybean growing season, across regions and averaged across yield area, ADM and seed N, C, P, Ca, Fe, Mn, Zn, Cu, and B concentrations differed ($P < 0.05$; Table 6) among soybean growth stages. Aboveground dry matter initially increased ($P < 0.05$; Figure 5) from mid-R5 (150 g) to mid-R6 (188 g), then decreased to HM (171 g), but ADM at HM was 14% greater ($P < 0.05$) than ADM at mid-R5. This was expected, as soybean at the end of the R6 stage begins to yellow and the leaves begin to senesce (UACES, 2014).

Seed P, Ca, Fe, Mn, Zn, Cu, and B concentrations all decreased (Figures 5 and 6) from mid-R5 to HM. Furthermore, seed P, Ca, Fe, Mn, Zn, Cu, and B concentrations were all greater ($P < 0.05$) at the mid-R5 growth stage than at the other two growth stages and were, on average, 30% greater at mid-R5 than at HM. Seed Ca concentration was also 10% greater ($P < 0.05$) at mid-R6 than at HM. It is important to remember that this study merely analyzed seed nutrient concentrations and not contents. Similarly, it was assumed that contents of some nutrients did not decrease, but that contents of other nutrients increased, therefore lowering concentrations of these nutrients at later growth stages. Uptake, partitioning, and remobilization of nutrients in soybean was studied from the 1930s to the 1970s (Bender et al., 2015); however, studies of within-seed tissue macronutrients and micronutrients are limited, as are studies of seed elemental concentrations throughout reproductive growth.

Seed N and C concentrations trended differently compared to numerous aforementioned seed nutrients (i.e., P, Ca, Fe, Mn, Zn, Cu, and B), numerically increasing from mid-R5 to HM (Figure 7). Seed N concentration was greatest ($P < 0.05$) at HM (57.6 g kg^{-1}), and was greater ($P < 0.05$) at mid-R6 (56.1 g kg^{-1}) than at mid-R5 (54.7 g kg^{-1}). Similar to seed N, seed C concentration was greatest at HM, which did not differ ($P < 0.05$) than that at mid-R6. Seed C concentration was, on average, 5% greater ($P < 0.05$) at HM and mid-R6 than at mid-R5. Nitrogen demand for soybean is greater than for other crops due to the high protein content, and this demand is met by accumulation as well as remobilization from vegetative tissue (van Roekel et al., 2015). In Illinois on a silty clay loam, Bender et al. (2015) reported one-half of total N accumulation occurred after the beginning of R5, in addition to remobilization from leaf and stem N. In Gainesville, FL, Salado-Navarro et al. (1985) reported that as rates of N relocated from vegetative tissue to seed increased, rates of senescence of vegetative tissue increased.

In contrast to ADM, seed Mg and S concentrations numerically decreased from mid-R5 to mid-R6 and subsequently increased to HM (Figure 7). Seed Mg concentration was 9% greater ($P < 0.05$) at mid-R5 and HM, which did not differ, than at mid-R6. Similar to seed Mg, seed S concentration at HM (2.1 g kg^{-1}), which did not differ from that at mid-R5 (2.06 g kg^{-1}), was greater than seed S at mid-R6 (2.02 g kg^{-1}), which also did not differ from that at mid-R5. As with yield area, seed Na concentration did not differ among growth stages (Table 6).

Rotundo and Westgate (2008) reported in a meta-analysis that differences in seed concentration primarily result from differing extents of inhibition of accumulation of individual components. This inhibition is a result of stress, either by drought, high temperatures, or low N fertility. In the meta-analysis by Rotundo and Westgate (2008), water and temperature stresses decreased protein, oil, and residual content, while supplemental N increased protein content, had no effect on oil content, and decreased residual content. While Slaton et al. (2013) reported fertilization and other management practices influenced seed nutrient concentration in Arkansas, Kleese et al. (1968) reported in Minnesota that genotypes of soybean may be more important than location or year in determination of accumulation of mineral elements. However, the methods for determination of elemental concentration of seeds in Kleese et al. (1968) was different than that used in this study.

Correlations

For the 2015 soybean growing season, seed yield, SGR, EFP, dry matter allocation coefficient (DMAC), HI, effective filling period 2 (EFP2, calculated from DMAC), seed N concentration, FASW, and planting day of year (PDOY) were linearly correlated ($P < 0.05$; Table 7) with at least one other measured or calculated variable. Yield was weakly negatively correlated with SGR ($P < 0.01$; $r = -0.31$) and seed N ($P < 0.05$; $r = -0.28$), while weakly positively correlated with EFP ($P < 0.01$; $r = 0.36$). Furthermore, yield was moderately negatively correlated ($P < 0.001$) with DMAC and PDOY ($r = -0.45$ and $r = -0.62$, respectively). Finally, yield was moderately positively correlated ($P < 0.001$; $r = 0.45$) with EFP2. It was expected that SGR would not be strongly correlated with soybean yield, as variation in SGR may cause large differences in seed number that are not related to yield (Egli, 1998).

For the correlation of soybean yield with seed N concentration, enhanced productivity (i.e., greater yields) and greater seed quality (i.e., greater protein content) are traits that are often negatively correlated (Fabre and Planchon, 2000); therefore, it was expected that seed N would not be strongly correlated with yield. Fabre and Planchon (2000) reported that soybean protein content involved N_2 fixation efficiency during the entire reproductive growth period, while yield was more related to N assimilation at the beginning of reproductive growth and high N_2 fixation rates during the R6 growth stage.

Similar to SGR and seed N concentration, differences in EFP, given the many factors that influence soybean yield, are not expected to be associated with differences in yield. However, Egli (1998) reported modification of the EFP through direct selection increased soybean yield. However, Egli (1998) also reported EFP was not related to yield. Outside of Gainesville, FL, Salado-Navarro et al. (1985) reported an average moderate negative correlation between soybean yield and DMAC (r = -0.61). Similar to SGR and EFP, because DMAC and EFP2 are inverse properties, if yield is negatively correlated with DMAC, it can be expected that yield and EFP2 be positively correlated.

As hypothesized, yield was negatively correlated with PDOY. The day of the year to plant has been studied by agronomists for many years and Egli and Cornelius (2009) reported a rapid decline in soybean yield when planting dates occurred after June 7 in Arkansas. Furthermore, research by the University of Arkansas demonstrated that soybean yield potential decreases by at least 33.6 kg ha^{-1} (0.5 bu ac^{-1}) each day for every day sown after June 15 (UACES, 2014). In a regional analysis conducted by Egli and Cornelius (2009), no agricultural factor was demonstrated to affect soybean productivity more than planting date; however, planting date effects on yield can vary considerably due to deviations in rainfall amounts and distribution, as well as other environmental factors. Nevertheless, delaying planting beyond a critical date produces soybean that do not have the same yield potential as early plantings, and shifts reproductive growth of all soybean maturity groups into a less-favorable environment later in the growing season (Bastidas et al., 2008; Egli and Bruening, 2000; Egli and Cornelius, 2009). In a regional analysis by Salmeron et al. (2016), the soybean yield response to planting date was affected by location and the maturity group choices within a location.

Seed growth rate was strongly negatively correlated ($P < 0.001$; Table 7) with EFP (r = -0.86), while moderately positively correlated ($P < 0.001$) with DMAC (r = 0.49), HI (r = 0.42), N concentration (r = 0.40), FASW (r = 0.61), and PDOY (r = 0.72). Although in the environment, SGR and EFP are independent of each other (van Roekel et al., 2015), EFP estimations were based on the SGR in this study; therefore it was expected that SGR and EFP were correlated. It was also expected that SGR and EFP have a negative correlation, since achieving a specified yield with a longer EFP permits a slower growth rate, and achieving the same yield with a shorter EFP requires a more rapid SGR (Egli, 1998). Seed growth rate and DMAC were expected to be correlated, as the calculations for deriving the values were similar, both taking into account seed weight increases from the mid-R5 to mid-R6 sample dates, as well as the FASW.

Similar to EFP, it was expected that SGR and FASW be correlated. It is intuitive that a greater SGR should lead to a greater FASW, since variation in FASW occurs due to seeds growing rapidly or slowly for longer or shorter times. Egli (1998) also reported a strong positive correlation ($r = 0.93$) between SGR and FASW for seven soybean cultivars. It was also expected that a later PDOY would lead to a greater SGR, as the EFP is reduced due to late plantings (Salmeron et al., 2016). This result is intuitive as well, since the mother plant would more quickly incorporate mass into seed if the window for translocation of mass material was shortened.

Effective filling period, derived from SGR, was moderately negatively correlated ($P < 0.001$; Table 7) with DMAC and PDOY ($r = -0.55$ and $r = -0.57$, respectively) and weakly negatively correlated with HI ($P < 0.05$; $r = -0.29$), seed N concentration ($P < 0.05$; $r = -0.24$), and FASW ($P < 0.01$; $r = -0.33$). Because SGR and DMAC were positively correlated and SGR and EFP were negatively correlated, it is intuitive that EFP and DMAC would be negatively correlated as well. Typically, a longer EFP is associated with a lower DMAC, and thus, DMAC has been suggested as an alternative to SGR, as the entire aboveground plant is accounted for in the calculation (van Roekel et al., 2015). A lower DMAC increases EFP by slowing the rate of remobilization of C and N to the soybean seed. Similar to SGR, it was expected that a later PDOY would lead to a reduction in the EFP because the amount of time for each growth stage of soybean would decrease (Bastidas et al., 2008; Salmeron et al., 2016). However, it was unexpected that FASW was negatively correlated with EFP, since van Roekel et al. (2015) reported the EFP and the resulting FASW should be positively correlated, as both are reduced by stresses including drought, high temperature, and low N fertility levels. However, seeds are usually larger (i.e., weigh more) because they have high SGR, not due to a long EFP (Egli, 1998). Final average seed weight is influenced by a combination of genetic and environmental factors. Perhaps this illustrates that the rate component of EFP determination (i.e., SGR) is a more important factor than the mass component (i.e., FASW) in calculation of the EFP for soybean.

The DMAC was strongly negatively correlated ($P < 0.001$; Table 7) with EFP2 ($r = -0.85$) and was weakly positively correlated to PDOY ($P < 0.001$; $r = 0.40$). Similar to SGR with respect to EFP, DMAC was embedded in the calculation of EFP2; therefore, it was expected that DMAC and EFP2 would be correlated.

Harvest index was weakly positively correlated with EFP2 and seed N concentration ($P < 0.01$; $r = 0.31$ and $P < 0.05$; $r = 0.24$, respectively), while moderately positively correlated ($P < 0.001$; $r = 0.49$) with FASW. Similar to FASW, it was unexpected that HI was not more strongly correlated with EFP2, since HI is necessary for the EFP2 calculation. Interest in HI, the total amount of biomass partitioned to yield, has been supported by observations that improved cultivars resulted in greater yields with no changes in total biomass (Egli, 1998). However, for soybean and other crops that senesce, HI correlations must be cautiously interpreted. Similar to yield, HI describes the final product, but explains little regarding how the final product level was achieved (Egli, 1998).

Effective filling period 2, derived from DMAC, was weakly positively correlated with FASW ($P < 0.01$; $r = 0.35$), while seed N was moderately positively correlated ($P < 0.001$) to FASW ($r =$

0.43) and PDOY (*r* = 0.49). It was expected that EFP2 and FASW would be correlated, as EFP2 and EFP are both measures of the seed-filling period and EFP2 is mathematically derived from the FASW through the HI. To the author's knowledge, research regarding correlations of seed N concentration with FASW and PDOY do not exist at present. Furthermore, FASW was moderately correlated ($P < 0.001$) to PDOY (*r* = 0.44). This coincides with research from Iowa State University that observed significant seed size differences between the first three planting dates (March 30, April 13, and April 27) and the last three planting dates (May 10, May 30, and June 6) in a study investigating PDOY effects on yield (ISU, 2009). The last three planting dates produced seeds that were, on average, 11 % heavier than seeds harvested from soybean planted at the first three dates (ISU, 2009).

Although six of eight variables had significant relationships with yield, no variable in this study was strongly correlated with yield (i.e., > ± 0.75); the only strong correlations were negative and were embedded in calculations (i.e., EFP with SGR and EFP2 with DMAC). However, the inverse relationship between yield and PDOY, as hypothesized, further validates past research studying PDOY. Nevertheless, it seems that there are other factors (i.e., genetic, agronomic and/or environmental) that should be further studied and may be greater correlated with yield.

Conclusions and Implications

Across regions in the 2015 "Grow for the Green" soybean yield contest in Arkansas, measured and calculated plant properties differed between high- and average-yield areas and across growth stages. Unexpectedly, in high- and average-yield areas, seed number increased from mid-R5 to mid-R6 and from mid-R6 to HM. However, as expected HI and FASW increased from mid-R5 to mid-R6 and from mid-R6 to HM in both yield areas.

As hypothesized, the correlation analysis demonstrated the inverse relationship between yield and PDOY. Similar to what has been reported previously (Egli and Cornelius, 2009; Heatherly and Spurlock, 1999; Purcell et al., 2007; Salmeron et al., 2016), this study further validates the importance of PDOY and its effects on yield. The trend of most yield-contest entries in Arkansas, dating back to 2002 (ASA, 2014) and the majority in this research (4 of 7 of the high-yield areas in this study) is moving towards taking advantage of the early soybean production system (ESPS) system by planting early maturing group IV varieties earlier in the season to avoid late-summer droughts and lengthen the seed-filling period. By encompassing diverse landscapes and cropping systems, this research is invaluable to soybean producers, whether or not entering areas into yield contests, across all of Arkansas.

Egli (1998) suggested that yield is predominantly source limited in the real world of the producer's field. Therefore, in order to achieve high yields, management practices should focus on maximizing photosynthate production during the entire EFP in order to increase seed number, as well as limiting stresses during the EFP to extend the EFP and increase FASW (UACES, 2014). Other factors (i.e., genetic, agronomic and/or environmental) should be further studied and may be better correlated with yield, which would further help soybean producers across Arkansas and elsewhere. Future research should mimic the approach used in this study by conducting studies on producer fields, despite the logistics, as was in the present study, being challenging.

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Table 1. Summary of the 2007 to 2012 "Grow for the Green" soybean yield contest results including the 1st- and 10th-place growers and county where the crop was harvested. For years 2011 and 2012, the contest was divided into three soybean-production categories: early season, full season, and double-cropped. Production system, variety, seeding rate, planting date, fertilizer, and soil texture data were provided by the grower. Rank and final yield were verified by the Arkansas Soybean Association (2015).

Year	Rank	County	Production System	Variety	Seeding Rate/ha[†]	Planting date	Fertilizer	Soil Surface Texture	Final Yield (kg ha^{-1})
2007	1st	Craighead	NA	Pioneer 94B73	395360	4/20	10-60-20	NA	6197
	10th	Desha	NA	Armor 47-F8	NA	NA	NA	NA	5026
2008	1st	Phillips	NA	USB 74B88	345940	5/27	NA	Silt loam	6300
	10th	Lonoke	NA	Armor 47-F8	350882	5/28	0-46-100	Silt loam	4275
2009	1st	Phillips	NA	Asgrow 4703	333585	4/29	NA	Silt loam	5887
	10th	Craighead	NA	Armor 47-F8	NA	5/19	NA	Silt loam	4125
2010	1st	Phillips	NA	Asgrow 4907	345940	4/1	40.9 kg K	Silt loam	6030
	10th	Phillips	NA	Pioneer 94M80	333585	4/5	27.2 kg K	Silt loam	4762
2011	1st	Poinsett	Early season	Pioneer 94Y70	336056	4/9	0-40-60 in fall; 45-40-40 in spring	Silt loam	6313
	10th	Clay	Full season	Pioneer 94Y70	442541	5/18	4540 kg poultry litter	Sandy loam	5383
2012	1st	Desha	Early season	Armor 4744	343469	4/1	112 kg ha^{-1} potash; 56 kg ha^{-1} urea	Buckshot	6376
	10th	Chicot	Early season	Pioneer 94Y70	395360	4/15	112 kg ha^{-1} potash	Loam	5986

[†] NA indicates not available.

Table 2. Summary of the 2013 "Grow for the Green" soybean yield contest data including the 1st- and 2nd-placed growers for each region and county where crop was harvested. 2013 was the first year the contest was broken into geographical regions. Variety, seeding rate, planting date, fertilizer, and soil texture data were provided by the grower. Rank and final yield verified by the Arkansas Soybean Association (2014).

Region	Rank	County	Variety	Seeding Rate/ha	Planting Date	Fertilizer	Soil Surface Texture	Final Yield (kg ha^{-1})
1	1st	Craighead	Pioneer 94Y70	370650	4/8	224 kg ha^{-1} potash	Fine sandy loam	5772
	2nd	Craighead	Pioneer 46T21	395360	4/20	NA	Silt loam	5634
2	1st	Clay	Pioneer 47T36	390418	5/25	0-30-90; 2 kg B	Fine sandy loam	5938
	2nd	Randolph	Pioneer 47T36	383005	5/25	69 kg ha^{-1} 0-46-0; 90 kg ha^{-1} 0-0-60; 91 kg poultry litter	Silt loam	5758
3	1st	Jackson	Pioneer 94Y23	383005	4/15	907 kg litter, potash	Sandy loam	6108
	2nd	Woodruff	Asgrow 4632	345940	5/18	0-36-72	Silt loam	6022
4	1st	Lonoke	Pioneer 94Y70	395360	4/25	336 kg ha^{-1} 0-18-36; 1814 kg poultry litter; 224 kg ha^{-1} urea	Silt loam	6339
	2nd	Arkansas	Asgrow 4633	316288	5/15	907 kg poultry litter	NA	6192
5	1st	Phillips	Asgrow 4533	296520	4/23	90 kg ha^{-1} potash	Silt loam	6262
	2nd	Phillips	Asgrow 4232	358295	4/17	NA	Silt loam	6152
6	1st	Desha	Asgrow 4632	420070	4/23	1361 kg poultry litter	NA	7232†‡
	2nd	Drew	Pioneer 93Y92	358295	4/24	112 kg ha^{-1} urea	Silt loam	6771†
7	1st	Pope	Pioneer 94Y70	370650	5/13	18-46-0, 1814 kg poultry litter	Silt loam	7044†
	2nd	Pope	Pioneer 94Y70	370650	5/13	10-46-0	Silt loam	6597

† Top 3 for the state. ‡ State record. § NA indicates not available.

Table 3. Climate and geographical data for the Arkansas counties represented in the 2015 plant sampling. Climate data were obtained from the SRCC (2015) and are 30-year normal values.

				Air Temperature		
Region	**County**	**MLRA**[†]	**Annual Precipitation (mm)**	**July (°C)**	**January (°C)**	**Annual (°C)**
1	Craighead	131A	1225	26.8	2.1	15.1
2	Cross	131A,134	1225	26.9	3.1	15.6
3	Woodruff	131A	1251	27.7	2.6	16.0
4	Lonoke	131B, 131D	1234	27.3	5.2	16.9
5	Phillips	131A, 134	1291	28.1	4.7	17.0
6	Desha	131B	1363	28.1	5.8	17.2
7	Conway	118A	1267	27.0	3.4	15.5

[†] Major Land Resource Area (2014): 118A: Arkansas Valley and Ridges, Eastern Part; 131A: Southern Mississippi River Alluvium; 131B: Arkansas River Alluvium; 131C: Red River Alluvium; 131D: Southern Mississippi River Terraces; 134: Southern Mississippi Valley Loess.

Table 4. Variety planted, planting day of year (PDOY) and final yield for high-(HY) and average- yield (AY) areas for the fields sampled in the seven regions in the "Grow for the Green" yield contest across Arkansas in 2015. Variety, PDOY, and yield from average-yield areas were reported by growers, while yields from high-yield areas were reported by growers or verified by the Arkansas Soybean Association (2014). Values are rounded.

	HY			AY		
Region	**Variety**	**PDOY**	**Yield**	**Variety**	**PDOY**	**Yield**
1	Asgrow 4633	107	6070	Asgrow 4633	100	3723
2	USG 74E88	166	4602	USG 74E88	166	4031
3	Asgrow 4632	121	7324	Pioneer 46T21	120	5913
4	Pioneer 47T36	157	5241	Pioneer 47T36	156	4770
5	Asgrow 4835	98	5375	Asgrow 4632	98	4938
6	Pioneer 47T36	98	7324	Pioneer 45T11	96	6585
7	Rev 49R94	156	2822	Pioneer 94Y70	155	2688

Table 5. Summary of minimum and maximum values for plant properties calculated from high- and average-yield areas for the seven regions in the "Grow for the Green" yield contest across Arkansas in 2015. Values are rounded.

Plant Property†	Region 1	2	3	4	5	6	7
SGR	1.37-4.00	0.88-2.14	2.11-3.08	2.24-3.67	3.20-3.96	3.61-5.18	2.89-4.27
EFP	30-72	41-99	35-50	39-64	35-48	23-39	30-40
DMAC	5.59-15.8	7.53-13.0	8.05-13.2	4.50-9.68	10.8-12.5	6.97-16.2	8.35-16.2
HI	0.50-0.60	0.39-0.53	0.37-0.61	0.52-0.67	0.41-0.65	0.52-0.72	0.48-0.60
EFP2	36-90	40-59	28-65	62-133	37-57	33-76	37-68
Seed N	5.29-5.85	5.42-5.94	5.34-5.90	5.24-6.14	5.66-6.20	5.58-6.14	5.22-6.18
FASW	99-159	78-103	97-122	132-162	121-155	121-140	111-142

† Units and abbreviations are as follows: SGR (seed growth rate), mg $seed^{-1}$ d^{-1}; EFP (effective filling period, derived from SGR), d; DMAC (dry matter allocation coefficient), d^{-1}; HI (harvest index), g g^{-1}; EFP2 (derived from DMAC), d; Seed N, %; FASW (final average seed weight), mg.

Table 6. Analysis of variance summary of the effects of yield area (i.e., high- and average-yield area), growth stage (i.e., mid-R5, mid-R6, and harvest maturity), and their interaction on selected plant properties and seed concentrations measured across Arkansas in 2015.

Variable†	Yield Area	Growth Stage	Yield Area x Growth Stage
Yield	0.010	-	-
SGR	NS‡	-	-
EFP	NS	-	-
DMAC	NS	-	-
EFP2	NS	-	-
ADM	< 0.001	< 0.001	NS‡
HI	0.007	< 0.001	0.040
Seed Number	0.001	< 0.001	0.011
Average Seed Weight	NS	< 0.001	0.023
Seed Concentration			
C	0.040	< 0.001	NS
N	NS	< 0.001	NS
P	NS	< 0.001	NS
K	< 0.001	< 0.001	0.024
Ca	NS	< 0.001	NS
Mg	NS	< 0.001	NS
S	NS	0.048	NS
Na	NS	NS	NS
Fe	NS	< 0.001	NS
Mn	NS	0.002	NS
Zn	NS	< 0.001	NS
Cu	NS	< 0.001	NS
B	0.009	< 0.001	NS

† Units and abbreviations are as follows: Yield, kg ha^{-1}; SGR (seed growth rate), mg $seed^{-1}$ d^{-1}; EFP (effective filling period, derived from SGR), d; DMAC (dry matter allocation coefficient), d^{-1}; EFP2 (derived from DMAC), d; ADM (aboveground dry matter), g; HI (harvest index), g g^{-1}; FASW (final average seed weight) mg; C, N, P, K, Ca, Mg, S, g kg^{-1}; Na, Fe, Mn, Zn, Cu, B, mg kg^{-1}.

‡ Effects and interactions that are not significant at the 0.05 level are represented by NS.

Table 7. Pairwise correlations between yield (kg ha^{-1}), seed growth rate (SGR, mg $seed^{-1}$ d^{-1}), effective filling period (derived from SGR; EFP, d), dry matter allocation coefficient (DMAC, d^{-1}), harvest index (HI, %), effective filling period 2 (derived from DMAC; EFP2, d), seed N concentration (%), final average seed weight (FASW, mg), and planting day of year (PDOY, d).

	SGR†	EFP	DMAC	HI	EFP2	Seed N	FASW	PDOY
Yield	-0.31**	0.36**	-0.45***	0.09	0.45***	-0.28*	0.21	-0.62***
SGR	-	-0.86***	0.49***	0.42***	-0.20	0.40***	0.61***	0.72***
EFP	-	-	-0.55***	-0.29*	0.35**	-0.24*	-0.33**	-0.57***
DMAC	-	-	-	0.11	-0.85***	0.17	-0.08	0.40***
HI	-	-	-	-	0.31**	0.24*	0.49***	0.20
EFP2	-	-	-	-	-	-0.07	0.35**	-0.23
Seed N	-	-	-	-	-	-	0.43***	0.49***
FASW	-	-	-	-	-	-	-	0.44***

† * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

‡ $n = 70$

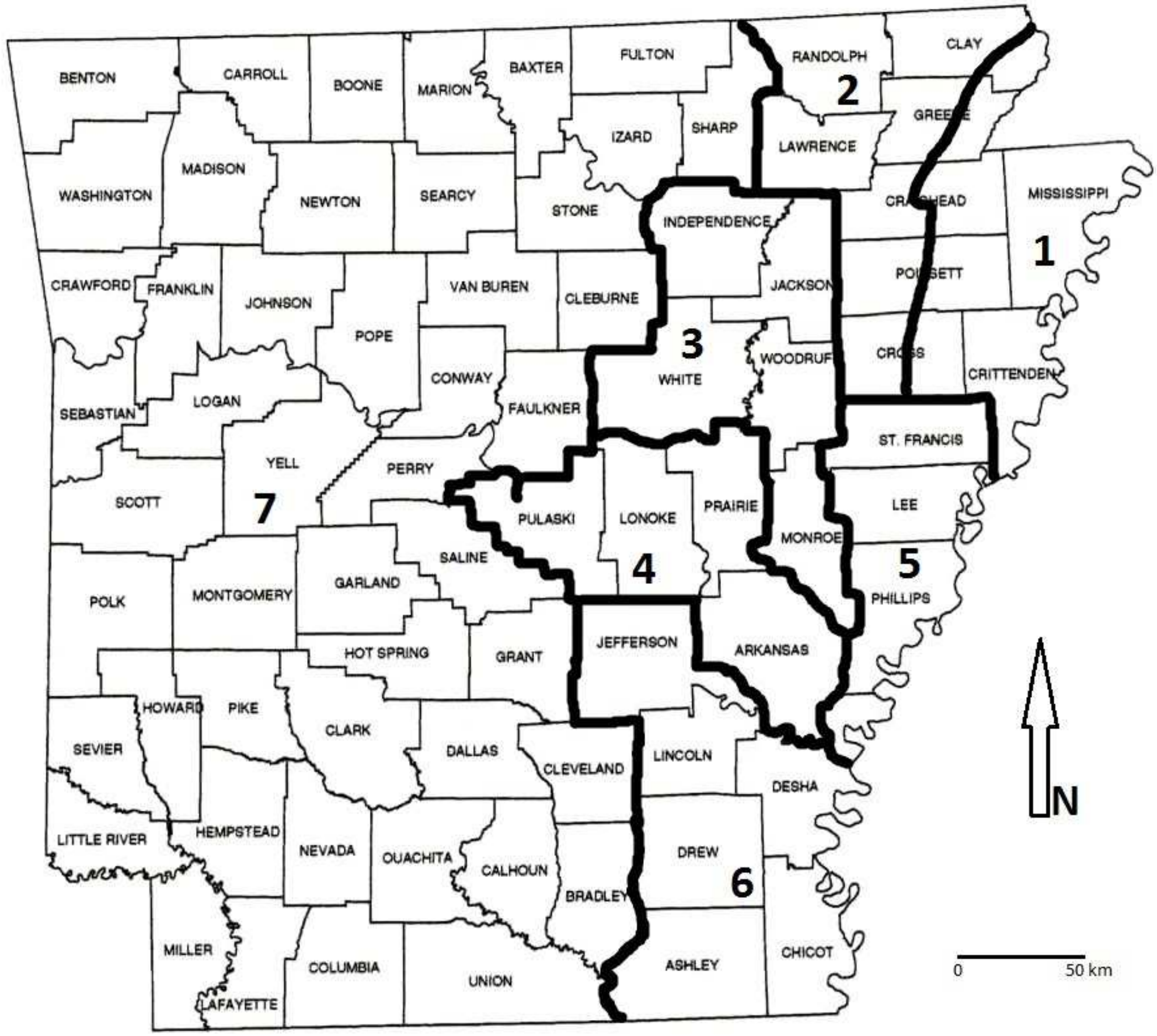

Figure 1. Seven regions for the "Grow for the Green" contest sponsored by the Arkansas Soybean Promotion Board together with the Arkansas Soybean Association. Division 1: Northeast Delta; Division 2: Northeast; Division 3: White River Basin; Division 4: Central and Grand Prairie; Division 5: East Central Delta; Division 6: Southeast Delta; Division 7: Western.

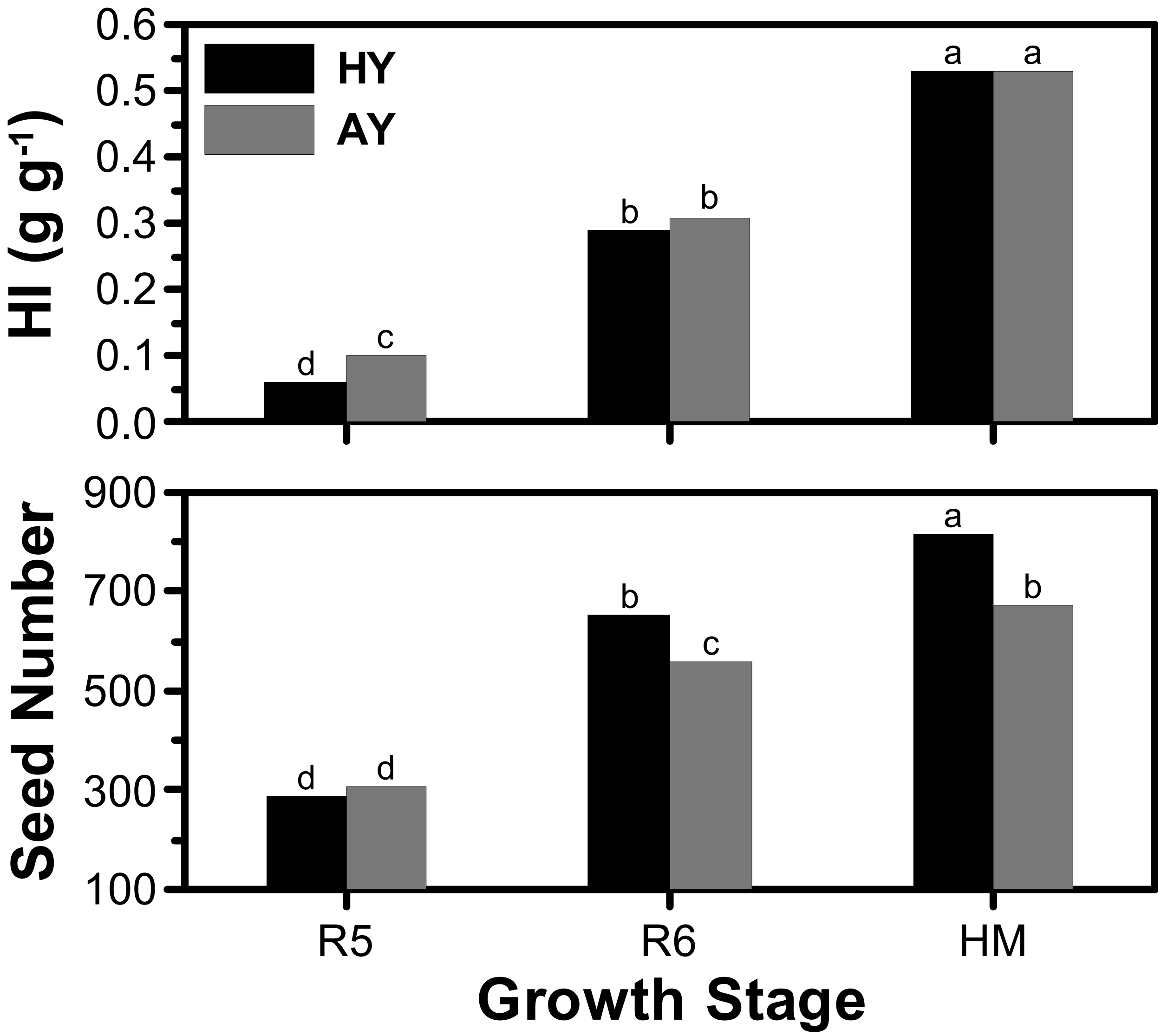

Figure 2. Soybean harvest index (HI) and seed number measured at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and harvest maturity (HM) across regions in high- (HY) and average-yield (AY) areas of the "Grow for the Green" yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at $\alpha = 0.05$.

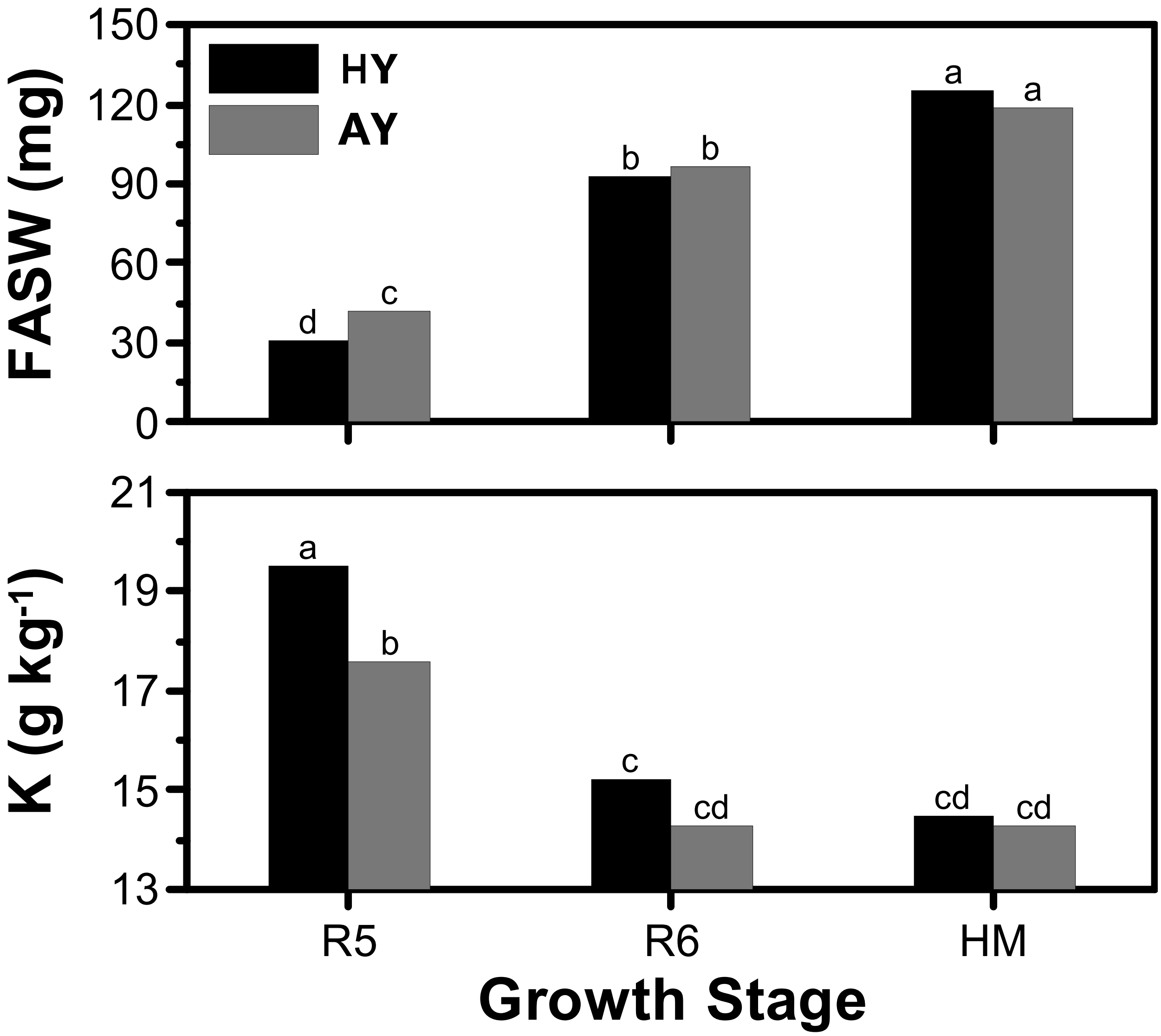

Figure 3. Soybean final average seed weight (FASW) and seed K concentration measured at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and harvest maturity (HM) across regions in high- (HY) and average-yield (AY) areas of the “Grow for the Green” yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at $\alpha = 0.05$.

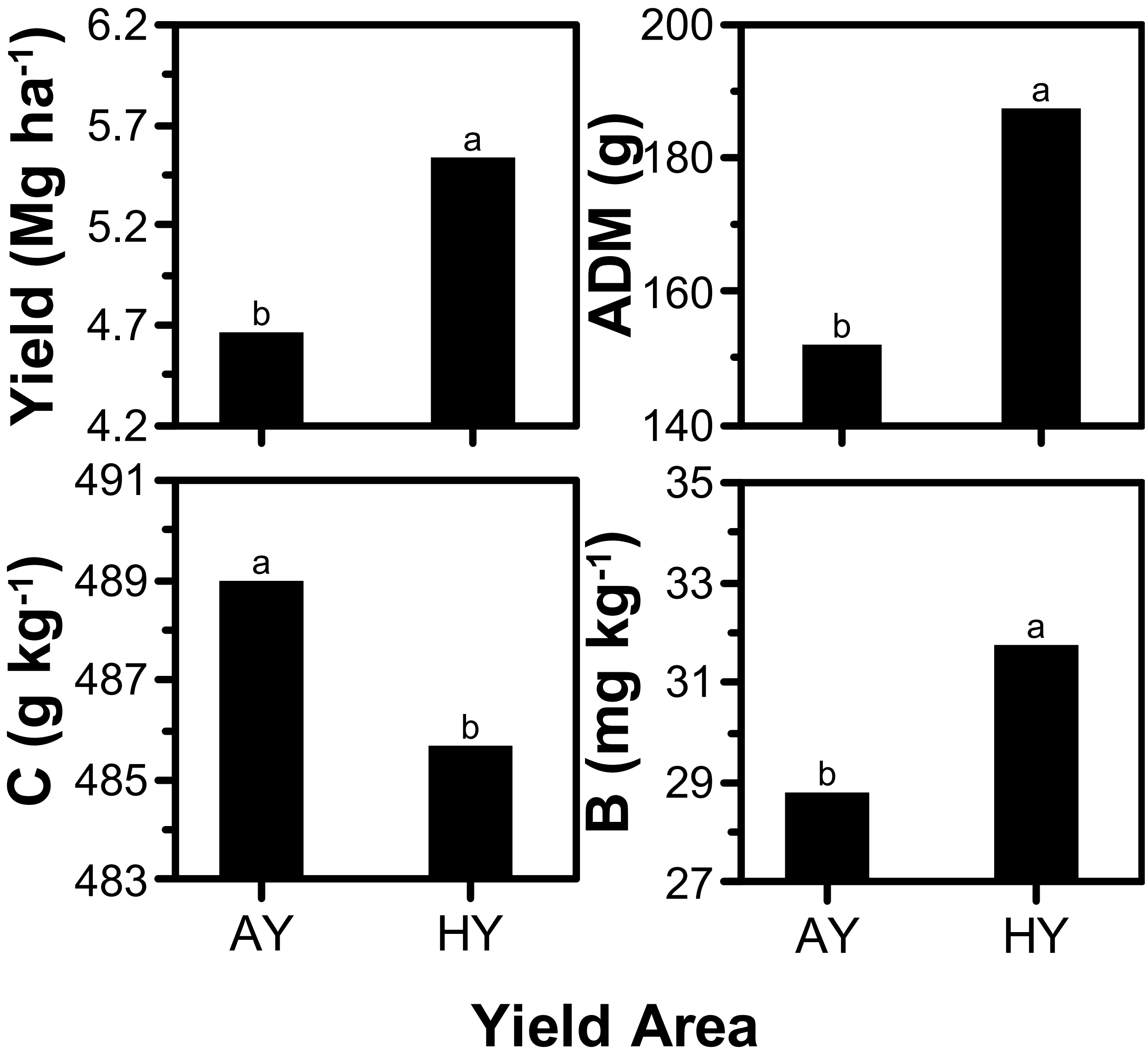

Figure 4. Soybean yield, and aboveground dry matter (ADM), and seed C and B concentrations, averaged across growth stage, measured in average- (AY) and high-yield (HY) areas of the "Grow for the Green" yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at $\alpha = 0.05$.

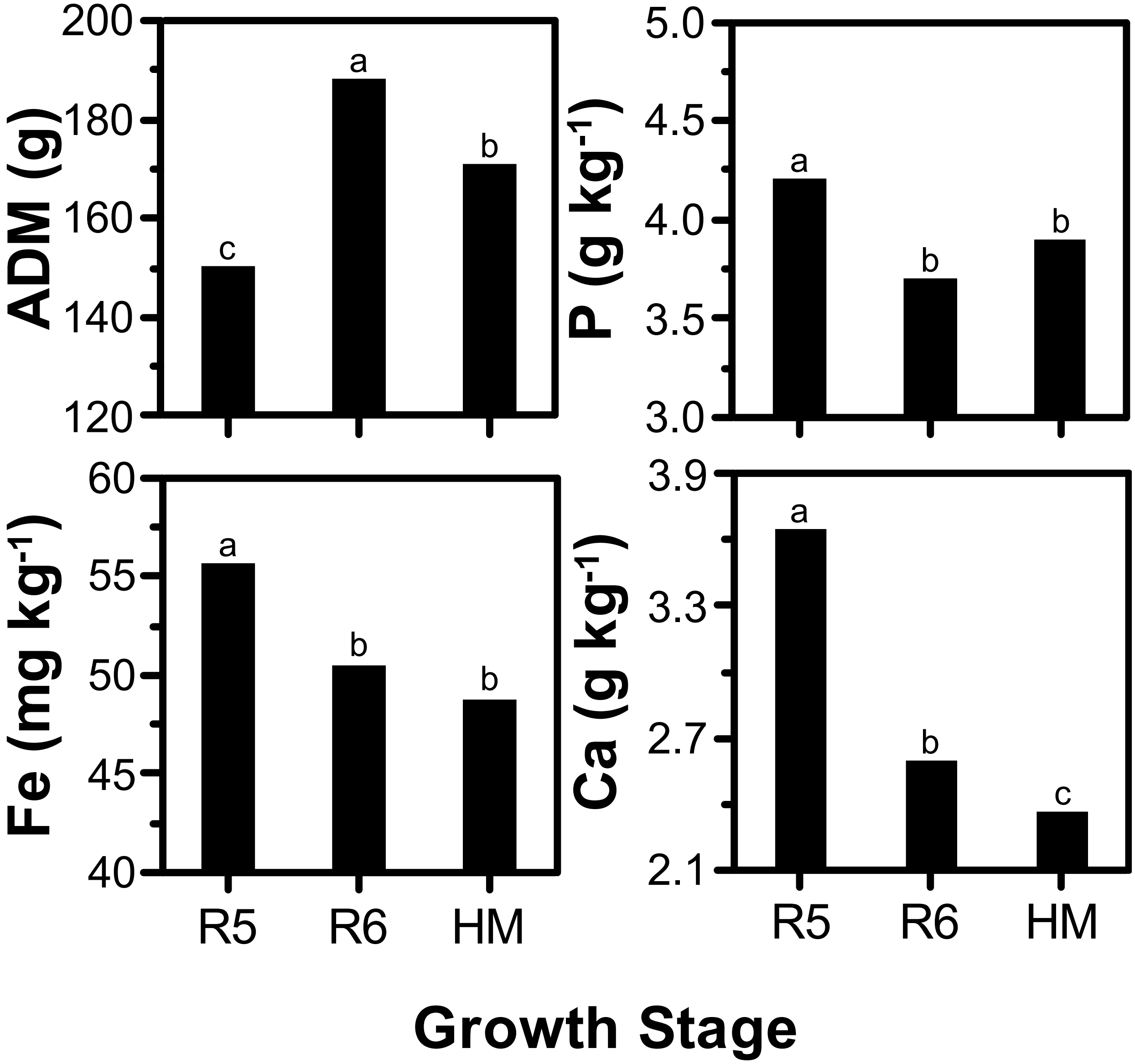

Figure 5. Soybean aboveground dry matter (ADM) and seed P, Fe, and Ca concentrations, averaged across yield area, measured at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and also at harvest maturity (HM) of the "Grow for the Green" yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at $\alpha = 0.05$.

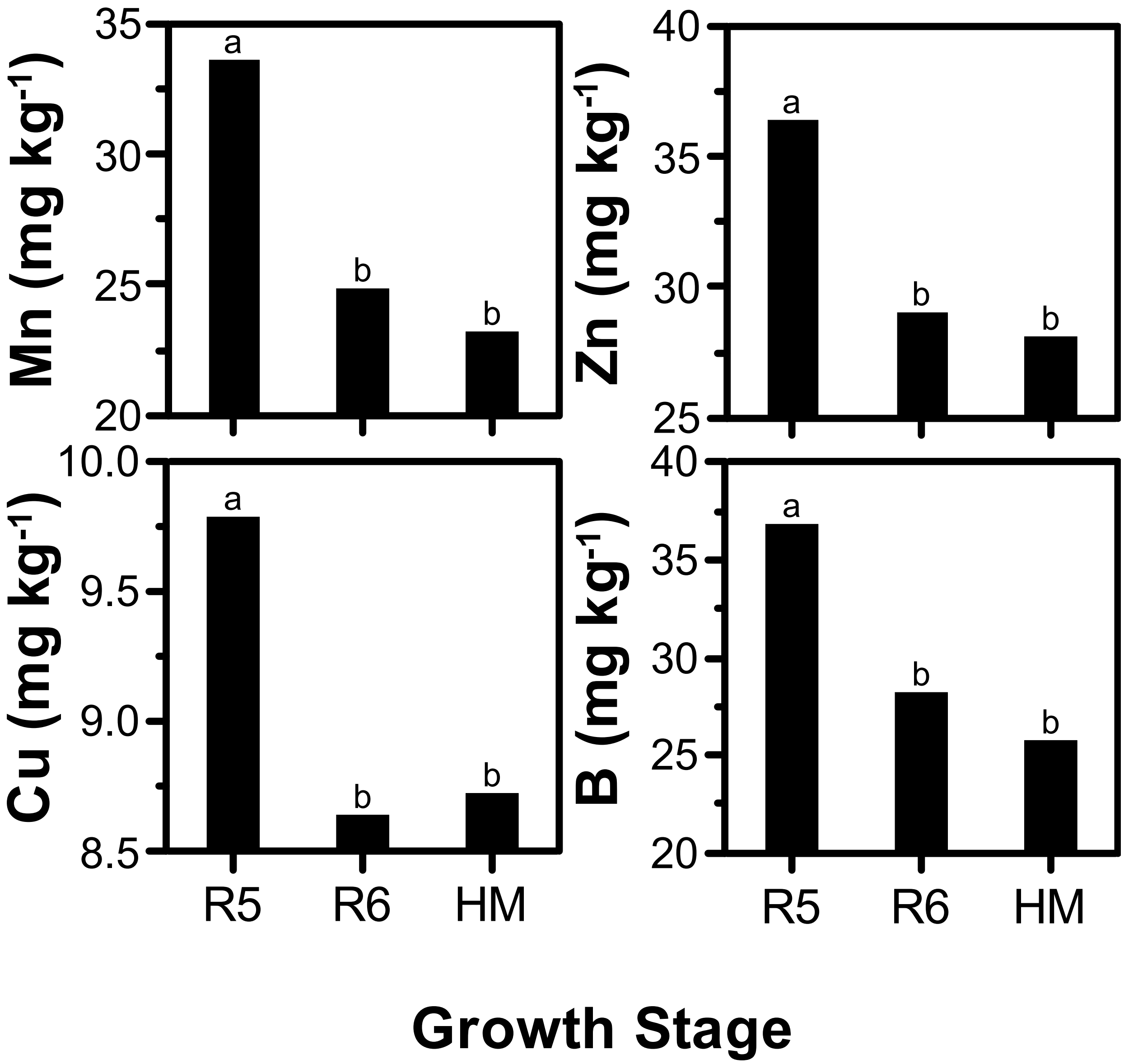

Figure 6. Soybean seed Mn, Zn, Cu, and B concentrations, averaged across yield area, measured at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and also at harvest maturity (HM) of the "Grow for the Green" yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at $\alpha = 0.05$.

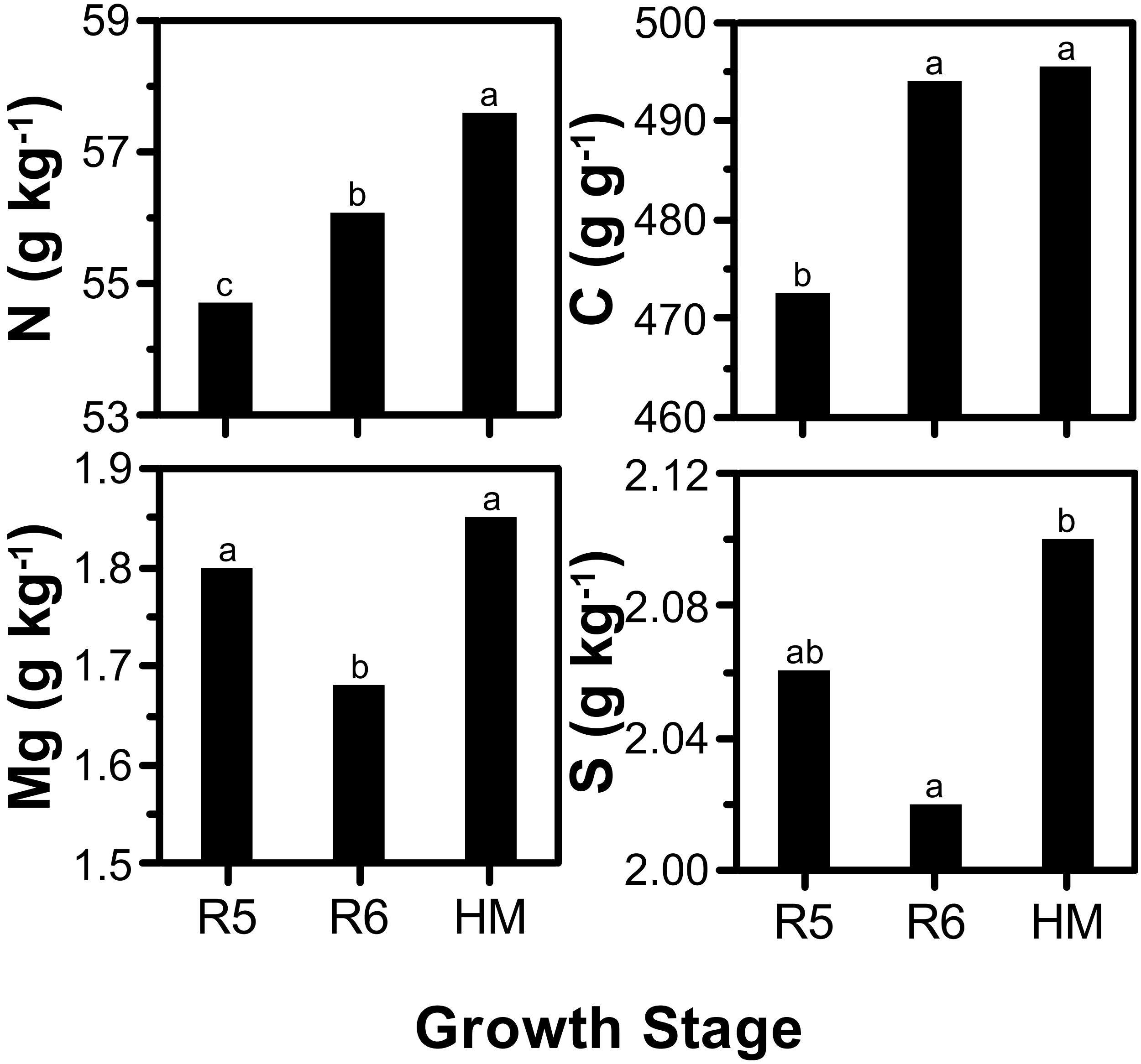

Figure 7. Soybean seed N, C, Mg, and S concentrations, averaged across region and yield area, measured at the mid-R5 and mid-R6 growth stages (as defined by Fehr et al., 1971) and also at harvest maturity (HM) of the "Grow for the Green" yield contest across Arkansas in 2015. Means with the same letter within each plant property are not significantly different at α = 0.05.

Summary and Overall Conclusions

Averaged across the 2014 and 2015 growing seasons, measured soil properties differed between high- and average-yield soybean areas and between soil depths among regions in the "Grow for the Green" yield contest in Arkansas. Soil OM was greater in average-yield areas in one region, but did not differ between yield areas in other regions. Inconsistencies occurred for total soil C and N content differences, as contents in some regions were greater in some high-yield areas than in average-yield areas, while the opposite occurred in other regions. However, in at least three regions, extractable soil P was greater in the high-yielding areas compared to the average-yielding areas. Between yield areas, there were no differences for extractable soil K and soil pH. Sand content was greater in high-yield areas in one region and did not differ between yield areas in other regions. Nevertheless, a greater clay content occurred in the average-yield areas than high-yield areas in one region, and similar to SOM and sand, clay content did not differ between yield areas in the other regions.

Multiple regression analyses of soil physical, chemical, and biological properties in the top 20 cm revealed numerous properties were significantly related to soybean yield. However, in final multiple regression models little soil property consistency existed when either the high- and average-yield-area datasets were analyzed separately or when the two datasets were combined. Additionally, regression analysis demonstrated that variations in soybean yield were less explained for the average-yield-area and the combined datasets and most explained for the high-yield-area dataset. These results revealed that the soil environment plays an important part in attaining high soybean yields.

For the 2014 and 2015 soybean growing seasons and averaged across yield area, microbial growth rate, and H, E_H, D, and E_D differed among regions for the EcoPlate™ data.

Furthermore, H and E_H were greater in high-yield than in average-yield areas across regions. For high- and average-yield areas, PCA results indicated that a variety of C substrates were utilized, but amines and amides did not greatly contribute to substrate utilization. However, in average-yield areas the greatest contributors were mostly carbohydrates, while in high-yield areas, a greater variety of C types were used.

In the 2015 soybean growing season, measured and calculated plant properties differed between high- and average-yield areas and across growth stages, averaged across regions. In both high- and average-yield areas, seed number increased from mid-R5 to mid-R6 and from mid-R6 to HM, while HI and FASW increased from mid-R5 to mid-R6 and from mid-R6 to HM in both yield areas. Correlation analysis revealed an inverse relationship between harvested yield and PDOY. This research corroborates with others, demonstrating the importance of the relationship of PDOY with yield.

This research, which incorporated diverse landscapes and cropping systems, may be invaluable to Arkansas's and other state's soybean producers. Utilizing the early soybean production system, limiting stress during the seed-filling period, maximizing photosynthate production, and site-specific management of certain soil properties may unlock the key to achieving high (i.e., greater than 6719 kg ha^{-1} or 100 bu ac^{-1}) soybean yields.

To meet the needs of an increasing global population and ensuing rise in food production efforts, continuous increases in yields are necessary to alleviate crop production expansion onto poorer quality soils, which may decrease land quality and threaten sustainability. Nevertheless, for a more complete comprehension of properties contributing to high yield, additional factors (i.e., genetic, agronomic and/or environmental) that may be more correlated with yield, beyond those evaluated in this research, may need to be further studied, while mimicking the approach of investigations on producers' fields.

Appendix A.

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Crow	2014	6	1	HY	10-20	1.4003	38.5	57.7	3.8
Crow	2014	6	1	HY	10-20	1.2733	34.2017	61.3983	4.4
Crow	2014	6	1	HY	10-20	1.38847	40.8333	56.0667	3.1
Crow	2014	6	1	HY	10-20	1.43463	38.1667	58.0333	3.8
Crow	2014	6	1	HY	10-20	1.31015	37.1257	59.5743	3.3
Crow	2014	6	1	AY	10-20	1.43985	36.7931	58.2069	5
Crow	2014	6	1	AY	10-20	1.49049	32.3333	62.3667	5.3
Crow	2014	6	1	AY	10-20	1.38345	37.6667	55.9333	6.4
Crow	2014	6	1	AY	10-20	1.43399	36.8333	56.6667	6.5
Crow	2014	6	1	AY	10-20	1.50399	37.1257	58.9743	3.9
Brantley	2014	4	2	HY	10-20	1.33734	21.9894	58.2106	19.8
Brantley	2014	4	2	HY	10-20	1.25084	28.3333	56.9667	14.7
Brantley	2014	4	2	HY	10-20	1.33399	26.5197	57.2803	16.2
Brantley	2014	4	2	HY	10-20	1.25719	26.4804	58.6196	14.9
Brantley	2014	4	2	HY	10-20	1.39158	29.1417	55.4583	15.4
Brantley	2014	4	2	AY	10-20	1.28606	27.6887	54.2113	18.1
Brantley	2014	4	2	AY	10-20	1.20158	23.9854	56.2146	19.8
Brantley	2014	4	2	AY	10-20	1.35463	22.1557	57.5443	20.3
Brantley	2014	4	2	AY	10-20	1.29355	34.1317	55.1683	10.7
Brantley	2014	4	2	AY	10-20	1.22749	33.8333	54.8667	11.3
Bevis	2014	4	1	HY	10-20	1.36542	39.9534	57.7466	2.3
Bevis	2014	4	1	HY	10-20	1.40562	24.6667	71.5333	3.8
Bevis	2014	4	1	HY	10-20	1.15453	27.8333	67.7667	4.4
Bevis	2014	4	1	HY	10-20	1.31966	24.6667	71.0333	4.3
Bevis	2014	4	1	HY	10-20	1.15709	23.6807	73.0193	3.3
Bevis	2014	4	1	AY	10-20	1.47823	23.1797	72.0203	4.8
Bevis	2014	4	1	AY	10-20	1.49724	22.322	73.178	4.5
Bevis	2014	4	1	AY	10-20	1.24414	27.5217	67.5783	4.9
Bevis	2014	4	1	AY	10-20	1.40729	22.8333	72.2667	4.9
Bevis	2014	4	1	AY	10-20	1.37695	20.4923	75.0077	4.5
Miles	2014	6	2	HY	10-20	1.36187	32.6667	63.4333	3.9
Miles	2014	6	2	HY	10-20	1.28217	11.843	68.357	19.8
Miles	2014	6	2	HY	10-20	1.36562	11.6566	69.5434	18.8

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Miles	2014	6	2	HY	10-20	1.32025	14.1717	67.1283	18.7
Miles	2014	6	2	HY	10-20	1.35911	14	66.8	19.2
Miles	2014	6	2	AY	10-20	1.34847	14.5	65.5	20
Miles	2014	6	2	AY	10-20	1.30118	10.4876	69.2124	20.3
Miles	2014	6	2	AY	10-20	1.19118	12.1667	67.0333	20.8
Miles	2014	6	2	AY	10-20	1.27384	13.4937	66.7063	19.8
Miles	2014	6	2	AY	10-20	1.36251	12.5	68.1	19.4
Taylor	2014	5	1	HY	10-20	1.40054	8.81764	57.6824	33.5
Taylor	2014	5	1	HY	10-20	1.41291	12.5	59.1	28.4
Taylor	2014	5	1	HY	10-20	1.45946	8.48363	60.3164	31.2
Taylor	2014	5	1	HY	10-20	1.49729	10.6667	59.7333	29.6
Taylor	2014	5	1	HY	10-20	1.48468	10.6546	61.5454	27.8
Taylor	2014	5	1	AY	10-20	1.39059	0.33333	51.1667	48.5
Taylor	2014	5	1	AY	10-20	1.39315	10.9886	58.2114	30.8
Taylor	2014	5	1	AY	10-20	1.34443	5.14362	49.4564	45.4
Taylor	2014	5	1	AY	10-20	1.37498	10.845	62.955	26.2
Taylor	2014	5	1	AY	10-20	1.50946	8.33333	52.3667	39.3
Culp	2014	5	2	HY	10-20	1.45916	13.3267	57.7733	28.9
Culp	2014	5	2	HY	10-20	1.45542	10.8216	58.8784	30.3
Culp	2014	5	2	HY	10-20	1.42645	9.84697	59.353	30.8
Culp	2014	5	2	HY	10-20	1.37034	5.31062	50.6894	44
Culp	2014	5	2	HY	10-20	1.43828	9.5	58.1	32.4
Culp	2014	5	2	AY	10-20	1.22941	11.3226	58.7774	29.9
Culp	2014	5	2	AY	10-20	1.28286	8.48363	56.8164	34.7
Culp	2014	5	2	AY	10-20	1.36502	6.81363	59.9864	33.2
Culp	2014	5	2	AY	10-20	1.4231	4.47562	49.9244	45.6
Culp	2014	5	2	AY	10-20	1.39108	7.85096	56.149	36
Martin	2014	2	2	HY	10-20	1.43276	6.66667	73.5333	19.8
Martin	2014	2	2	HY	10-20	1.34645	23.1667	58.5333	18.3
Martin	2014	2	2	HY	10-20	1.48281	23.8477	57.2523	18.9
Martin	2014	2	2	HY	10-20	1.27744	17.6687	65.1313	17.2
Martin	2014	2	2	HY	10-20	1.29601	20.3333	61.7667	17.9

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	**Year**	**Region**	**Site**	**HY/AY**	**Depth**	**Bulk density (g cm-3)**	**Sand %**	**Silt %**	**Clay %**
Martin	2014	2	2	AY	10-20	1.38153	8.0173	72.5827	19.4
Martin	2014	2	2	AY	10-20	1.29734	18.829	61.771	19.4
Martin	2014	2	2	AY	10-20	1.27581	22.5	59.1	18.4
Martin	2014	2	2	AY	10-20	1.43695	12.6747	68.5253	18.8
Martin	2014	2	2	AY	10-20	1.38138	18.1697	63.0303	18.8
Haigwood	2014	3	1	HY	10-20	1.38463	15.6647	66.9353	17.4
Haigwood	2014	3	1	HY	10-20	1.28153	10.3206	70.7794	18.9
Haigwood	2014	3	1	HY	10-20	1.30227	6.33333	70.6667	23
Haigwood	2014	3	1	HY	10-20	1.42478	8.66667	71.9333	19.4
Haigwood	2014	3	1	HY	10-20	1.37754	8.31663	72.8834	18.8
Haigwood	2014	3	1	AY	10-20	1.45473	11.9906	69.6094	18.4
Haigwood	2014	3	1	AY	10-20	1.35202	7.48163	72.1184	20.4
Haigwood	2014	3	1	AY	10-20	1.46369	5.68862	59.8114	34.5
Haigwood	2014	3	1	AY	10-20	1.46709	5.97862	72.1214	21.9
Haigwood	2014	3	1	AY	10-20	1.42345	6.47963	71.0204	22.5
Galloway	2014	3	2	HY	10-20	1.61094	37.0407	44.0593	18.9
Galloway	2014	3	2	HY	10-20	1.4935	58.5828	24.5172	16.9
Galloway	2014	3	2	HY	10-20	1.49256	39.8333	41.6667	18.5
Galloway	2014	3	2	HY	10-20	1.40355	41.2158	39.7842	19
Galloway	2014	3	2	HY	10-20	1.53099	49.5658	33.0342	17.4
Galloway	2014	3	2	AY	10-20	1.50877	39.2881	41.3119	19.4
Galloway	2014	3	2	AY	10-20	1.41591	53.9078	27.6922	18.4
Galloway	2014	3	2	AY	10-20	1.46034	30.6947	47.4053	21.9
Galloway	2014	3	2	AY	10-20	1.44438	40.8333	38.7667	20.4
Galloway	2014	3	2	AY	10-20	1.46906	53.3333	27.7667	18.9
Moore	2014	7	1	HY	10-20	1.52266	6.64663	60.6534	32.7
Moore	2014	7	1	HY	10-20	1.4664	6.68663	61.3134	32
Moore	2014	7	1	HY	10-20	1.44621	4.30862	55.1914	40.5
Moore	2014	7	1	HY	10-20	1.41685	3.97462	55.1254	40.9
Moore	2014	7	1	HY	10-20	1.39985	3.5	59.1	37.4
Moore	2014	7	1	AY	10-20	1.36143	6.02129	59.4787	34.5
Moore	2014	7	1	AY	10-20	1.41069	4.19162	59.7084	36.1

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Moore	2014	7	1	AY	10-20	1.32931	0.9686	52.7314	46.3
Moore	2014	7	1	AY	10-20	1.37788	2.02927	52.8707	45.1
Moore	2014	7	1	AY	10-20	1.3102	3.5	56.9	39.6
Fisher	2014	2	1	HY	10-20	1.33305	5.31062	71.7894	22.9
Fisher	2014	2	1	HY	10-20	1.1631	4.80962	74.5904	20.6
Fisher	2014	2	1	HY	10-20	1.33695	5.5	74.2	20.3
Fisher	2014	2	1	HY	10-20	1.25064	4.14162	74.5584	21.3
Fisher	2014	2	1	HY	10-20	1.28635	4.33333	75.9667	19.7
Fisher	2014	2	1	AY	10-20	1.23734	4.64262	70.5574	24.8
Fisher	2014	2	1	AY	10-20	1.32483	1.66667	74.4333	23.9
Fisher	2014	2	1	AY	10-20	1.29714	4.02528	74.1747	21.8
Fisher	2014	2	1	AY	10-20	1.24562	4.35795	72.342	23.3
Fisher	2014	2	1	AY	10-20	1.35325	4.16667	73.1333	22.7
Qualls	2014	1	1	HY	10-20	1.36719	5.76667	67.2333	27
Qualls	2014	1	1	HY	10-20	1.53059	8.16667	69.6333	22.2
Qualls	2014	1	1	HY	10-20	1.40803	5.02329	72.0767	22.9
Qualls	2014	1	1	HY	10-20	1.46547	4.83333	73.2667	21.9
Qualls	2014	1	1	HY	10-20	1.31828	6.31263	70.9874	22.7
Qualls	2014	1	1	AY	10-20	1.43611	4.47562	65.9244	29.6
Qualls	2014	1	1	AY	10-20	1.3632	3.02728	63.0727	33.9
Qualls	2014	1	1	AY	10-20	1.49433	1.33333	71.6667	27
Qualls	2014	1	1	AY	10-20	1.24236	1.5	70.3	28.2
Qualls	2014	1	1	AY	10-20	1.28315	0.83333	69.5667	29.6
Bingham	2014	1	2	HY	10-20	1.27369	7.31463	72.4854	20.2
Bingham	2014	1	2	HY	10-20	1.28759	6.81363	74.9864	18.2
Bingham	2014	1	2	HY	10-20	1.3302	5.66667	75.5333	18.8
Bingham	2014	1	2	HY	10-20	1.35049	4.83333	76.9667	18.2
Bingham	2014	1	2	HY	10-20	1.33296	11.8236	72.2764	15.9
Bingham	2014	1	2	AY	10-20	1.36468	15.6647	69.0353	15.3
Bingham	2014	1	2	AY	10-20	1.31552	13.1737	72.0263	14.8
Bingham	2014	1	2	AY	10-20	1.34296	10.1796	73.3204	16.5
Bingham	2014	1	2	AY	10-20	1.24892	12	74.5	13.5

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Bingham	2014	1	2	AY	10-20	1.24724	10.845	74.255	14.9
Lowe	2014	7	2	HY	10-20	1.32862	15.1637	70.9363	13.9
Lowe	2014	7	2	HY	10-20	1.39685	17	70.1	12.9
Lowe	2014	7	2	HY	10-20	1.26443	13.5063	71.5937	14.9
Lowe	2014	7	2	AY	10-20	1.32956	19.5057	66.0943	14.4
Lowe	2014	7	2	AY	10-20	1.28635	16.1657	69.8343	14
Lowe	2014	7	2	AY	10-20	1.31389	14.9967	70.0033	15
Crow	2014	6	1	HY	0-10	1.25887	14.6627	70.9373	14.4
Crow	2014	6	1	HY	0-10	1.19379	14.3287	70.7713	14.9
Crow	2014	6	1	HY	0-10	1.24291	13.4937	71.0063	15.5
Crow	2014	6	1	HY	0-10	1.24621	13.3267	72.2733	14.4
Crow	2014	6	1	HY	0-10	1.24374	48.1667	34.2333	17.6
Crow	2014	6	1	AY	0-10	1.31241	40	42.5	17.5
Crow	2014	6	1	AY	0-10	1.15724	43.3868	41.6132	15
Crow	2014	6	1	AY	0-10	1.27739	45.8333	37.1667	17
Crow	2014	6	1	AY	0-10	1.33813	45.9415	37.6585	16.4
Crow	2014	6	1	AY	0-10	1.33153	46.2258	35.5742	18.2
Brantley	2014	4	2	HY	0-10	1.24916	37.3333	45.1667	17.5
Brantley	2014	4	2	HY	0-10	1.11325	41.9494	42.5506	15.5
Brantley	2014	4	2	HY	0-10	1.20409	46.3928	36.4072	17.2
Brantley	2014	4	2	HY	0-10	1.16719	47.3333	36.6667	16
Brantley	2014	4	2	HY	0-10	1.20803	46.0588	38.9412	15
Brantley	2014	4	2	AY	0-10	1.1769	47.1058	38.5942	14.3
Brantley	2014	4	2	AY	0-10	1.03961	48.7691	37.9309	13.3
Brantley	2014	4	2	AY	0-10	1.14113	48.2298	37.8702	13.9
Brantley	2014	4	2	AY	0-10	0.82236	47.6048	38.4952	13.9
Brantley	2014	4	2	AY	0-10	0.94315	48.8978	39.1022	12
Bevis	2014	4	1	HY	0-10	1.23025	48.2298	38.6702	13.1
Bevis	2014	4	1	HY	0-10	1.32606	49.0648	41.8352	9.1
Bevis	2014	4	1	HY	0-10	1.1068	50.1667	38.8333	11
Bevis	2014	4	1	HY	0-10	1.24596	51.0978	37.8022	11.1
Bevis	2014	4	1	HY	0-10	1.12404	57.0808	33.9192	9

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Bevis	2014	4	1	AY	0-10	1.34458	57.1667	32.3333	10.5
Bevis	2014	4	1	AY	0-10	1.26044	61.5768	27.9232	10.5
Bevis	2014	4	1	AY	0-10	1.23128	73.9479	17.4521	8.6
Bevis	2014	4	1	AY	0-10	1.37916	49.3988	40.0012	10.6
Bevis	2014	4	1	AY	0-10	1.26468	55.1667	35.8333	9
Miles	2014	6	2	HY	0-10	1.18498	54.4088	34.4912	11.1
Miles	2014	6	2	HY	0-10	1.26079	58.4165	31.5835	10
Miles	2014	6	2	HY	0-10	1.3197	73.5529	17.5471	8.9
Miles	2014	6	2	HY	0-10	1.21522	49.6667	39.8333	10.5
Miles	2014	6	2	HY	0-10	1.22379	74.7829	16.2171	9
Miles	2014	6	2	AY	0-10	1.18128	69.9399	20.5601	9.5
Miles	2014	6	2	AY	0-10	1.11246	67.4349	22.5651	10
Miles	2014	6	2	AY	0-10	1.07778	76.8796	13.3204	9.8
Miles	2014	6	2	AY	0-10	1.15064	78.0439	13.5561	8.4
Miles	2014	6	2	AY	0-10	1.13833	74.5	16.6	8.9
Taylor	2014	5	1	HY	0-10	1.31074	74.6667	16.3333	9
Taylor	2014	5	1	HY	0-10	1.30118	65.8333	23.6667	10.5
Taylor	2014	5	1	HY	0-10	1.35217	77.5	12.6	9.9
Taylor	2014	5	1	HY	0-10	1.41478	75.4509	15.4491	9.1
Taylor	2014	5	1	HY	0-10	1.37433	27.5217	56.3783	16.1
Taylor	2014	5	1	AY	0-10	1.21227	37.9574	49.0426	13
Taylor	2014	5	1	AY	0-10	1.08591	44.3888	43.6112	12
Taylor	2014	5	1	AY	0-10	0.9598	36.8737	48.0263	15.1
Taylor	2014	5	1	AY	0-10	1.0569	38	49.4	12.6
Taylor	2014	5	1	AY	0-10	1.15128	26.0187	56.6813	17.3
Culp	2014	5	2	HY	0-10	1.27739	38.8778	49.3222	11.8
Culp	2014	5	2	HY	0-10	1.2869	43.6128	44.5872	11.8
Culp	2014	5	2	HY	0-10	1.30192	39.4544	44.7456	15.8
Culp	2014	5	2	HY	0-10	1.16113	38.2901	50.4099	11.3
Culp	2014	5	2	HY	0-10	1.32961	12.1576	58.3424	29.5
Culp	2014	5	2	AY	0-10	1.40882	10.6546	58.4454	30.9
Culp	2014	5	2	AY	0-10	1.24433	10.4876	55.6124	33.9

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Culp	2014	5	2	AY	0-10	1.20153	10.1667	57.8333	32
Culp	2014	5	2	AY	0-10	1.33468	11.8333	55.9667	32.2
Culp	2014	5	2	AY	0-10	1.21744	9.5	50.3	40.2
Martin	2014	2	2	HY	0-10	1.33837	8.83333	52.2667	38.9
Martin	2014	2	2	HY	0-10	1.30498	8.5163	51.5837	39.9
Martin	2014	2	2	HY	0-10	1.28424	7.85096	53.449	38.7
Martin	2014	2	2	HY	0-10	1.25069	8.18363	48.5164	43.3
Martin	2014	2	2	HY	0-10	1.29596	11.8333	76.8667	11.3
Martin	2014	2	2	AY	0-10	1.22675	15.3333	77.0667	7.6
Martin	2014	2	2	AY	0-10	1.32207	14.338	78.162	7.5
Martin	2014	2	2	AY	0-10	1.29118	14.1667	76.6333	9.2
Martin	2014	2	2	AY	0-10	1.27153	12.6587	78.7413	8.6
Martin	2014	2	2	AY	0-10	1.28783	10.8333	74.3667	14.8
Haigwood	2014	3	1	HY	0-10	1.23384	12	79.4	8.6
Haigwood	2014	3	1	HY	0-10	1.35128	13.4937	78.7063	7.8
Haigwood	2014	3	1	HY	0-10	1.2697	11.8236	77.9764	10.2
Haigwood	2014	3	1	HY	0-10	1.39719	12.5	79.3	8.2
Haigwood	2014	3	1	HY	0-10	1.16897	12.6587	79.7413	7.6
Haigwood	2014	3	1	AY	0-10	1.36852	9.68064	81.1194	9.2
Haigwood	2014	3	1	AY	0-10	1.27783	9.66667	81.2333	9.1
Haigwood	2014	3	1	AY	0-10	1.25498	10.3333	82.0667	7.6
Haigwood	2014	3	1	AY	0-10	1.32734	11.0113	81.3887	7.6
Haigwood	2014	3	1	AY	0-10	1.3368	9.65264	81.7474	8.6
Galloway	2014	3	2	HY	0-10	1.33749	9.31864	79.7814	10.9
Galloway	2014	3	2	HY	0-10	1.47833	10.0133	78.6867	11.3
Galloway	2014	3	2	HY	0-10	1.40039	8.66667	80.4333	10.9
Galloway	2014	3	2	HY	0-10	1.34493	8.81764	79.2824	11.9
Galloway	2014	3	2	HY	0-10	1.39975	39.6208	51.1792	9.2
Galloway	2014	3	2	AY	0-10	1.38985	43.3333	47.8667	8.8
Galloway	2014	3	2	AY	0-10	1.30094	39.7651	50.8349	9.4
Galloway	2014	3	2	AY	0-10	1.38867	38.7108	52.9892	8.3
Galloway	2014	3	2	AY	0-10	1.34798	37.9574	52.8426	9.2

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Galloway	2014	3	2	AY	0-10	1.3435	36.9594	53.2406	9.8
Moore	2014	7	1	HY	0-10	1.41089	41.6667	48.9333	9.4
Moore	2014	7	1	HY	0-10	1.33768	37.1667	51.0333	11.8
Moore	2014	7	1	HY	0-10	1.35616	38.2098	52.8902	8.9
Moore	2014	7	1	HY	0-10	1.29818	37.7088	52.8912	9.4
Moore	2014	7	1	HY	0-10	1.34167	44.5	45.2	10.3
Moore	2014	7	1	AY	0-10	1.24611	43.5538	46.6462	9.8
Moore	2014	7	1	AY	0-10	1.23374	53.9078	34.2922	11.8
Moore	2014	7	1	AY	0-10	1.27054	58	33.2	8.8
Moore	2014	7	1	AY	0-10	1.1768	39.3788	50.3212	10.3
Moore	2014	7	1	AY	0-10	1.23906	45.2761	45.1239	9.6
Fisher	2014	2	1	HY	0-10	1.11182	44.3333	46.2667	9.4
Fisher	2014	2	1	HY	0-10	0.92094	55	32.1	12.9
Fisher	2014	2	1	HY	0-10	1.08645	55.5	35.7	8.8
Fisher	2014	2	1	HY	0-10	1.03473	30.3333	54.8667	14.8
Fisher	2014	2	1	HY	0-10	1.06818	54.9098	28.5902	16.5
Fisher	2014	2	1	AY	0-10	1.04448	61.4105	24.7895	13.8
Fisher	2014	2	1	AY	0-10	0.94025	57.0808	27.6192	15.3
Fisher	2014	2	1	AY	0-10	0.98325	61.2558	23.7442	15
Fisher	2014	2	1	AY	0-10	0.9533	56.8333	26.7667	16.4
Fisher	2014	2	1	AY	0-10	1.07005	57.5848	25.6152	16.8
Qualls	2014	1	1	HY	0-10	1.2968	57.9158	20.9842	21.1
Qualls	2014	1	1	HY	0-10	1.31286	52.3333	27.0667	20.6
Qualls	2014	1	1	HY	0-10	1.2597	56.2458	21.5542	22.2
Qualls	2014	1	1	HY	0-10	1.31522	50.7651	25.6349	23.6
Qualls	2014	1	1	HY	0-10	1.21966	46.5	33	20.5
Qualls	2014	1	1	AY	0-10	1.27665	50.2338	30.5662	19.2
Qualls	2014	1	1	AY	0-10	1.26429	50.7651	30.1349	19.1
Qualls	2014	1	1	AY	0-10	1.33113	50.0998	32.0002	17.9
Qualls	2014	1	1	AY	0-10	1.23754	51.4305	29.1695	19.4
Qualls	2014	1	1	AY	0-10	1.23778	47.5618	31.3382	21.1
Bingham	2014	1	2	HY	0-10	1.17818	48.7308	30.1692	21.1

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Bingham	2014	1	2	HY	0-10	1.36601	50.2661	28.2339	21.5
Bingham	2014	1	2	HY	0-10	0.86823	49.2318	30.7682	20
Bingham	2014	1	2	HY	0-10	1.26631	51.6667	27.8333	20.5
Bingham	2014	1	2	HY	0-10	1.23251	6.48855	44.5115	49
Bingham	2014	1	2	AY	0-10	1.00966	6.66667	53.8333	39.5
Bingham	2014	1	2	AY	0-10	1.12601	6.33333	49.2667	44.4
Bingham	2014	1	2	AY	0-10	1.19256	7.83333	48.8667	43.3
Bingham	2014	1	2	AY	0-10	1.1068	9.98664	46.2134	43.8
Bingham	2014	1	2	AY	0-10	1.25325	5.47762	45.3224	49.2
Lowe	2014	7	2	HY	0-10	1.18555	6.83333	36.7667	56.4
Lowe	2014	7	2	HY	0-10	1.1297	8.65063	38.4494	52.9
Lowe	2014	7	2	HY	0-10	1.18555	8.29772	43.0023	48.7
Lowe	2014	7	2	HY	0-10	1.29842	10	42.2	47.8
Lowe	2014	7	2	HY	0-10	1.12852	9.48564	45.0144	45.5
Lowe	2014	7	2	AY	0-10	1.26097	9.5143	40.3857	50.1
Lowe	2014	7	2	AY	0-10	1.1967	10.6667	40.5333	48.8
Lowe	2014	7	2	AY	0-10	1.26097	10.3333	36.3667	53.3
Lowe	2014	7	2	AY	0-10	1.25793	12.3333	27.8667	59.8
Lowe	2014	7	2	AY	0-10	1.32828	12.8333	31.7667	55.4
Miles	2015	6	1	HY	0-10	1.26414	28	65.6341	6.36586
Miles	2015	6	1	HY	0-10	1.20542	22.6667	69.5288	7.80458
Miles	2015	6	1	HY	0-10	1.16542	22.3447	69.8817	7.77363
Miles	2015	6	1	HY	0-10	1.24261	22.1667	69.0154	8.81792
Miles	2015	6	1	HY	0-10	1.2231	21.1757	70.0398	8.78448
Miles	2015	6	1	HY	10-20	1.40128	23.8477	65.8514	10.3009
Miles	2015	6	1	HY	10-20	1.33148	22.6547	70.0172	7.32809
Miles	2015	6	1	HY	10-20	1.3269	19.5057	69.5666	10.9277
Miles	2015	6	1	HY	10-20	1.32015	20.6747	70.4897	8.83559
Miles	2015	6	1	HY	10-20	1.27626	20.5	69.1033	10.3967
Miles	2015	6	1	AY	0-10	1.18507	21.6667	68.502	9.83138
Miles	2015	6	1	AY	0-10	1.15005	20.8417	64.5797	14.5786
Miles	2015	6	1	AY	0-10	1.15557	17.4983	53.915	28.5866

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Miles	2015	6	1	AY	0-10	1.22	21.1757	64.4019	14.4224
Miles	2015	6	1	AY	0-10	1.22911	21.324	64.1556	14.5204
Miles	2015	6	1	AY	10-20	1.28547	21.324	65.8291	12.8468
Miles	2015	6	1	AY	10-20	1.4197	17.6667	60.6638	21.6695
Miles	2015	6	1	AY	10-20	1.31704	14.1717	52.6968	33.1315
Miles	2015	6	1	AY	10-20	1.3102	19.9933	62.931	17.0756
Miles	2015	6	1	AY	10-20	1.28695	20.5077	63.8031	15.6892
Qualls	2015	1	1	HY	0-10	1.33172	33.7991	57.8571	8.34387
Qualls	2015	1	1	HY	0-10	1.34823	40.8333	52.5	6.66667
Qualls	2015	1	1	HY	0-10	1.30438	57.9175	36.8213	5.26124
Qualls	2015	1	1	HY	0-10	1.41512	49.2681	44.4194	6.31247
Qualls	2015	1	1	HY	0-10	1.40773	43.5	49.202	7.29796
Qualls	2015	1	1	HY	10-20	1.41744	31.9694	58.6163	9.41426
Qualls	2015	1	1	HY	10-20	1.46315	38.2901	54.3818	7.32809
Qualls	2015	1	1	HY	10-20	1.42571	57.9158	35.2366	6.8476
Qualls	2015	1	1	HY	10-20	1.47606	48.8978	41.4516	9.65059
Qualls	2015	1	1	HY	10-20	1.45808	43.1138	46.3116	10.5747
Qualls	2015	1	1	AY	0-10	1.38764	55.3333	37.6013	7.06537
Qualls	2015	1	1	AY	0-10	1.3367	44.2218	47.7253	8.05288
Qualls	2015	1	1	AY	0-10	1.34	53.1667	39.2637	7.56966
Qualls	2015	1	1	AY	0-10	1.41921	67.6019	25.3186	7.07953
Qualls	2015	1	1	AY	0-10	1.30089	42.2178	49.1867	8.5955
Qualls	2015	1	1	AY	10-20	1.50512	45.5578	44.7916	9.65059
Qualls	2015	1	1	AY	10-20	1.46266	41.5	49.3753	9.1247
Qualls	2015	1	1	AY	10-20	1.47729	52.9058	39.004	8.09016
Qualls	2015	1	1	AY	10-20	1.56192	68.3965	24.0489	7.55456
Qualls	2015	1	1	AY	10-20	1.4401	37.3747	53.4396	9.1856
Taylor	2015	5	1	HY	0-10	1.12084	15.6647	74.1771	10.1582
Taylor	2015	5	1	HY	0-10	1.1864	15.4977	76.3745	8.12786
Taylor	2015	5	1	HY	0-10	1.10123	16.1677	74.7678	9.06452
Taylor	2015	5	1	HY	0-10	1.12202	15.3333	75.6256	9.04109
Taylor	2015	5	1	HY	0-10	1.13517	13.1667	77.7086	9.1247

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Taylor	2015	5	1	HY	10-20	1.29118	12.4916	76.793	10.7153
Taylor	2015	5	1	HY	10-20	1.36044	14	75.815	10.185
Taylor	2015	5	1	HY	10-20	1.24404	14.6667	75.702	9.63129
Taylor	2015	5	1	HY	10-20	1.3699	14.837	76.0565	9.10649
Taylor	2015	5	1	HY	10-20	1.26448	12.6587	78.2405	9.10086
Taylor	2015	5	1	AY	0-10	1.31571	15.1697	55.1895	29.6408
Taylor	2015	5	1	AY	0-10	1.2565	16.0013	55.011	28.9877
Taylor	2015	5	1	AY	0-10	1.24547	11.8333	56.9257	31.241
Taylor	2015	5	1	AY	0-10	1.31764	12	53.6752	34.3248
Taylor	2015	5	1	AY	0-10	1.20685	13.3333	54.9119	31.7547
Taylor	2015	5	1	AY	10-20	1.32685	12.6587	53.463	33.8784
Taylor	2015	5	1	AY	10-20	1.40355	13.1667	55.4506	31.3827
Taylor	2015	5	1	AY	10-20	1.20232	12.1667	51.7441	36.0892
Taylor	2015	5	1	AY	10-20	1.38212	11.1667	50.0089	38.8244
Taylor	2015	5	1	AY	10-20	1.40118	12.6587	48.5552	38.7861
Galloway	2015	3	1	HY	0-10	1.24586	45.5	44.7866	9.71342
Galloway	2015	3	1	HY	0-10	1.38488	47.5	42.6915	9.80854
Galloway	2015	3	1	HY	0-10	1.23217	46.0588	44.5276	9.41361
Galloway	2015	3	1	HY	0-10	1.28054	44.8333	44.9511	10.2156
Galloway	2015	3	1	HY	0-10	1.32823	45.8918	44.28	9.8282
Galloway	2015	3	1	HY	10-20	1.39148	46.0588	44.5744	9.36683
Galloway	2015	3	1	HY	10-20	1.46025	46	44.2866	9.71342
Galloway	2015	3	1	HY	10-20	1.30961	46.9395	43.7311	9.32944
Galloway	2015	3	1	HY	10-20	1.3464	44.9434	45.2193	9.83726
Galloway	2015	3	1	HY	10-20	1.4134	45.1098	44.2448	10.6454
Galloway	2015	3	1	AY	0-10	1.28852	43.0528	48.0007	8.94654
Galloway	2015	3	1	AY	0-10	1.28419	45.5	44.6431	9.85694
Galloway	2015	3	1	AY	0-10	1.34069	40.7148	46.798	12.4873
Galloway	2015	3	1	AY	0-10	1.26473	37.5418	52.6301	9.8282
Galloway	2015	3	1	AY	0-10	1.38079	41.5	49.1052	9.39478
Galloway	2015	3	1	AY	10-20	1.32374	40.1198	49.685	10.1952
Galloway	2015	3	1	AY	10-20	1.42764	46.4405	43.7223	9.83726

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Galloway	2015	3	1	AY	10-20	1.35798	35.5	47.4328	17.0672
Galloway	2015	3	1	AY	10-20	1.23379	38.7891	51.5169	9.69403
Galloway	2015	3	1	AY	10-20	1.3866	37.3747	53.2584	9.36683
Brantley	2015	4	1	HY	0-10	1.22512	16	72.6163	11.3837
Brantley	2015	4	1	HY	0-10	1.13576	16.6667	72.5853	10.748
Brantley	2015	4	1	HY	0-10	1.12103	18.9953	71.2634	9.74122
Brantley	2015	4	1	HY	0-10	1.19212	17.9973	70.8051	11.1976
Brantley	2015	4	1	HY	0-10	1.15532	10.6667	71.5974	17.7359
Brantley	2015	4	1	HY	10-20	1.36872	10.6546	70.6024	18.743
Brantley	2015	4	1	HY	10-20	1.22374	10.0133	71.3186	18.6681
Brantley	2015	4	1	HY	10-20	1.23754	10.1536	72.026	17.8204
Brantley	2015	4	1	HY	10-20	1.25571	10.1667	72.0974	17.7359
Brantley	2015	4	1	HY	10-20	1.27128	9.15164	72.5647	18.2837
Brantley	2015	4	1	AY	0-10	1.23768	21.3427	55.8331	22.8242
Brantley	2015	4	1	AY	0-10	1.30227	19.827	57.879	22.294
Brantley	2015	4	1	AY	0-10	1.25778	21.5	58.719	19.781
Brantley	2015	4	1	AY	0-10	1.17537	19.4943	56.8314	23.6743
Brantley	2015	4	1	AY	0-10	1.31163	19.0047	56.1294	24.8659
Brantley	2015	4	1	AY	10-20	1.32729	21.4904	54.91	23.5996
Brantley	2015	4	1	AY	10-20	1.25296	20.8417	56.4051	22.7532
Brantley	2015	4	1	AY	10-20	1.37172	22.6787	56.4757	20.8456
Brantley	2015	4	1	AY	10-20	1.31542	17.8333	54.4197	27.747
Brantley	2015	4	1	AY	10-20	1.41153	19.827	57.8089	22.3641
Moore	2015	7	1	HY	0-10	1.46936	14.9967	53.7824	31.2209
Moore	2015	7	1	HY	0-10	1.46734	22	51.1455	26.8545
Moore	2015	7	1	HY	0-10	1.45897	13.8277	55.5786	30.5938
Moore	2015	7	1	HY	0-10	1.44453	14.1617	51.3865	34.4519
Moore	2015	7	1	HY	0-10	1.42493	16.8333	53.4232	29.7435
Moore	2015	7	1	HY	10-20	1.52749	11.6766	56.3167	32.0067
Moore	2015	7	1	HY	10-20	1.56768	21.823	47.294	30.883
Moore	2015	7	1	HY	10-20	1.45094	11.1556	54.007	34.8373
Moore	2015	7	1	HY	10-20	1.55926	11.3226	52.4296	36.2477

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Moore	2015	7	1	HY	10-20	1.47724	15.3307	50.2175	34.4519
Moore	2015	7	1	AY	0-10	1.34995	3.30661	56.8781	39.8153
Moore	2015	7	1	AY	0-10	1.21764	5.47762	58.0802	36.4422
Moore	2015	7	1	AY	0-10	1.3935	5.81162	56.7789	37.4095
Moore	2015	7	1	AY	0-10	1.26192	7.81563	51.7642	40.4202
Moore	2015	7	1	AY	0-10	1.27153	7.5183	50.96	41.5217
Moore	2015	7	1	AY	10-20	1.30601	3.69261	50.9067	45.4007
Moore	2015	7	1	AY	10-20	1.26478	5.64462	44.3623	49.9931
Moore	2015	7	1	AY	10-20	1.50399	4.66667	49.3871	45.9463
Moore	2015	7	1	AY	10-20	1.17118	3.80762	41.4178	54.7746
Moore	2015	7	1	AY	10-20	1.19818	4.5	35.9592	59.5408
Martin	2015	2	1	HY	0-10	1.29759	11.4896	71.7843	16.726
Martin	2015	2	1	HY	0-10	1.23576	10.1667	71.5475	18.2858
Martin	2015	2	1	HY	0-10	1.2632	9.31864	71.7725	18.9089
Martin	2015	2	1	HY	0-10	1.23542	9.65264	70.2278	20.1196
Martin	2015	2	1	HY	0-10	1.22966	9.18164	71.9082	18.9101
Martin	2015	2	1	HY	10-20	1.38498	8.65063	72.5166	18.8327
Martin	2015	2	1	HY	10-20	1.35946	10.6667	70.029	19.3044
Martin	2015	2	1	HY	10-20	1.43305	10.8216	69.244	19.9344
Martin	2015	2	1	HY	10-20	1.27512	9.83333	70.7046	19.4621
Martin	2015	2	1	HY	10-20	1.40709	9.31864	70.3999	20.2814
Martin	2015	2	1	AY	0-10	1.237	12.8257	70.3158	16.8585
Martin	2015	2	1	AY	0-10	1.16389	12.6747	73.1946	14.1308
Martin	2015	2	1	AY	0-10	1.21773	16.8333	69.5656	13.601
Martin	2015	2	1	AY	0-10	1.20764	10.8333	73.9943	15.1724
Martin	2015	2	1	AY	0-10	1.33956	10.3333	73.3533	16.3134
Martin	2015	2	1	AY	10-20	1.37158	12.0093	69.814	18.1767
Martin	2015	2	1	AY	10-20	1.49153	10.3333	71.3073	18.3594
Martin	2015	2	1	AY	10-20	1.34581	29.3587	56.4539	14.1874
Martin	2015	2	1	AY	10-20	1.31931	12.6667	72.161	15.1724
Martin	2015	2	1	AY	10-20	1.45626	10.6786	69.2821	20.0393
Hook	2015	1	2	HY	0-10	1.37695	53	26	21

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Hook	2015	1	2	HY	0-10	1.33961	54	25	21
Hook	2015	1	2	HY	0-10	1.38951	50	26	25
Hook	2015	1	2	HY	0-10	1.397	53	23	24
Hook	2015	1	2	HY	0-10	1.41079	54	24	23
Hook	2015	1	2	HY	10-20	1.44512	54	23	23
Hook	2015	1	2	HY	10-20	1.41222	53	24	22
Hook	2015	1	2	HY	10-20	1.49985	53	21	26
Hook	2015	1	2	HY	10-20	1.51365	54	20	26
Hook	2015	1	2	HY	10-20	1.48828	55	23	23
Hook	2015	1	2	AY	0-10	1.4235	63	16	21
Hook	2015	1	2	AY	0-10	1.41631	63	14	23
Hook	2015	1	2	AY	0-10	1.28635	64	16	20
Hook	2015	1	2	AY	0-10	1.32246	63	16	21
Hook	2015	1	2	AY	0-10	1.41882	64	16	20
Hook	2015	1	2	AY	10-20	1.58074	64	15	21
Hook	2015	1	2	AY	10-20	1.48567	64	14	22
Hook	2015	1	2	AY	10-20	1.43862	64	16	21
Hook	2015	1	2	AY	10-20	1.36532	64	15	21
Hook	2015	1	2	AY	10-20	1.4569	65	15	21
Bennett	2015	6	2	HY	0-10	1.17473	18	55	26
Bennett	2015	6	2	HY	0-10	1.25148	20	54	26
Bennett	2015	6	2	HY	0-10	1.23813	17	58	24
Bennett	2015	6	2	HY	0-10	1.24872	19	58	23
Bennett	2015	6	2	HY	0-10	1.25562	19	56	25
Bennett	2015	6	2	HY	10-20	1.31172	18	53	28
Bennett	2015	6	2	HY	10-20	1.34074	19	53	27
Bennett	2015	6	2	HY	10-20	1.33236	17	57	25
Bennett	2015	6	2	HY	10-20	1.35764	33	56	11
Bennett	2015	6	2	HY	10-20	1.33271	31	57	12
Bennett	2015	6	2	AY	0-10	1.25419	33	53	14
Bennett	2015	6	2	AY	0-10	1.20739	33	56	11
Bennett	2015	6	2	AY	0-10	1.26291	29	59	12

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Bennett	2015	6	2	AY	0-10	1.27103	30	57	14
Bennett	2015	6	2	AY	0-10	1.20325	34	54	12
Bennett	2015	6	2	AY	10-20	1.35483	34	49	16
Bennett	2015	6	2	AY	10-20	1.33877	32	55	13
Bennett	2015	6	2	AY	10-20	1.42936	27	59	14
Bennett	2015	6	2	AY	10-20	1.44	31	54	15
Bennett	2015	6	2	AY	10-20	1.37601	33	53	14
Gregory	2015	7	2	HY	0-10	1.43744	28	52	20
Gregory	2015	7	2	HY	0-10	1.42783	31	48	21
Gregory	2015	7	2	HY	0-10	1.40315	31	51	18
Gregory	2015	7	2	HY	0-10	1.47882	29	45	26
Gregory	2015	7	2	HY	0-10	1.38921	27	49	23
Gregory	2015	7	2	HY	10-20	1.40842	36	43	22
Gregory	2015	7	2	HY	10-20	1.55335	29	47	24
Gregory	2015	7	2	HY	10-20	1.58961	27	50	22
Gregory	2015	7	2	HY	10-20	1.54399	26	45	29
Gregory	2015	7	2	HY	10-20	1.59212	24	46	30
Gregory	2015	7	2	AY	0-10	1.40547	63	28	9
Gregory	2015	7	2	AY	0-10	1.36951	37	51	12
Gregory	2015	7	2	AY	0-10	1.30985	76	18	6
Gregory	2015	7	2	AY	0-10	1.3398	52	37	11
Gregory	2015	7	2	AY	0-10	1.29345	79	16	5
Gregory	2015	7	2	AY	10-20	1.49059	67	26	6
Gregory	2015	7	2	AY	10-20	1.46059	34.1667	51.198	14.6353
Gregory	2015	7	2	AY	10-20	1.4201	77.2879	14.7719	7.94021
Gregory	2015	7	2	AY	10-20	1.50118	50	35.9485	14.0515
Gregory	2015	7	2	AY	10-20	1.37591	76.8796	15.7587	7.3617
Kelly	2015	5	2	HY	0-10	1.19571	31.8333	56.2069	11.9597
Kelly	2015	5	2	HY	0-10	1.20113	32.0307	58.0075	9.9618
Kelly	2015	5	2	HY	0-10	1.23862	30	58.5448	11.4552
Kelly	2015	5	2	HY	0-10	1.23074	27.4784	60.8372	11.6844
Kelly	2015	5	2	HY	0-10	1.15833	27.9774	60.9127	11.1099

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Kelly	2015	5	2	HY	10-20	1.31187	30.5277	58.8302	10.6421
Kelly	2015	5	2	HY	10-20	1.33808	30.1937	57.383	12.4233
Kelly	2015	5	2	HY	10-20	1.35251	28.3333	54.6608	17.0059
Kelly	2015	5	2	HY	10-20	1.29498	24.5157	58.3563	17.128
Kelly	2015	5	2	HY	10-20	1.30419	27.9774	58.0726	13.95
Kelly	2015	5	2	AY	0-10	1.1733	17.1667	62.8959	19.9375
Kelly	2015	5	2	AY	0-10	1.20621	15.3333	64.1064	20.5602
Kelly	2015	5	2	AY	0-10	1.18522	16	66.8174	17.1826
Kelly	2015	5	2	AY	0-10	1.2069	15.5	67.561	16.939
Kelly	2015	5	2	AY	0-10	1.18571	17.1677	63.8867	18.9457
Kelly	2015	5	2	AY	10-20	1.36867	12.841	62.5042	24.6549
Kelly	2015	5	2	AY	10-20	1.27941	15.1667	60.3893	24.444
Kelly	2015	5	2	AY	10-20	1.2932	14.0053	64.3278	21.6669
Kelly	2015	5	2	AY	10-20	1.27685	13.8333	66.124	20.0427
Kelly	2015	5	2	AY	10-20	1.34547	14.6667	62.7019	22.6315
Garner	2015	2	2	HY	0-10	1.15532	13.6607	72.6222	13.7171
Garner	2015	2	2	HY	0-10	1.12227	12	76.4827	11.5173
Garner	2015	2	2	HY	0-10	1.16828	12.9927	76.0938	10.9135
Garner	2015	2	2	HY	0-10	1.17192	12.6587	76.7582	10.5831
Garner	2015	2	2	HY	0-10	1.0803	3.64061	77.2183	19.1411
Garner	2015	2	2	HY	10-20	1.25581	2.63861	74.403	22.9584
Garner	2015	2	2	HY	10-20	1.1866	3	75.3111	21.6889
Garner	2015	2	2	HY	10-20	1.23596	2.33333	78.9675	18.6991
Garner	2015	2	2	HY	10-20	1.2897	2.66667	76.6581	20.6753
Garner	2015	2	2	HY	10-20	1.18975	3.13961	76.5938	20.2666
Garner	2015	2	2	AY	0-10	1.16266	3.80762	77.5567	18.6357
Garner	2015	2	2	AY	0-10	1.2164	2.63861	77.7689	19.5925
Garner	2015	2	2	AY	0-10	1.12025	0.86494	80.5738	18.5613
Garner	2015	2	2	AY	0-10	1.1598	1.63661	80.2331	18.1303
Garner	2015	2	2	AY	0-10	1.14108	1.80361	80.0182	18.1782
Garner	2015	2	2	AY	10-20	1.23719	3.16667	76.7216	20.1117
Garner	2015	2	2	AY	10-20	1.29502	2.33333	78.5115	19.1551

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Garner	2015	2	2	AY	10-20	1.28719	2.5	78.3972	19.1028
Garner	2015	2	2	AY	10-20	1.25202	2.16667	79.6431	18.1903
Garner	2015	2	2	AY	10-20	1.22133	0.8016	79.4972	19.7012
Scoggins	2015	3	2	HY	0-10	1.43069	45.9415	36.964	17.0945
Scoggins	2015	3	2	HY	0-10	1.41537	45.6088	36.7911	17.6001
Scoggins	2015	3	2	HY	0-10	1.36246	46.5598	36.743	16.6973
Scoggins	2015	3	2	HY	0-10	1.37305	48.2298	34.0996	17.6706
Scoggins	2015	3	2	HY	0-10	1.31177	46.2258	36.6112	17.1631
Scoggins	2015	3	2	HY	10-20	1.53517	45.8918	35.9779	18.1303
Scoggins	2015	3	2	HY	10-20	1.49951	46.2741	36.6313	17.0945
Scoggins	2015	3	2	HY	10-20	1.37961	46.4405	36.5083	17.0512
Scoggins	2015	3	2	HY	10-20	1.46739	48.0628	34.3123	17.6249
Scoggins	2015	3	2	HY	10-20	1.53099	46.1667	35.6915	18.1419
Scoggins	2015	3	2	AY	0-10	1.39601	48.4365	34.8909	16.6727
Scoggins	2015	3	2	AY	0-10	1.33113	46.3333	36.5379	17.1287
Scoggins	2015	3	2	AY	0-10	1.32985	52.2378	32.6366	15.1256
Scoggins	2015	3	2	AY	0-10	1.36153	57.4148	27.3618	15.2234
Scoggins	2015	3	2	AY	0-10	1.35163	50.0668	35.7295	14.2037
Scoggins	2015	3	2	AY	10-20	1.4703	51.2641	34.0811	14.6548
Scoggins	2015	3	2	AY	10-20	1.49453	49.9335	35.4585	14.6081
Scoggins	2015	3	2	AY	10-20	1.57133	50.5	34.3561	15.1439
Scoggins	2015	3	2	AY	10-20	1.50103	46.8938	37.373	15.7332
Scoggins	2015	3	2	AY	10-20	1.44975	48.3968	36.3301	15.2731
Helms	2015	4	2	HY	0-10	1.28719	31.3627	49.2654	19.3719
Helms	2015	4	2	HY	0-10	1.32995	31.5297	50.059	18.4113
Helms	2015	4	2	HY	0-10	1.31453	32.3333	49.8679	17.7988
Helms	2015	4	2	HY	0-10	1.32709	31.1957	49.5007	19.3036
Helms	2015	4	2	HY	0-10	1.20803	29.8071	52.94	17.2529
Helms	2015	4	2	HY	10-20	1.46488	29.8071	49.8035	20.3895
Helms	2015	4	2	HY	10-20	1.39655	29.1917	50.4843	20.324
Helms	2015	4	2	HY	10-20	1.39571	33	48.6255	18.3745
Helms	2015	4	2	HY	10-20	1.41458	30.3333	50.3335	19.3332

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

ID	Year	Region	Site	HY/AY	Depth	Bulk density (g cm-3)	Sand %	Silt %	Clay %
Helms	2015	4	2	HY	10-20	1.39438	30.6387	48.7579	20.6034
Helms	2015	4	2	AY	0-10	1.32365	29.7	52.3766	17.9234
Helms	2015	4	2	AY	0-10	1.29611	26.3527	52.3026	21.3447
Helms	2015	4	2	AY	0-10	1.31911	31.0287	49.5994	19.3719
Helms	2015	4	2	AY	0-10	1.2069	31.9694	48.4343	19.5963
Helms	2015	4	2	AY	0-10	1.23414	28.5237	51.1523	20.324
Helms	2015	4	2	AY	10-20	1.41911	23.3467	55.2307	21.4226
Helms	2015	4	2	AY	10-20	1.45463	23.0127	53	23.9873
Helms	2015	4	2	AY	10-20	1.39872	28.3567	50.5796	21.0637
Helms	2015	4	2	AY	10-20	1.39463	27.1877	51.3897	21.4226
Helms	2015	4	2	AY	10-20	1.42842	21.8437	53.4671	24.6893

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.46	0.0795	1.04208	48.4155	75.9724	903.295	93.3887	6.27339	19.5761
5.52	0.081	1.37312	70.01	64.5069	694.356	79.5768	9.10315	20.1203
6.28	0.0646	1.10787	68.8859	71.4202	845.052	90.3891	6.63596	18.0739
5.88	0.083	1.11843	35.4761	67.1981	704.712	78.076	7.66584	15.1393
6.52	0.0902	1.41185	75.4961	58.83	943.393	98.8902	7.30582	23.1857
6.35	0.0627	1.15732	46.6911	134.718	1667.38	569.049	10.1594	77.9025
6.29	0.0622	1.229	12.8766	93.4271	1002.03	458.987	7.37305	47.8072
6.24	0.0407	1.00023	25.4547	89.2955	1053.82	425.59	5.00989	49.5713
6.44	0.0487	1.10387	20.7922	57.5682	1024.43	191.777	5.87291	25.2825
6.2	0.0317	0.86628	30.0638	58.1969	885.137	181.711	4.81277	25.2495
7.29	0.1022	1.00411	17.0919	55.7783	988.146	101.358	9.36711	33.4426
6.63	0.0967	1.35123	20.2499	48.1568	928.687	92.3823	9.02499	24.4566
6.59	0.0984	1.08367	14.8031	48.4038	865.272	83.2726	9.54138	20.0654
7.07	0.0851	1.15375	13.5369	46.6511	926.511	93.116	6.05819	18.783
7.41	0.1271	0.99605	13.1827	38.94	1056.98	105.403	9.59689	33.0645

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.8	0.1197	1.17722	40.6988	117.923	878.243	91.608	11.3003	20.5335
7.34	0.1502	1.44756	48.1766	170.435	1192.94	117.664	14.7877	23.5332
6.94	0.0823	0.938	55.616	102.842	958.681	101.53	6.87203	17.0781
6.74	0.1125	1.21683	72.0617	114.133	1046.69	96.9158	8.90231	12.3569
6.93	0.1127	1.28112	36.9235	130.112	1008.02	103.232	7.29465	17.4709
7.07	0.1006	1.67005	7.30414	161.035	3030.51	543.74	14.6869	112.385
7.39	0.1274	1.21937	5.2559	63.8552	1718.07	250.865	12.4463	51.4784
7.06	0.1021	1.83686	7.79251	128.917	2575.32	463.743	10.6897	64.9836
7.07	0.1282	1.93823	22.8828	49.1392	1828.94	268.909	12.0791	46.284
7.12	0.1041	1.51381	17.8721	105.627	2331.88	429.318	12.7935	71.0696
7.13	0.0893	1.14754	14.587	70.8842	1644.18	248.905	5.83954	25.615
7.02	0.0916	1.26059	5.32759	88.4952	1786.96	264.001	6.93039	22.6069
6.95	0.0935	1.45358	4.90976	89.7008	1989.32	306.279	7.24846	25.9649
7.29	0.0822	1.39626	4.15884	153.907	3072.7	498.667	5.08969	43.515
7.14	0.1018	1.25849	4.52133	97.8956	2156.43	318.589	6.25496	29.6214
7.07	0.1315	1.25519	46.4785	75.3778	1049.64	146.051	12.8447	21.468
6.42	0.0828	0.98306	16.2524	60.0941	742.878	115.376	8.31225	18.8885
6.6	0.1436	0.81392	18.001	51.2235	638.74	87.9156	10.7912	22.5638
7.06	0.0865	0.87246	11.3593	42.1283	887.566	120.049	8.47569	23.7441
6.52	0.1021	0.88344	9.81648	45.8842	675.077	87.0342	9.73187	20.2144
7.63	0.1579	1.10399	53.2646	75.8148	881.541	151.566	13.6861	27.3154
7.58	0.1478	1.46751	32.5301	67.8085	1382.8	232.136	17.1613	50.9578
7.35	0.1317	1.78724	19.6573	109.144	1924.99	575.416	10.5394	101.604
7.45	0.1745	1.3369	19.6267	61.4826	1303.13	233.127	15.2805	45.0987
7.47	0.1395	1.21241	22.1046	51.8454	1063.63	184.53	12.281	38.5868
7.5	0.0731	0.85216	94.337	267.359	1219.03	178.799	4.7671	6.49271
6.95	0.0459	0.51047	70.1527	210.205	716.49	107.552	4.13356	9.21437
6.56	0.0435	0.91382	20.7721	134.316	1096.97	197.176	5.08119	8.55792
6.33	0.0601	0.74704	36.4956	159.144	917.871	149.941	5.51003	9.768
6.73	0.048	0.64619	58.1302	208.409	849.958	143.918	4.85081	9.69426
5.39	0.0661	1.95236	25.8275	157.97	2232.8	322.175	12.1636	18.8324
5.97	0.0567	1.69254	19.241	163.465	2558.39	371.578	9.11401	21.0908
6.17	0.0653	2.32927	48.5021	220.513	2888.4	496.618	7.26869	22.5963

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.16	0.059	2.13463	32.9485	211.715	2953.77	494.795	5.79503	24.7178
5.9	0.0747	2.12595	29.0804	173.692	2623.45	402.354	8.29783	23.4923
6.74	0.1094	1.48099	25.8652	131.154	1018.39	150.154	6.33363	26.1776
6.97	0.0758	1.16744	22.6698	84.366	927.293	114.142	4.20041	24.1983
6.83	0.0677	1.30816	43.2726	99.4531	1001.08	119.246	5.50958	24.9884
6.98	0.0717	1.30954	25.2822	116.129	970.807	128.515	5.22309	23.1522
6.99	0.0952	1.17958	43.991	139.473	937.51	130.352	4.67833	21.1106
5.82	0.1011	1.56622	42.2185	240.559	1018.71	127.636	8.90319	11.7349
6.37	0.09	1.21035	13.6958	132.836	1276.25	108.561	7.85253	21.1621
6.53	0.0608	1.20452	28.9877	109.862	933.238	84.5152	5.21743	16.7124
6.69	0.0805	1.14862	27.5633	127.259	1084.45	87.4822	5.55628	14.6183
7.06	0.071	1.42332	16.9543	121.691	1231.62	99.4308	5.17693	22.3288
7.76	0.1708	2.06839	136.293	134.572	2164.4	206.549	28.4283	36.2499
7.81	0.1585	1.58113	44.3361	46.137	1677.53	182.265	21.8012	27.3941
7.87	0.1767	0.99602	7.22386	27.2002	1347.14	158.658	20.4789	41.8636
7.9	0.207	1.75806	36.4891	35.0401	1832.05	189.915	26.9136	42.8411
7.93	0.1595	1.88542	54.1167	48.526	1854.43	189.165	34.1724	36.954
7.88	0.1688	1.73768	30.1336	50.6736	1770.84	167.378	21.1685	29.5844
8.07	0.1806	1.94773	7.49675	32.8741	2096.47	178.743	38.2945	42.6236
7.37	0.302	1.7225	12.7023	47.2393	1386.83	192.843	29.4631	49.0836
7.93	0.1517	1.6932	6.08179	32.2767	1524.64	171.348	18.7605	33.462
8.09	0.1727	1.88463	8.46695	37.6438	1796.31	190.772	24.0671	34.9519
5.37	0.0824	1.57945	96.4566	100.491	566.343	72.5818	10.7768	14.2745
6.13	0.0959	1.7958	69.5191	86.5127	767.961	86.4003	11.1678	14.865
6.05	0.127	1.64101	50.8009	114.308	756.342	83.8699	8.20901	11.2723
6.03	0.0727	1.35012	27.9607	69.6983	745.885	86.3742	8.91889	14.8389
5.97	0.0892	1.40914	56.3685	88.5696	715.091	79.2104	9.08947	12.6126
5.94	0.1286	1.36147	85.4265	76.6278	752.215	50.3027	11.9423	17.8747
5.86	0.1267	1.4042	77.7814	122.159	643.568	55.8134	9.09499	12.0783
6.11	0.0955	1.35296	49.3886	96.6254	600.327	58.4493	7.53296	12.0837
6.04	0.0883	1.22919	67.4377	52.539	601.044	52.7887	8.73575	16.7562
5.94	0.0659	1.19365	37.3126	85.1171	611.178	51.6199	7.2362	12.8274
7.48	0.0594	0.99863	14.7601	61.2264	879.507	38.8236	6.30384	11.8055

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
7.5	0.0706	1.05742	20.3653	69.9215	1002.13	54.1609	5.7251	10.8955
6.52	0.0748	1.03591	16.8055	47.6241	676.798	43.2917	5.78614	5.95323
6.18	0.0393	0.68235	27.9769	72.2571	337.368	24.4008	4.88639	4.15465
6.72	0.0713	1.17225	16.2076	57.6347	690.991	50.1323	6.12853	7.156
7.44	0.0525	0.97044	39.9895	94.2259	866.677	35.5417	4.68419	5.27052
6.79	0.0426	1.11384	29.0227	68.9517	521.633	49.6631	4.85377	6.50955
6.7	0.0549	1.27061	25.3463	79.3477	748.732	35.305	7.09329	5.3171
6.85	0.0508	0.72953	25.1978	80.284	493.234	33.1878	4.55821	4.99927
6.84	0.0349	0.71287	35.4348	85.8593	492.628	24.926	4.44935	4.4001
7.37	0.1451	1.33619	10.1058	96.4652	1617.26	288.816	26.3472	60.807
7.07	0.09	1.38868	29.261	100.734	1451.48	241.8	8.86173	31.7168
7.38	0.0744	1.31327	32.9431	70.1462	1314.53	217.281	7.09936	23.9294
7.09	0.0437	1.19787	14.4202	81.084	1455.02	263.049	6.45668	21.7991
7.78	0.0924	1.40462	28.7868	132.949	3001.21	490.592	20.9017	64.7438
7.23	0.0768	2.67674	9.22449	236.731	3771.97	655.635	5.7017	34.378
7.07	0.1039	2.62802	7.24039	228.474	3565.66	632.306	5.74769	30.1367
7.29	0.117	2.74801	6.60979	242.82	3845.15	650.679	10.4435	31.8818
7.24	0.0728	2.70333	7.22088	230.377	3576.06	648.908	5.5611	30.6224
7.2	0.113	3.08201	6.91262	234.352	3579.35	650.038	5.78469	31.5977
6.1	0.0617	1.05272	31.3688	72.8715	835.569	183.827	11.5054	24.7337
6.43	0.071	1.72077	27.4967	89.6362	839.149	152.699	9.37481	20.6649
6.77	0.0828	1.35607	24.9237	70.8725	856.32	127.822	7.24321	16.9891
6.62	0.0772	1.65147	37.129	100.677	975.656	132.873	9.42799	21.1834
6.68	0.0892	1.67747	34.0286	82.4683	1033.39	169.306	11.3959	22.6394
5.76	0.076	1.44475	25.4259	60.7261	686.771	127.554	8.35478	23.9213
5.33	0.1	1.51265	24.5652	89.8141	646.101	120.536	13.1791	20.66
5.57	0.0994	1.779	33.2741	93.7679	747.585	151.798	14.4638	22.947
6.09	0.0735	1.57184	19.3087	51.5452	787.608	152.679	9.67812	28.5492
5.45	0.1248	1.41473	30.2441	71.0899	742.632	146.825	14.0217	29.5729
6.7	0.0797	0.94852	35.8166	173.178	612.861	79.0476	5.94054	9.41208
5.83	0.1088	0.90467	43.7836	223.038	642.541	75.5012	5.18113	7.0215
6.88	0.0636	0.88109	12.4063	145.993	498.924	89.1234	5.56632	7.14806
6.43	0.1184	1.05888	34.6772	141.949	605.748	68.5941	7.07359	8.59053

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.45	0.0928	0.88579	22.7953	124.816	565.069	65.6645	5.91075	11.1027
6.5	0.1236	1.15706	45.6623	160.24	735.287	114.097	5.26523	8.59973
6.27	0.0995	1.38126	25.4466	124.561	687.539	113.139	7.0254	7.94522
6.58	0.0835	1.09443	62.9616	77.748	896.685	144.158	4.93316	12.2932
5.97	0.101	1.31625	70.6743	132.906	685.657	79.7277	7.26474	5.98892
6.42	0.0866	1.29701	78.5606	112.532	839.852	123.477	5.72259	11.0109
6.32	0.0928	1.47606	27.515	74.9744	1162.67	157.76	8.48156	13.8067
6.64	0.1143	1.1543	7.30531	49.7439	1183.72	162.092	5.22253	11.754
6.63	0.1211	1.56945	17.3413	63.3345	1326.69	175.394	7.5223	12.7356
6.86	0.1233	1.20794	8.97011	48.7842	1214.63	136.603	7.01318	15.8015
6.59	0.0987	1.51129	11.3937	65.3292	1207.57	156.104	7.07281	14.83
6.89	0.0921	1.73561	35.9124	92.4134	1596.11	244.191	6.93561	12.8026
6.82	0.1461	1.58665	31.5052	71.0038	1589.84	264.144	6.14469	9.71882
6.43	0.1765	1.66385	35.2223	89.448	1463.34	226.34	10.0416	13.6261
6.86	0.1514	1.7241	49.2594	73.161	1579.71	251.564	8.95707	18.4336
6.35	0.106	1.88062	50.8929	74.6367	1334.7	203.704	7.16062	10.3627
8.13	0.249	2.25941	12.8047	230.75	6074.87	662.41	35.7611	122.7
8	0.1763	2.98733	10.0454	247.111	4331.44	840.82	4.81231	28.6911
7.95	0.1231	2.77609	12.1157	246.002	4167.63	839.25	4.81774	21.513
7.92	0.1472	2.53064	11.4371	238.034	4064.63	774.885	5.77651	23.5284
7.64	0.1104	2.94036	9.12896	268.628	4241.5	973.11	5.50572	31.588
7.53	0.1085	2.68464	15.6933	260.927	4028.07	877.315	6.10912	24.4111
6.1	0.1152	1.32125	82.515	157.603	869.712	98.227	9.50726	23.5789
6.03	0.1039	1.52501	103.553	136.595	902.05	99.5702	11.1032	20.6773
6.29	0.1383	1.31996	91.8049	148.979	853.405	106.501	12.6376	17.532
5.75	0.1043	1.41635	89.0415	142.061	702.941	81.2073	9.81478	18.1488
6.23	0.18	1.51665	65.8291	143.926	832.81	87.03	10.2245	17.8067
5.53	0.0954	2.04354	51.4949	123.737	1108.4	336.732	13.8131	31.4437
5.34	0.0932	2.41087	44.6414	158.208	948.949	322.268	15.1543	26.6875
5.44	0.0662	1.9426	24.7529	96.702	960.972	301.596	9.29586	31.7763
5.37	0.0541	1.89977	28.8836	94.7267	1122.8	260.434	10.9533	28.5073
5.22	0.0709	1.90787	31.3385	80.4386	803.847	215.665	9.94501	25.0301
7.01	0.1067	1.70404	61.5648	203.38	1086.22	105.722	10.8325	20.2747

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.84	0.1147	1.92779	57.9971	197.707	1055.62	95.3219	10.3165	11.7449
6.14	0.1375	1.52842	39.6887	174.805	796.837	77.7676	9.87265	14.2815
6.3	0.1143	1.64302	30.712	114.258	960.265	96.564	8.55541	13.5687
6.48	0.1224	1.7871	64.2003	136.494	1035.62	89.8371	9.39668	13.0051
6.09	0.1332	1.32715	65.5717	204.299	748.718	73.492	8.90044	8.67465
6.26	0.1636	2.01756	83.138	234.779	1036.97	99.9546	12.8777	14.8801
6.57	0.1084	1.55413	87.6794	193.852	900.737	93.2932	8.54188	11.8387
6.38	0.1146	1.80295	92.6774	206.744	987.105	98.5012	9.57884	10.8085
6.64	0.1462	1.83335	70.808	213.127	1021.19	101.341	9.59699	9.38305
7.12	0.1653	2.39304	30.576	125.604	2204.27	396.57	15.4507	70.9802
6.49	0.1718	2.00024	11.7155	93.1044	1507.53	241.837	11.9563	30.6553
5.97	0.216	2.20722	27.6463	104.375	1771.77	282.137	12.1594	30.8503
6.24	0.1432	1.94359	17.6611	85.3932	1675.55	280.528	13.2014	46.4571
5.88	0.1585	2.35581	29.2695	80.41	1442.87	235.124	15.6936	49.9635
6.07	0.1142	2.02768	34.0501	101.67	1480.86	230.459	11.4636	15.5316
5.6	0.1568	1.81739	32.9973	118.615	1357.42	211.246	11.0961	10.4602
5.89	0.1473	1.99802	16.5256	95.479	1589.74	242.896	9.18392	14.9511
6.86	0.0967	1.45916	12.8659	171.19	2646.1	442.53	5.78866	29.0884
6.45	0.0883	1.57607	15.6529	108.761	1628.39	254.448	6.61764	14.7655
7.29	0.1744	2.96296	119.277	183.299	1566.77	207.78	20.0414	26.6843
6.74	0.0867	0.85808	38.3117	115.262	554.843	77.9179	8.99775	19.6163
6.84	0.0908	0.97006	39.9314	93.4033	628.403	93.6277	8.59211	20.3241
6.99	0.0844	0.98902	44.7091	112.746	845.471	113.286	9.41981	18.784
7.15	0.1477	1.30215	46.5622	158.375	686.561	96.1076	10.7087	17.939
7.81	0.1121	1.53593	79.8222	110.629	1020.04	165.421	12.2697	30.984
7.58	0.216	2.01704	222.254	151.453	1446.75	307.667	26.4246	49.2766
7.66	0.096	1.98832	52.6345	97.8602	1524.16	319.281	9.72605	35.6272
7.55	0.1677	1.7822	87.4762	152.625	1338.61	226.693	21.9868	41.1907
7.59	0.1479	1.49582	57.2025	126.807	1171.7	206.219	14.401	34.8896
6.96	0.1064	1.98378	137.306	299.774	1437.67	100.908	6.75756	7.74007
7.06	0.0685	0.95546	77.3997	274.393	735.729	77.9368	4.67006	5.94967
6.04	0.0608	1.66295	66.1306	168.861	974.073	124.559	6.84389	10.1958
6	0.0659	1.55796	97.0728	218.039	882.859	111.566	8.29413	11.6095

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.78	0.0957	1.34644	110.56	313.424	957.37	103.654	6.31135	10.1717
6.04	0.0727	2.30318	44.2729	204.561	2406.31	380.65	9.75676	23.5765
5.99	0.074	2.52032	53.4393	194.947	2282.8	354.238	8.40903	15.6898
5.95	0.0642	2.65732	58.1633	249.627	2645.38	461.734	7.33628	17.7352
6.03	0.0757	2.84999	47.7562	243.787	2721.33	469.533	7.41289	21.2479
5.8	0.0731	2.5464	56.5598	215.311	2452.15	403.537	9.95779	23.6396
6.53	0.0891	1.81263	57.6725	234.802	958.906	133.86	7.83006	13.4135
6.83	0.079	1.54305	57.5711	157.64	949.94	116.94	6.23008	16.5667
7.22	0.0875	1.79785	65.7169	191.855	1220.44	148.455	7.33351	16.8436
6.87	0.0767	1.95468	69.5932	223.082	1012.95	134.329	6.55161	11.8494
7.01	0.1002	2.05839	87.9978	281.069	1137.01	147.893	6.73903	16.4084
5.95	0.0871	1.79273	64.9694	292.834	910.283	120.754	9.13847	8.9253
6.65	0.0829	1.50014	50.4427	189.946	891.604	94.5911	5.26523	10.6826
6.96	0.0794	1.68951	64.1187	339.75	938.634	122.11	7.72129	10.6176
6.74	0.0679	1.53283	60.7851	281.254	821.218	93.7683	6.43763	8.71943
7.32	0.0709	1.55896	44.1023	344.532	923.36	127.499	5.0822	12.3214
7.67	0.1223	2.41328	142.694	218.874	1965.53	200.345	35.2703	26.9687
7.9	0.1391	1.81143	60.3205	88.1693	1572.49	185.675	19.6415	27.3918
7.87	0.1665	1.86872	32.5558	64.6713	1530.31	196.142	23.9792	37.5032
7.85	0.1622	2.05008	57.8703	81.3878	1782.23	214.289	26.117	35.4906
7.98	0.1878	1.96933	54.5563	58.4549	1798.03	194.312	37.763	44.92
7.99	0.1664	2.20524	47.4002	73.0671	1795.82	180.816	19.6436	33.3959
8.22	0.1853	1.95778	14.4098	56.891	1736.3	196.282	27.2801	33.5122
7.22	0.239	1.77454	20.6661	96.5982	1337.91	205.107	31.9668	48.3409
8.01	0.1328	2.11333	13.1913	74.2937	1565.04	186.692	15.5931	28.1946
8.13	0.1438	2.02786	14.6505	73.4411	1724.37	207.117	21.1136	33.2651
5.56	0.1048	1.80265	98.217	229.666	576.174	77.0969	14.8683	12.195
5.87	0.0756	1.76357	57.2022	183.448	711.152	83.0509	10.6294	14.9055
5.91	0.0934	1.80934	65.614	278.653	593.008	76.5381	11.9176	8.53439
5.97	0.082	1.70255	37.2592	137.818	729.721	86.1256	11.4319	13.8979
6.04	0.1049	2.2913	46.3008	217.685	674.696	92.5067	10.7288	11.5001
5.68	0.1233	1.77285	128.612	165.607	619.808	54.3376	14.9283	16.0083
5.71	0.0959	1.53798	83.7293	191.277	507.266	53.85	10.2105	9.12419

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
5.81	0.1039	1.73365	80.8124	190.859	496.689	54.9263	10.8025	9.74055
5.52	0.1178	1.70074	64.428	156.754	529.997	60.1359	10.9343	10.4423
5.83	0.0836	1.68766	79.0456	175.279	528.44	58.5541	9.82216	9.03681
7.76	0.0982	1.23872	24.4037	115.621	1001.39	62.7584	6.25337	12.5914
7.53	0.1025	1.19735	50.8995	88.0276	921.197	62.153	5.66491	5.38772
6.45	0.0729	1.18699	71.2809	132.018	615.289	62.5277	6.63467	5.84312
6.39	0.0487	0.84112	38.9858	78.8274	328.35	43.6638	4.72206	4.22562
6.47	0.0811	1.22411	46.8588	128.121	586.776	58.0969	6.96891	6.40874
7.36	0.0681	2.01554	51.1579	101.428	779.173	50.2943	4.74001	5.17896
6.92	0.0489	1.30901	44.2577	88.5189	596.855	70.1405	5.48827	4.78709
6.68	0.0564	1.59478	56.0278	172.297	678.108	57.3769	6.95987	4.96245
6.41	0.0528	1.15709	68.1961	74.7391	409.767	51.6132	4.47582	3.49344
6.97	0.0494	1.12918	64.8665	108.109	571.444	47.9032	4.45619	4.26789
7.53	0.1547	1.99748	131.034	197.637	1737.14	320.36	23.2365	51.4522
6.98	0.1044	1.89839	99.6712	142.271	1396.18	247.408	11.3253	25.0849
7.32	0.0868	1.89085	85.873	141.062	1478.39	249.257	11.217	23.3076
7.28	0.081	1.99011	44.3294	128.869	1537.74	273.704	10.6593	22.8992
7.52	0.1122	2.07414	74.2456	149.998	1617.79	277.945	13.9811	27.1104
7.49	0.1216	3.40567	18.1803	216.865	3557.53	631.491	11.5201	33.0669
7.44	0.1165	3.25841	11.671	198.374	3338.92	604.022	10.1257	28.7618
7.41	0.0959	3.33873	13.8803	223.154	3432.52	624.189	10.5199	25.7507
7.38	0.1193	3.23555	12.6971	247.81	3616.18	682.461	11.8011	28.8991
7.4	0.1078	3.49698	13.4341	199.783	3481.26	626.924	10.4401	28.3062
6.52	0.0701	1.76331	38.1025	109.677	948.926	189.44	11.4195	21.3648
6.53	0.0897	1.87838	37.7518	125.654	876.149	164.561	11.1596	20.0329
6.97	0.1081	1.7186	57.3823	151.746	935.926	151.896	9.78186	18.4189
6.58	0.1046	2.02112	70.5079	171.62	1083.83	167.806	13.6698	22.5071
6.81	0.0948	3.93313	63.9741	175.75	1124.94	195.281	13.1676	18.8945
5.79	0.1031	1.96719	32.5241	116.516	682.469	132	10.7291	17.4221
5.72	0.221	1.93411	43.703	296.935	715.597	146.217	13.1891	19.139
5.45	0.1935	2.2947	55.4103	219.055	776.039	157.454	15.2545	19.6068
6.11	0.1676	1.94837	31.0913	163.347	812.671	166.45	10.9938	21.9034
6.49	0.1554	1.98612	38.9298	173.906	852.698	178.031	10.1748	20.8374

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.1	0.1347	1.31514	63.6091	272.401	536.954	70.5523	6.9931	9.01279
6.4	0.1382	1.85829	69.3887	398.862	483.036	58.7835	9.40607	10.4513
6.69	0.1045	1.59398	36.5387	293.44	474.512	79.1614	7.62923	7.25189
6.34	0.0945	1.50187	44.8458	248.639	557.353	65.8762	8.34661	9.01955
5.54	0.1013	1.46257	38.8619	323.47	544.959	60.0299	8.06787	12.5326
6.21	0.1648	1.56076	67.917	266.031	652.293	93.8251	6.98477	8.77727
6.03	0.1217	2.01352	37.8195	268.583	703.56	118.621	10.9083	9.18304
5.91	0.0747	1.42925	65.1658	135.37	734.811	110.162	7.25454	6.78846
6.2	0.0793	1.59591	77.4097	235.606	589.393	75.0561	6.74501	7.28683
5.65	0.1388	1.52464	84.1553	277.054	628.392	77.852	7.93088	8.31578
6.46	0.1063	1.67785	67.8541	169.076	1216.98	172.32	9.3374	11.5619
6.1	0.0797	1.39128	12.2977	57.4756	1001.95	135.904	6.55932	7.03969
6.81	0.124	1.97512	70.7971	163.95	1175.46	182.125	10.7611	12.4593
6.85	0.1136	1.72409	50.7315	123.525	1176.79	165.175	8.69975	12.1258
6.67	0.1166	1.61342	42.9733	136.44	1054.13	152.861	11.1155	10.6336
6.77	0.1278	2.08892	62.3457	203.193	1439.49	239.491	8.09841	10.4086
6.85	0.1614	2.13685	69.9455	142.614	1526.67	229.002	9.06576	10.6646
6.78	0.1098	2.33405	62.456	148.943	1494.21	228.504	7.84329	11.2168
7.38	0.1273	1.85834	86.0012	145.071	1448.57	215.806	8.26057	13.617
6.95	0.1316	2.17742	96.8162	220.688	1366.03	219.672	8.02154	7.61693
7.72	0.1492	2.94264	47.8852	290.279	3606.87	776.33	11.1494	35.8628
8.31	0.1513	2.43912	39.9049	222.392	4743.87	599.485	15.8274	97.5627
7.86	0.189	2.70962	43.3619	274.502	4338.63	729.18	16.1149	54.4574
7.62	0.1246	2.96915	44.0948	313.739	3255.9	820.57	7.61827	17.578
4.69	0.1338	3.10234	61.5582	344.793	3318.96	854.33	7.30704	17.5478
7.44	0.0988	3.10009	65.9101	319.362	3399.75	897.94	7.57942	17.9072
7.33	0.1064	3.16364	56.0261	313.953	3746.59	899.575	7.37893	20.0054
7.18	0.1152	3.28668	89.5619	356.915	3381.15	877.745	9.55563	18.5426
7.06	0.0935	3.11687	61.8055	308.594	3291.71	870.61	7.60036	20.2955
7.26	0.0928	2.88699	41.3213	283.556	3310.81	802.755	7.48294	19.2581
6.25	0.112	1.44858	47.367	82.195	999.58	113.278	8.35	14.441
6.5	0.103	1.91582	42.685	54.005	1158.17	124.634	6.962	23.319
6.3	0.178	2.05377	62.899	101.641	1284.35	151.631	18.398	14.603

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
5.84	0.137	1.5242	23.481	48.789	944.335	113.41	15.133	19.223
6.35	0.125	1.5893	30.866	54.212	1167.67	135.625	11.963	26.904
6.8	0.097	1.11707	19.119	58.329	1118.14	149.491	7.674	20.279
6.85	0.089	1.2731	22.48	45.129	1159.57	139.86	4.799	24.232
6.67	0.133	1.3594	28.219	90.698	1431.32	184.833	12.806	21.014
6.94	0.085	1.25351	19.395	54.654	1237.2	161.255	5.313	28.264
6.87	0.095	1.36683	16.41	54.018	1269.92	165.545	6.307	29.922
6.6	0.167	2.54974	75.209	65.876	1628.22	159.658	16.095	36.227
6.7	0.132	2.64184	114.73	104.796	2006.09	234.389	12.368	30.719
6.3	0.131	3.08379	59.942	140.724	2490.73	444.055	12.583	38.316
6.18	0.118	2.20248	33.316	88.241	1550.66	216.013	11.121	28.117
6.4	0.12	2.29412	34.011	79.672	1613.09	195.857	10.329	33.86
6.35	0.115	2.06182	53.753	55.196	1519.63	161.53	13.123	44.344
5.68	0.127	2.02389	55.837	83.456	1417.9	237.214	22.29	57.1
5.31	0.096	2.28516	36.966	124.564	1597.9	394.166	16.336	43.651
5.58	0.098	1.73098	21.507	62.694	1252.75	192.358	10.516	37.123
6.8	0.12	1.66849	59.085	163.483	1118.5	181.848	8.117	21.285
6.2	0.085	2.03724	25.035	68.947	1590.38	186.689	9.765	44.567
6.92	0.152	1.52066	48.764	143.906	921.947	148.862	9.401	13.781
7.11	0.101	1.44403	34.113	126.141	887.141	153.782	5.599	6.717
7.15	0.103	1.39749	61.371	150.083	949.78	150.925	6.384	8.001
7.2	0.093	1.33407	29.539	127.087	933.313	153.754	6.862	16.612
7.42	0.068	1.03671	25.071	147.586	870.245	153.625	4.376	13.842
7.44	0.07	0.93745	39.018	107.211	732.549	120.864	5.158	12.264
7.16	0.068	1.01641	33.012	131.302	680.012	120.793	4.11	6.96
7.22	0.055	0.83536	24.427	104.704	668.815	108.3	3.857	10.963
7.35	0.063	0.97315	16.328	106.025	738.597	130.672	4.361	13.11
7.48	0.077	1.06963	65.282	76.89	737.638	118.682	3.619	22.243
6.61	0.108	1.38902	27.707	106.58	661.426	84.244	6.916	14.492
6.65	0.092	1.74296	26.879	129.886	685.743	88.748	5.131	6.78
6.75	0.121	1.42237	55.678	77.452	760.984	100.85	5.448	12.334
7.15	0.16	1.9275	30.919	116.681	877.403	124.287	7.265	22.436
6.95	0.071	0.89055	78.371	126.857	613.933	97.667	5.894	19.888

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.68	0.068	0.90189	14.431	98.638	585.869	81.571	4.819	13.045
6.97	0.057	0.87185	21.021	103.451	527.726	75.409	3.164	7.681
7.3	0.063	0.7768	60.798	51.566	717.577	99.454	2.993	14.01
7.44	0.073	0.9864	21.524	103.784	777.463	120.28	4.955	17.295
5.58	0.09	2.35957	48.515	131.303	1135.98	134.516	9.53	8.962
5.62	0.086	2.63196	45.932	112.939	885.849	104.76	9.085	7.853
4.96	0.113	2.17515	47.966	71.274	609.848	86.163	11.538	8.267
5.35	0.1	2.33509	41.748	73.075	967.843	102.051	10.988	11.548
5.05	0.113	1.94534	38.652	86.171	679.55	86.06	10.515	9.9
5.68	0.07	1.34898	35.033	86.918	1080.39	89.614	6.704	8.39
6.1	0.068	1.12778	20.155	63.309	997.378	85.346	6.155	7.502
5.44	0.075	1.15998	25.553	57.808	794.836	73.455	7.686	8.568
5.8	0.073	1.20172	34.936	59.088	955.903	72.397	6.852	8.333
5.5	0.09	0.92225	26.356	75.212	825.76	67.591	7.334	10.404
6.03	0.142	2.63568	39.427	182.091	2606.96	439.97	7.659	19.16
5.81	0.206	2.95548	47.553	200.136	2517	397.842	9.961	20.5
6.08	0.17	3.16013	63.83	235.79	2620.48	470.588	9.343	15.915
5.94	0.172	3.53608	45.839	217.058	2893.77	488.452	7.49	18.515
5.84	0.21	3.38132	57.896	236.711	2621.59	471.14	10.599	17.609
6.69	0.123	1.9672	27.513	170.873	2986.28	516.765	3.113	27.361
6.09	0.118	2.26505	32.002	166.857	2708.24	427.422	8.788	24.153
5.99	0.155	2.5227	47.525	201.635	2782.82	507.195	8.258	21.233
6.19	0.123	2.53561	37.25	200.52	3045.48	504.916	6.218	23.514
6.24	0.177	2.41111	40.47	212.153	3062.48	554.646	5.415	23.598
6.08	0.122	1.6391	58.089	138.043	571.723	55.238	8.459	8.215
6.36	0.175	1.68886	56.581	126.124	812.798	46.287	8.792	10.889
6.04	0.126	1.35362	25.983	175.959	503.24	53.496	7.451	8.262
5.77	0.149	1.6584	21.129	77.121	529.378	55.883	10.025	9.439
6.02	0.141	1.33487	22.848	150.925	530.423	54.414	8.061	7.579
6.29	0.056	1.02279	14.694	109.991	495.498	58.518	5.084	10.489
6.89	0.091	1.08248	17.484	124.448	750.646	33.859	5.555	8.435
6.36	0.073	1.18152	14.103	187.311	495.472	23.251	5.373	8.714
5.54	0.064	0.92868	11.516	58.005	391.224	27.691	8.872	9.651

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.18	0.076	0.93686	9.083	110.622	569.87	41.42	6.092	8.998
6.27	0.132	1.80548	64.466	79.281	693.802	120.215	10.823	12.101
6.4	0.145	1.70409	34.839	102.897	656.163	129.21	6.371	11.098
6.65	0.079	1.30367	38.302	114.328	790.436	160.922	7.086	11.074
6.62	0.084	1.33624	19.117	67.529	678.329	127.899	5.465	13.236
6.6	0.125	1.31513	31.526	92.667	629.962	141.012	12.232	14.799
5.96	0.07	2.05247	56.817	81.678	494.59	68.697	9.154	10.908
6.08	0.068	1.18873	46.508	118.321	428.903	60.064	6.534	10.447
6.35	0.054	0.85645	19.573	150.89	711.596	135.382	5.112	10.583
6.25	0.072	1.4009	30.05	90.239	611.081	107.828	6.301	9.955
5.86	0.056	1.50359	48.075	91.568	394.557	65.375	8.153	9.222
5.83	0.175	1.81761	99.704	163.89	1354.77	142.357	28.297	14.309
5.44	0.271	2.45045	111.345	156.739	969.61	100.977	52.437	18.616
5.7	0.168	1.69019	78.75	115.394	949.093	96.334	25.08	16.047
5.76	0.172	1.94107	66.647	119.637	1124.04	117.633	32.357	24.893
5.7	0.238	2.04297	86.408	145.294	1048.6	113.762	28.779	16.612
6.35	0.167	1.73117	80.025	141.295	1464.96	162.968	29.082	18.217
6	0.129	2.27976	108.095	123.483	1173.02	118.324	20.214	17.932
6.2	0.1	1.12759	57.528	89.637	1075.16	108.385	14.964	17.968
6.26	0.123	1.94512	60.431	100.121	1254.69	133.792	19.132	22.286
6.35	0.12	1.28806	64.994	90.735	1223.29	129.164	16.748	17.945
6.51	0.115	1.34187	41.613	92.654	1345.85	189.48	8.044	45.529
6.73	0.111	1.44119	32.571	79.508	1355.73	233.205	7.427	99.859
6.22	0.16	1.88626	73.394	142.123	1260.14	161.047	10.045	18.636
6.5	0.159	1.9082	46.812	101.568	1446.3	290.387	11.883	81.125
6.46	0.199	1.68906	51.916	108.194	1462.29	260.804	11.438	70.933
7.63	0.099	1.43932	29.351	71.294	1549.8	215.53	7.17	45.582
7.6	0.115	1.77374	29.863	63.57	1405.1	248.074	7.805	79.15
6.97	0.127	2.31081	71.483	140.752	1410.64	181.984	9.3	31.729
7.35	0.127	1.70134	41.868	91.938	1741.83	429.052	8.564	94.157
7.1	0.228	1.90522	48.066	87.901	1605.98	290.988	13.217	110.786
6.33	0.131	2.66591	21.199	135.128	1851.67	365.849	14.535	30.872
6.25	0.101	2.0248	13.852	104.019	1551.25	302.247	11.414	29.245

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.45	0.103	2.51856	17.629	156.969	2060.25	414.302	11.343	26.697
6.17	0.101	2.86103	15.391	166.585	2107.75	447.917	10.229	23.525
6.18	0.15	3.31719	22.776	217.013	1914.4	391.819	14.094	20.514
6.35	0.114	2.15051	9.27	107.181	2019.08	405.093	10.464	26.435
6.4	0.125	2.86027	5.515	91.578	1812.33	378.097	13.832	31.852
6.64	0.106	2.18796	7.614	120.262	2336.42	486.774	10.512	29.497
6.54	0.093	2.12965	5.011	115.527	2335.96	502.247	7.621	22.96
6.5	0.112	2.44019	9.316	135.2	2243.08	477.308	10.922	23.139
6.8	0.17	3.45237	30.54	165.983	3403.43	601.852	12.291	40.244
7.05	0.173	3.72936	17.828	173.223	3230.97	624.714	9.088	31.818
6.96	0.157	3.31112	37.726	192.145	3212.34	638.258	13.969	44.921
6.53	0.164	3.47804	12.689	197.524	3595.08	700.631	9.963	39.135
6.94	0.147	3.38366	21.092	200.77	3607.47	689.773	9.749	35.72
6.9	0.134	2.79521	9.656	179.877	3711.19	649.025	11.436	42.81
7.35	0.124	3.04822	8.817	203.947	3932.14	749.623	7.979	42.286
6.93	0.125	2.70352	9.046	181.145	3545.16	672.939	12.008	42.689
7.3	0.134	3.10897	5.719	231.027	4202.14	820.727	8.018	46.756
7.16	0.135	3.15298	4.529	215.285	4249.33	798.711	7.971	47.057
6.42	0.152	2.28211	22.211	64.945	1277.41	187.904	23.906	40.828
6.3	0.256	2.16169	11.798	66.258	1342.68	214.577	45.728	63.512
6.35	0.438	2.33108	27.605	99.114	1555.97	223.295	77.292	77.288
6.48	0.148	2.31343	22.634	77.879	1362.83	210.687	26.181	38.305
6.45	0.271	2.05895	18.996	91.735	1411.93	210.629	64.665	56.775
6.75	0.195	1.74196	10.822	48.742	1442.1	205.471	34.16	62.088
6.58	0.464	1.89471	6.803	46.027	1546.25	217.151	106.64	100.374
6.92	0.312	1.7483	8.323	55.005	1723.88	235.084	66.409	70.33
6.55	0.212	1.95522	18.395	60.021	1449.68	215.787	41.341	51.347
6.76	0.32	1.91015	17.369	80.096	1593.03	226.748	79.496	77.248
6.86	0.11	2.47067	26.204	68.336	1576.93	212.947	13.32	29.952
7.55	0.198	2.19276	13.532	65.603	2093.65	224.159	27.92	37.959
7.62	0.187	2.60843	28.04	87.441	2634.86	190.375	20.955	30.105
7.7	0.126	2.49045	30.248	70.124	2086.04	218.779	10.145	25.76
7.51	0.256	2.33398	22.949	49.62	1945.73	219.469	57.948	68.22

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
7.36	0.175	0.64311	14.115	53.963	1750.38	230.309	25.88	49.622
7.65	0.255	1.5606	5.707	25.47	1938.69	221.839	64.081	86.727
7.94	0.175	2.70946	17.674	35.87	2383.58	193.051	20.77	40.948
7.8	0.191	1.91499	12.595	35.716	1937.33	210.473	28.451	59.146
7.7	0.261	1.69087	8.006	29.436	1748.33	201.937	46.188	82.732
6.72	0.097	1.89754	45.402	99.909	890.993	111.334	10.496	12.155
5.92	0.091	1.97537	37.724	75.681	889.383	109.337	8.589	9.912
5.86	0.114	1.9544	39.536	71.552	1125.35	147.67	10.391	13.676
5.8	0.104	1.93951	44.974	83.512	967.723	126.441	8.563	10.917
5.86	0.089	1.50693	35.732	74.562	941.803	111.991	9.633	13.05
6.1	0.129	1.54273	37.499	52.436	977.027	131.171	18.364	18.804
6	0.073	1.47608	33.422	47.653	814.177	104.509	7.476	10.829
6.04	0.084	1.75776	28.18	48.122	1138.79	156.571	9.806	16.672
5.97	0.082	1.49802	42.722	58.341	1258.01	171.074	7.847	15.069
6.25	0.081	1.29359	31.08	45.843	1089.07	137.128	8.953	16.526
6.54	0.077	1.7727	45.519	47.956	867.66	112.137	7.659	16.699
6.2	0.097	1.56539	34.817	41.285	1016.66	122.972	9.118	14.932
6.25	0.075	1.56371	47.031	97.569	725.551	90.06	5.943	6.444
6.5	0.082	1.53822	41.582	38.857	950.03	113.212	14.687	13.82
6.23	0.089	1.46186	42.509	41.684	846.943	89.749	9.652	13.232
6.75	0.145	1.46789	45.821	28.583	951.846	136.012	19.85	31.421
6.2	0.093	1.26537	33.107	29.961	872.162	107.08	7.387	17.936
6.9	0.07	1.0443	39.426	53.902	844.299	122.299	5.233	9.816
6.7	0.085	1.48027	31.695	29.917	852.235	110.232	8.534	17.523
6.9	0.089	1.39857	46.089	29.731	1024.69	127.668	7.41	16.829
6.25	0.195	2.1004	36.329	165.076	1585.61	301.855	11.782	28.09
6.1	0.15	1.88183	48.909	158.718	1513.85	262.176	10.061	23.166
5.85	0.126	1.59835	38.379	153.713	1219.88	221.531	10.885	17.304
5.8	0.142	1.54091	44.461	165.991	1074.94	189.121	10.242	18.785
5.8	0.136	1.72116	42.193	171.857	1189.24	219.188	10.983	16.984
6.22	0.125	1.60927	31.367	139.108	1549.39	285.091	8.944	24.341
6.27	0.117	1.57083	47.037	140.917	1497.74	249.403	10.767	22.436
5.56	0.105	1.34831	57.312	122.647	1051.61	190.823	11.564	19.684

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
5.9	0.102	1.30202	50.97	150.938	1117.82	194.454	9.42	15.439
5.55	0.092	1.32222	56.77	140.794	1150.54	213.251	10.494	16.68
5.9	0.161	1.75298	31.894	156.54	1537.05	297.674	12.855	27.035
5.8	0.167	2.27377	56.583	213.841	1183.67	201.519	11.97	13.396
5.67	0.125	1.81265	36.98	157.139	1275.31	247.277	12.166	15.703
5.76	0.145	1.85374	37.686	175.155	1333.8	265.848	10.532	19.299
5.7	0.159	2.37466	47.583	177.232	1234.31	234.057	14.857	17.162
6.2	0.108	1.45976	24.24	126.078	1529.98	300.857	9.147	23.759
6.23	0.42	1.2689	24.92	176.79	1250.93	220.985	7.402	15.098
6.1	0.086	1.16102	17.818	127.783	1216.9	247.319	7.545	17.793
4.9	0.093	1.06873	30.449	124.125	867.108	181.922	13.697	18.313
5.85	0.104	1.41188	25.309	138.871	1322.6	261.065	8.902	18.152
6	0.116	1.93655	70.424	133.955	1533.76	482.435	11.543	33.489
6.15	0.132	1.88889	53.324	144.953	1623.22	459.7	11.246	36.105
6.18	0.134	2.21667	77.491	159.414	1592.72	383.783	12.421	25.031
6.31	0.114	2.22254	84.722	267.595	1990.21	465.33	9.539	25.78
6.24	0.156	2.80832	171.655	247.555	1909.67	481.715	13.435	26.227
6.45	0.087	1.54637	29.789	138.083	1660.81	470.625	9.159	34.518
6.35	0.093	1.41339	18.391	140.662	1625.1	484.16	9.524	45.612
6.3	0.084	1.44662	22.856	153.712	1607.95	403.878	9.622	30.163
6.42	0.074	1.63849	53.883	214.783	1920.39	503.61	6.697	39.547
6.36	0.079	1.74563	39.765	251.556	2031.55	512.425	8.243	32.279
5.04	0.057	0.83174	57.615	99.016	262.241	97.831	6.791	7.352
6.04	0.127	1.54937	39.796	67.693	1058.58	226.792	10.965	26.09
6.03	0.088	1.05032	66.864	62.814	395.692	85.725	5.838	10.587
5	0.078	1.28545	72.596	116.338	437.503	134.403	9.901	9.323
6.55	0.089	0.98441	62.914	69.721	486.842	92.11	6.781	12.981
5.31	0.033	0.45304	31.172	62.101	299.145	95.099	4.632	5.45
6.1	0.09	0.96322	13.184	76.357	1071.81	252.329	8.221	29.128
5.15	0.061	0.70533	46.163	45.834	239.477	60.654	6.37	11.468
4.94	0.055	5.52404	33.195	82.942	496.2	143.042	9.477	8.29
6.05	0.063	0.54369	52.718	54.702	299.754	81.06	6.119	12.767
5.24	0.079	2.57109	44.647	108.402	933.312	262.728	19.621	17.227

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.3	0.089	2.40487	120.323	86.715	1605.05	248.874	10.204	67.535
6.6	0.097	1.82106	59.004	55.125	1193.39	193.238	7.433	22.249
6.46	0.079	1.76304	53.524	51.739	1251.37	212.6	5.635	19.973
6.62	0.081	1.86275	48.212	51.985	1297.85	227.966	5.66	25.874
6.42	0.089	2.00936	84.081	62.419	1308.9	213.299	6.79	23.055
6.48	0.087	1.434	88.847	62.358	979.334	151.672	5.907	75.086
6.8	0.064	1.129	45.958	45.428	1036.2	188.645	5.411	22.762
6.7	0.079	1.30043	47.513	74.654	1333.09	275.804	5.157	24.741
6.42	0.06	1.26854	38.48	63.367	1268.47	251.275	4.612	34.626
6.6	0.071	1.55336	72.491	59.268	1355.25	247.309	6.127	27.024
5.21	0.102	2.91035	61.039	83.983	723.568	217.593	25.221	13.662
5.2	0.087	2.4449	40.42	77.053	686.933	211.147	21.288	13.356
5.25	0.085	2.31489	39.489	91.927	668.506	238.761	17.146	28.683
5.32	0.074	2.68856	41.89	97.893	905.695	299.509	12.589	22.369
5.15	0.05	1.49558	26.726	83.826	880.035	259.549	11.283	25.243
4.78	0.083	2.25399	44.801	74.413	856.777	236.856	23.442	21.641
5	0.075	1.81818	28.235	59.361	784.649	200.297	19.914	16.489
4.95	0.094	1.84039	31.546	64.055	687.105	237.133	20.983	43.867
5.16	0.073	1.88462	26.79	71.677	1002.99	300.997	13.345	41.124
5.95	0.166	2.62914	47.506	83.181	1550.9	231.772	11.483	17.729
5.85	0.111	2.44068	53.915	83.324	1303.64	188.809	9.304	16.671
5.95	0.117	2.31919	34.216	140.268	1061.17	145.788	9.887	11.238
6.35	0.114	2.37601	66.84	135.008	1231.76	179.937	8.652	10.414
5.98	0.12	2.53761	44.197	123.712	1217.36	183.168	10.711	13.26
6.3	0.116	2.47045	32.281	73.056	1603.94	246.954	10.123	21.171
6.21	0.08	1.98448	36.356	61.365	1324.21	203.29	7.899	23.603
6.11	0.085	2.00796	23.959	69.835	1063.25	147.755	8.251	14.151
6.45	0.084	1.96092	53.391	88.971	1242.42	204.151	8.542	21.436
6.12	0.089	2.23474	39.615	65.587	1305.44	176.163	9.857	12.89
6.65	0.168	1.61728	63.43	92.507	1193.33	200.33	23.775	41.316
7.1	0.174	1.89648	36.242	85.191	1425.51	241.159	23.287	47.122
7.25	0.143	2.15798	41.145	71.32	1488.63	262.109	13.069	44.749
7.45	0.173	1.95672	36.587	80.696	1381.71	238.448	19.761	65.977

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
7.42	0.132	1.85493	33.068	48.576	1394.58	234.557	15.69	41.801
7.35	0.164	1.2655	41.679	65.016	1126.36	218.746	30.162	71.316
7.54	0.109	1.86852	37.956	68.653	1345.62	230.289	16.189	49.132
7.6	0.112	1.39185	33.897	45.614	1369.6	229.329	13.971	54.288
7.65	0.148	1.8012	47.399	57.919	1455.88	248.976	20.388	63.129
7.75	0.092	1.09901	18.115	35.411	1211.35	223.058	10.245	44.786
6.6	0.09	1.58815	32.242	55.474	628.52	77.35	7.492	14.247
5.45	0.075	1.60573	42.821	47.112	422.823	61.778	8.019	13.235
5.7	0.099	1.98485	50.328	75.872	513.667	63.406	9.353	15.285
5.21	0.08	1.35711	36.652	81.735	294.427	39.527	7.784	7.081
6.05	0.093	1.52567	33.42	56.529	507.123	67.036	8.145	14.279
6.4	0.055	1.00394	20.906	34.106	514.841	55.937	7.146	17.065
6.35	0.045	0.88053	19.083	34.783	401.435	57.05	5.71	16.022
6.14	0.056	1.13694	29.903	52.379	477.945	59.271	6.795	13.046
6.08	0.04	0.75888	13.376	57.471	299.899	34.609	4.775	6.936
6.4	0.045	0.96685	19.326	36.059	460.385	53.065	6.621	13.952
5.34	0.075	1.40715	38.695	66.184	299.142	41.745	9.325	7.531
6.2	0.094	1.38356	31.719	47.109	493.224	67.318	6.858	9.381
5.7	0.113	1.80406	54.701	39.155	510.586	62.746	8.076	13.299
5.28	0.094	1.78399	38.764	42.711	339.446	50.459	10.534	10.924
6.25	0.077	1.18611	22.75	49.106	476.007	70.71	6.108	12.141
5.66	0.044	0.95144	15.839	43.3	282.203	30.725	8.748	7.757
6.46	0.055	0.84358	16.156	28.158	415.735	49.673	9.422	10.389
6.21	0.053	1.01222	31.798	20.636	430.06	46.308	8.747	14.773
5.75	0.045	1.17293	23.539	23.865	333.62	31.358	10.23	11.607
6.15	0.045	0.92617	14.556	24.901	365.229	47.839	9.324	12.384
6.05	0.151	1.6027	145.735	129.389	839.657	111.894	13.688	66.851
6.08	0.16	1.84241	177.316	172.081	912.191	118.042	19.829	70.323
6.4	0.147	1.77835	199.607	148.54	999.052	121.518	11.946	52.031
6.1	0.164	1.64127	172.058	122.403	804.157	122.741	14.471	75.168
6.3	0.128	2.00887	165.17	120.52	890.173	118.895	14.817	70.364
6.31	0.113	1.21465	78.296	102.921	839.306	117.63	14.664	60.581
6.25	0.085	1.57439	115.901	129.14	910.579	112.904	10.631	38.152

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

pH (4-7 std)	EC (dS m-1)	SOM (%)	P (mg kg-1)	K (mg kg-1)	Ca (mg kg-1)	Mg (mg kg -1)	S (mg kg-1)	Na (mg kg-1)
6.65	0.087	1.41449	109.878	106.987	955.801	114.811	10.186	48.429
5.77	0.167	1.49847	139.587	96.684	805.393	108.912	18.675	73.078
6.36	0.1	1.20797	100.318	95.942	800.753	102.645	11.743	59.837
6.35	0.12	1.68304	184.569	149.242	942.285	132.741	11.8	55.123
6.08	0.161	1.81209	187.011	176.13	876.458	136.973	15.053	67.447
6.45	0.101	1.41183	164.49	125.022	843.631	122.124	9.989	53.726
6	0.162	1.74076	156.064	95.995	895.623	124.297	18.028	96.353
5.95	0.144	2.04692	155.636	128.075	1019.85	140.309	14.741	72.479
6.2	0.088	0.97605	100.555	92.904	714.485	100.039	10.187	59.451
5.18	0.112	1.19937	113.939	134.829	656.315	124.01	16.506	44.724
6.21	0.093	1.19763	82.774	85.912	848.903	133.656	10.063	45.667
5.93	0.103	1.45979	81.802	79.777	958.288	138.833	11.643	59.79
6.02	0.114	1.72614	82.444	110.023	1259.11	169.927	12.631	59.297

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
263.1	107.998	3.51499	1.38846	0.25993	0.859	0.0934	9.197
352.626	121.278	5.65549	1.56609	0.23265	0.857	0.0912	9.39693
276.009	112.152	4.04627	1.64464	0.25289	0.6805	0.0794	8.57053
209.308	82.4304	2.37257	1.18848	0.18027	0.7592	0.085	8.93176
374.748	116.681	4.52591	1.42311	0.32576	0.7212	0.0831	8.6787
260.38	164.821	1.0566	1.69119	0.2256	0.4968	0.0607	8.18451
197.838	62.7464	1.15955	1.19827	0.15243	0.6827	0.082	8.32561
229.684	68.8498	0.54033	0.93163	0.15894	0.5141	0.0645	7.97054
193.884	181.593	1.74301	1.39064	0.17092	0.549	0.0677	8.10931
175.343	179.31	0.84118	0.76277	0.13917	0.7651	0.0847	9.03306
201.078	94.2425	0.61094	1.02655	0.22388	0.9292	0.107	8.68411
254.188	97.961	0.75316	0.89738	0.26537	1.172	0.1215	9.64609
169.611	86.6581	0.52422	0.85074	0.19077	0.8792	0.1032	8.51938
182.851	113.996	1.10656	0.98096	0.23744	0.8352	0.1022	8.17221
183.463	122.174	0.60854	1.05946	0.23021	0.9076	0.1096	8.28102
184.506	39.0749	1.2308	0.69774	0.24592	0.2911	0.0561	5.18895

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
353.108	36.2503	1.01856	0.79201	0.64856	0.3636	0.0613	5.93148
317.825	44.0429	0.86831	0.80087	0.32766	0.2145	0.0434	4.9424
408.623	36.1741	1.26618	0.76215	0.42669	0.4124	0.0661	6.23903
338.951	21.8436	0.8975	0.85012	0.40235	0.1932	0.0502	3.84861
173.394	170.352	57.9177	0.39372	1.48621	0.9331	0.0972	9.59979
143.484	144.635	395.527	0.41381	1.02419	1.077	0.1087	9.908
177.665	177.226	152.493	0.59126	1.78169	0.7197	0.0824	8.73422
312.101	311.663	80.0391	1.39515	1.5733	0.8834	0.0951	9.28917
236.25	237.636	72.8345	0.74925	1.95811	1.198	0.1173	10.2131
287.67	286.272	147.646	0.78408	1.70863	0.4938	0.0599	8.24374
116.911	117.497	182.555	0.23869	1.22945	0.7218	0.0806	8.95533
142.59	143.228	145.645	0.38577	1.57006	0.5304	0.0668	7.94012
90.3773	88.5442	126.3	0.3596	1.23066	0.5835	0.068	8.58088
139.51	139.827	242.352	2.45021	1.41892	0.4798	0.0572	8.38811
177.527	177.574	98.5311	3.99534	1.20504	0.7327	0.0804	9.11318
119.84	120.871	66.4353	2.17923	0.84395	1.31	0.1053	12.4406
123.884	123.726	82.5984	2.46255	0.68466	0.9703	0.1012	9.58794
152.217	153.274	95.0913	2.20789	0.93014	1.034	0.098	10.551
138.475	140.484	118.908	2.47396	0.75531	1.053	0.1073	9.81361
255.974	253.089	68.9782	3.06414	1.07141	0.6172	0.0663	9.3092
230.981	228.848	56.3626	3.60375	1.24246	0.8656	0.0914	9.47046
201.018	198.345	50.7295	2.03319	1.19041	0.5264	0.0654	8.04893
218.008	217.62	72.0778	2.63558	1.16065	0.7693	0.0779	9.87548
211.511	212.438	48.1549	2.07933	0.85378	0.7522	0.0815	9.22945
273.772	269.718	78.6749	4.06517	1.75596	1.079	0.1096	9.84489
238.312	240.715	22.48	3.1319	0.66486	0.8755	0.0937	9.34365
184.824	183.306	28.3261	2.08571	1.54353	1.115	0.1135	9.82379
196.72	196.568	21.1001	2.56425	1.17738	1.06	0.1108	9.56679
211.959	208.33	35.0071	3.38714	1.00362	1.309	0.1295	10.1081
243.107	243.901	115.697	2.50652	2.79613	0.3965	0.0617	6.42626
215.266	212.963	72.4796	2.03718	3.02588	0.4308	0.0623	6.91493
315.923	315.763	53.9847	2.89708	3.40793	0.616	0.0774	7.95866
275.55	275.707	63.6446	3.00714	3.56169	0.94	0.0999	9.40941

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
218.315	217.764	47.8098	2.76451	3.24665	0.5582	0.069	8.08986
156.162	237.632	1.21081	1.35994	0.48023	1.043	0.1091	9.56004
156.879	281.982	1.52554	1.27226	0.30744	0.9105	0.1013	8.98815
181.093	330.333	2.34086	1.50681	0.29067	0.9072	0.1032	8.7907
164.431	249.243	1.43444	1.30969	0.37739	0.5656	0.0805	7.02609
174.217	243.798	1.57917	1.28589	0.6139	0.7576	0.0895	8.4648
175.378	213.197	1.0368	1.28993	0.53001	0.541	0.0684	7.90936
151.197	149.105	0.3615	1.23554	0.52202	0.3507	0.0552	6.35326
142.585	207.041	0.85814	1.17826	0.57755	0.6024	0.0724	8.32044
150.518	262.823	1.00756	1.31683	0.38801	0.2814	0.0482	5.83817
147.304	232.006	0.67653	1.24956	0.59793	0.4106	0.0601	6.83195
459.468	118.859	14.2241	2.07171	1.23448	1.792	0.1625	11.0277
386.853	192.787	2.01323	0.91868	0.74773	0.5045	0.0615	8.20325
155.05	182.542	0.53978	0.45926	0.26726	0.4551	0.0542	8.39668
338.471	212.957	2.38822	0.97373	0.32933	0.8715	0.0921	9.46254
352.094	131.347	2.9766	1.14159	0.42622	0.6892	0.0776	8.88144
346.923	202.883	0.56818	0.64192	0.35874	0.589	0.0747	7.88487
273.869	250.679	0.97338	0.90343	0.40037	0.3565	0.0556	6.41187
342.826	84.085	0.84287	0.7031	0.29499	0.3453	0.0521	6.62764
142.797	238.643	0.59684	0.9139	0.33259	0.3778	0.0582	6.49141
195.015	246.469	0.83681	0.96446	0.37315	0.4115	0.0603	6.82421
265.847	286.912	2.20619	1.28794	0.05476	0.8477	0.0923	9.18418
189.235	361.198	2.67614	1.47934	0.0858	1.466	0.1401	10.464
178.932	330.894	2.46964	1.27451	0.099	1.176	0.1119	10.5094
175.198	331.8	1.05231	0.92882	0.02855	1.041	0.108	9.63889
182.458	372.452	2.0163	1.2886	0.06147	0.9547	0.0987	9.67275
238.013	261.676	2.93012	1.4493	0.07298	0.5772	0.0735	7.85306
187.775	335.174	2.94192	1.26486	0.11706	0.8388	0.0926	9.05832
171.864	212.581	1.91617	0.98179	0.09825	0.7818	0.0856	9.13318
186.923	222.328	2.0288	1.16763	0.05419	0.6991	0.0802	8.71696
181.687	266.328	1.67703	1.04718	0.08107	0.577	0.0724	7.96961
118.733	294.439	1.75422	1.74554	0.06134	1.266	0.1224	10.3431
109.807	270.236	1.77125	1.85344	0.10826	0.5754	0.0728	7.90385

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
112.238	250.001	1.92116	2.09017	0.055	1.085	0.1123	9.66162
87.8354	120.597	0.87179	1.05104	0.055	0.8208	0.0953	8.6128
119.848	276.558	2.6831	3.0775	0.09594	0.7792	0.0854	9.12412
104.289	167.647	1.39907	1.10601	0.06579	0.5439	0.0631	8.61965
106.438	158.364	1.29081	1.10009	0.055	0.2387	0.0441	5.4127
123.706	227.712	1.89985	1.90533	0.06695	0.4783	0.0659	7.25797
80.981	97.0818	0.64545	0.66906	0.055	0.3543	0.0587	6.03578
101.221	156.512	1.25842	1.56996	0.055	0.3777	0.0584	6.46747
110.203	96.5543	1.2329	1.40774	0.13105	1.303	0.128	10.1797
135.42	103.09	2.96983	1.65397	0.18744	1.479	0.1491	9.91952
160.983	115.728	3.55665	1.57885	0.16912	1.5	0.1436	10.4457
123.931	58.8251	1.67783	1.25785	0.07443	1.678	0.158	10.6203
171.699	164.769	3.76158	2.67166	0.50843	1.324	0.1381	9.58726
176.681	83.4341	3.99827	3.53027	0.5689	0.9568	0.1091	8.76994
167.142	109.52	5.05148	3.28416	0.56168	0.7668	0.0955	8.02932
173.283	117.835	4.65262	3.62715	0.63536	1.109	0.1269	8.73916
177.849	101.731	4.98961	3.74663	0.64257	0.9809	0.1127	8.70364
166.497	96.9844	4.95826	3.70709	0.63916	1.066	0.1226	8.69494
164.032	173.367	0.53354	0.7585	0.055	0.925	0.1178	7.85229
175.87	182.228	1.4394	1.29471	0.055	0.822	0.0993	8.27795
158.047	218.112	1.2101	1.12179	0.055	1.112	0.1135	9.79736
198.885	198.409	1.16974	1.29129	0.055	0.8659	0.1038	8.342
193.597	170.108	1.30025	1.35559	0.055	0.9416	0.1088	8.65441
299.695	61.2793	1.22265	1.04993	0.055	0.5626	0.0873	6.44444
260.879	103.949	1.32795	1.04342	0.055	0.3977	0.0721	5.51595
291.573	123.07	1.72248	1.24063	0.055	0.5883	0.0803	7.32628
231.979	134.758	1.63665	1.12671	0.055	0.5065	0.0798	6.34712
311.495	61.0748	1.35792	3.48566	0.055	0.4873	0.0743	6.55855
153.044	197.146	2.45263	0.7761	0.11812	0.8215	0.1106	7.42767
160.265	223.081	2.2277	0.69566	0.38913	0.669	0.0882	7.58503
104.083	119.71	0.9461	0.52555	0.06706	0.8468	0.1068	7.92884
147.398	186.059	1.88929	0.72907	0.09929	0.7041	0.091	7.73736
131.65	179.206	1.96911	0.65078	0.07613	0.6803	0.0854	7.96604

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
202.732	126.882	2.86691	0.88283	0.07988	0.6082	0.0915	6.64699
162.864	151.951	1.94594	0.76643	0.0676	0.3309	0.0702	4.71368
212.784	76.4648	2.5275	0.86798	0.055	0.463	0.078	5.9359
210.49	110.559	3.82252	0.86429	0.04261	0.3348	0.0744	4.5
183.456	94.3379	3.25876	0.95435	0.05438	0.4844	0.0797	6.07779
199.85	24.235	4.35343	1.57877	0.055	1.267	0.1338	9.46936
171.273	159.036	0.9509	0.9927	0.055	0.9946	0.1152	8.63368
209.871	100.517	2.1954	1.41178	0.055	0.9543	0.1163	8.2055
158.278	63.8056	1.28514	0.84873	0.055	1.264	0.1308	9.66361
124.61	99.6633	1.4078	0.73079	0.055	1.118	0.1237	9.038
279.918	58.7672	3.50708	1.89836	0.0598	1.128	0.1244	9.06752
266.371	73.1442	3.84888	2.06317	0.06156	0.811	0.1018	7.9666
267.783	53.3017	4.1169	1.79247	0.05398	0.3915	0.0681	5.7489
324.303	70.5739	3.96368	1.95331	0.08516	0.9303	0.1112	8.36601
298.975	61.2983	3.74698	1.70009	0.05328	1.12	0.1207	9.2792
157.45	70.8994	0.95178	4.35041	1.24223	1.117	0.1249	8.94315
165.865	67.9372	0.70842	3.99393	1.476	1.012	0.1154	8.7695
176.198	62.0582	0.77484	3.54818	1.29168	0.955	0.1162	8.21859
158.373	57.8823	0.79506	3.43542	1.27343	1.114	0.1211	9.19901
166.642	36.9679	0.77109	3.20189	1.28871	1.048	0.1195	8.76987
156.083	59.7018	1.18792	3.73903	1.2595	0.8002	0.1072	7.46455
374.833	110.03	6.86871	1.19031	0.35767	0.9476	0.1065	8.89765
388.186	135.44	7.12696	1.51379	0.36998	0.9256	0.1152	8.03472
314.271	114.43	5.88482	1.36141	0.39062	0.762	0.0989	7.70475
292.596	92.9959	3.80847	1.01091	0.26704	0.9085	0.1053	8.62773
328.202	142.149	6.02687	1.43135	0.31704	1.289	0.1433	8.99512
320.471	93.7871	7.32666	2.4788	0.25266	0.882	0.1153	7.64961
326.4	58.5263	5.21484	1.79796	0.23722	0.9734	0.1141	8.53111
311.76	36.8799	2.13719	1.65042	0.2169	0.7943	0.1093	7.26715
315.772	67.1861	2.58708	1.80802	0.19259	1.195	0.1183	10.1014
301.345	70.5016	2.05527	1.46042	0.17293	0.7471	0.1026	7.28168
352.313	83.0293	1.18847	0.89267	0.51241	0.8687	0.1057	8.21854
327.653	91.228	1.20255	0.82608	0.5314	0.8451	0.1066	7.92777

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
224.056	87.4123	0.83162	0.72612	0.29324	0.5671	0.0841	6.74316
252.009	112.64	0.89077	0.99905	0.35096	0.6576	0.0922	7.13232
345.795	107.095	1.20648	0.81345	0.45929	0.9533	0.1233	7.73155
236.639	55.0984	1.92853	0.58152	0.24735	0.8477	0.1046	8.10421
399.121	33.9544	2.11016	0.59305	0.44853	1.061	0.1147	9.25022
386.683	34.01	1.73879	0.59496	0.3911	1.062	0.1193	8.90193
423.977	42.4046	1.94048	0.60192	0.39857	0.9603	0.1093	8.78591
379.831	37.2301	1.85294	0.71436	0.47278	0.7417	0.0995	7.45427
336.344	129.467	2.40773	1.90603	0.38551	0.6515	0.0906	7.19095
212.197	183.161	1.45132	1.3143	0.29152	0.7979	0.0994	8.02716
251.92	151.482	1.26811	1.72197	0.28491	0.624	0.0902	6.91796
301.317	137.995	1.36527	1.52033	0.29785	0.5541	0.082	6.75732
289.105	289.639	84.0037	1.78911	1.57865	0.8166	0.0883	9.24802
296.797	298.098	121.974	2.7215	2.17278	0.6677	0.0788	8.47335
179.503	179.021	116.207	0.9213	1.38069	0.8376	0.0904	9.26549
171.49	170.903	112.247	1.20304	1.6023	0.4324	0.0581	7.44234
92.8111	91.1275	94.428	0.98857	1.25273	0.6666	0.0796	8.37437
142.68	141.992	148.945	1.12499	1.53353	0.5065	0.0638	7.93887
206.516	203.137	153.292	11.4518	2.42678	0.5422	0.0669	8.10463
127.901	126.968	72.7442	3.76106	0.95424	0.5345	0.0648	8.24846
132.943	134.654	84.5346	3.11935	0.77746	0.3029	0.047	6.44468
174.176	172.965	78.3039	5.35206	1.16778	0.5251	0.0679	7.73343
152.352	152.991	104.215	4.66381	0.99374	0.5518	0.0657	8.39878
274.493	274.091	78.5395	4.36361	1.36254	0.6006	0.0682	8.80645
221.262	220.057	70.663	8.92114	2.37275	0.7159	0.0717	9.98466
209.701	209.961	79.0617	3.90779	1.4978	0.3311	0.0477	6.9413
209.191	207.67	87.3559	6.80693	1.79338	0.5296	0.059	8.97627
210.611	209.908	62.5969	4.30758	1.57253	0.6101	0.0569	10.7223
264.444	265.674	65.3075	6.58285	1.69247	0.592	0.0633	9.35229
278.588	274.081	39.194	3.65122	0.67641	0.5818	0.0662	8.78852
218.059	214.772	47.1231	3.76738	1.43923	0.2928	0.0482	6.07469
342.847	343.065	50.0882	4.36519	1.28947	0.2642	0.039	6.77436
252.914	254.375	47.9457	5.51516	1.31966	1.011	0.1189	8.50294

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
209.619	208.75	101.534	3.17493	2.44533	1.02	0.1123	9.08281
222.827	223.053	64.857	3.00336	2.37939	0.9596	0.1057	9.07852
246.692	247.29	38.8593	3.06586	2.96845	1.049	0.1074	9.76723
224.37	227.25	53.9527	3.13452	3.02216	1.157	0.1278	9.05321
226.974	229.499	57.4814	3.10545	2.8415	0.5545	0.0722	7.68006
176.252	175.352	262.865	1.91383	1.25298	0.7266	0.0829	8.76478
185.488	340.428	1.93994	1.23978	0.39379	0.6275	0.0728	8.61951
181.013	384.374	2.72597	1.54287	0.47891	0.5356	0.0718	7.45961
179.845	267.145	1.7776	1.25448	0.42896	0.8013	0.0846	9.47163
221.297	300.222	2.19916	1.35253	0.77653	1.73	0.1669	10.3655
192.282	253.759	1.63425	1.34769	0.4886	1.665	0.165	10.0909
163.542	286.803	1.74633	1.20474	0.5742	1.647	0.1554	10.5985
154.648	292.417	1.47395	1.24749	0.71249	1.524	0.1603	9.50717
159.611	345.088	2.4811	1.2132	0.61718	1.686	0.1621	10.401
148.588	304.937	1.55285	1.19192	0.73891	1.056	0.1119	9.437
476.696	119.754	11.248	1.95429	1.22717	1.004	0.1113	9.02066
398.586	134	2.38255	0.97376	0.84411	1.08	0.1185	9.11392
314.873	130.301	1.52358	0.80166	0.64235	1.109	0.1178	9.41426
404.911	147.444	3.14762	1.11108	0.4937	1.207	0.1306	9.24196
350.005	129.823	2.48054	1.00426	0.4334	0.7851	0.1052	7.46293
437.613	141.63	1.34911	0.68263	0.52759	1.092	0.1287	8.48485
305.087	186.533	1.19471	0.86742	0.46623	0.9394	0.1146	8.19721
277.029	99.081	1.07453	0.64355	0.29574	1.135	0.1254	9.05104
204.565	224.356	1.08904	1.0597	0.40552	1.2	0.128	9.375
248.529	201.527	1.00362	1.05798	0.45343	0.2875	0.0641	4.48518
244.612	286.133	2.83963	1.38971	0.11405	0.8007	0.1113	7.19407
188.298	357.316	2.44336	1.2781	0.16035	0.5552	0.0814	6.82064
173.483	345.708	3.11761	1.28904	0.13171	0.8458	0.1028	8.22763
170.215	338.007	1.81002	0.99073	0.08227	0.8495	0.1115	7.61883
170.325	329.779	2.25245	1.09328	0.12146	1.123	0.12	9.35833
265.085	247.07	3.82814	1.48924	0.11601	1.063	0.1091	9.74335
193.569	301.181	3.1732	1.22484	0.08665	1.273	0.1318	9.65857
172.045	220.448	3.56572	1.06963	0.09961	1.117	0.1174	9.51448

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
189.719	248.29	2.90222	1.03467	0.08149	1.147	0.1189	9.64676
187.741	280.086	3.04623	1.07194	0.09822	0.7078	0.0924	7.66017
112.467	277.779	2.66243	1.90436	0.09218	0.8135	0.1003	8.11067
110.833	260.246	2.55348	1.93317	0.17575	0.9072	0.1038	8.73988
122.026	264.946	3.16428	2.17892	0.11478	0.9086	0.1002	9.06786
87.6412	116.866	1.17485	0.89444	0.055	0.7561	0.0923	8.19177
115.524	271.878	2.99117	2.76276	0.15405	0.8414	0.091	9.24615
100.357	165.118	2.32447	1.25474	0.09586	1.061	0.1131	9.38108
111.194	185.64	2.2009	1.47637	0.055	0.7782	0.0887	8.77339
130.97	242.578	2.74496	1.87194	0.12235	0.869	0.0938	9.26439
98.8776	106.202	1.64753	0.83923	0.055	0.7826	0.0927	8.44229
111.644	176.254	2.03388	1.28598	0.055	0.4294	0.0683	6.28697
146.624	105.528	9.26428	3.35631	0.33227	0.415	0.064	6.48438
163.625	96.4972	10.2394	3.18293	0.20609	0.3853	0.0562	6.85587
185.236	132.538	10.389	2.46994	0.35441	0.5251	0.0745	7.04832
152.867	79.3555	6.09964	1.72923	0.17628	0.3961	0.0598	6.62375
160.992	105.741	6.70454	2.4568	0.34346	0.7693	0.0906	8.49117
156.613	137.494	5.05455	3.38027	0.68544	1.075	0.105	10.2381
144.509	136.166	4.86012	3.09176	0.55426	0.8607	0.0888	9.69257
150.192	133.795	5.09512	3.31563	0.59105	0.7949	0.0859	9.25378
151.995	131.399	4.97638	3.54167	0.65578	0.8291	0.0955	8.68168
154.9	137.941	4.51155	3.25358	0.61697	0.6203	0.0698	8.88682
194.753	154.459	1.56094	1.34226	0.055	0.7811	0.0871	8.96785
178.88	173.379	1.81822	1.3957	0.04918	0.6077	0.0683	8.89751
169.219	202.222	2.54174	1.41341	0.0646	0.9664	0.0953	10.1406
199.18	175.95	2.58768	1.60284	0.11517	0.6029	0.0806	7.48015
212.286	168.866	2.49225	1.77943	0.14854	0.8279	0.0967	8.56153
248.511	62.4672	1.73025	0.98827	0.055	0.6713	0.0872	7.69839
242.013	96.4574	2.04741	0.98143	0.055	0.9444	0.0999	9.45345
279.793	100.185	2.43221	1.129	0.07454	0.7726	0.0957	8.07315
222.085	120.822	2.04332	1.12706	0.05724	0.8109	0.0943	8.59915
254.883	70.6703	1.84168	1.07849	0.08305	0.7189	0.0962	7.47297
201.727	170.078	2.47468	0.61289	0.10774	0.4818	0.0791	6.09102

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
131.959	161.95	1.89438	0.52288	0.10604	0.5862	0.0855	6.85614
169.538	172.606	2.1849	0.59331	0.11494	0.7242	0.0945	7.66349
152.158	196.035	2.31719	0.50376	0.10689	1.29	0.1137	11.3456
221.086	127.884	3.0302	0.73505	0.09325	1.272	0.1076	11.8216
160.602	156.224	2.38972	0.69551	0.10439	1.145	0.1069	10.7109
189.084	93.4749	2.64525	0.71039	0.05733	1.102	0.0992	11.1089
207.794	103.489	3.57996	0.75805	0.05022	1.237	0.116	10.6638
207.769	130.409	4.14581	1.03813	0.09112	0.9684	0.09	10.76
226.304	41.3173	4.00985	1.40364	0.055	0.8831	0.0796	11.0942
177.351	49.3149	1.93648	1.02854	0.055	0.9182	0.0916	10.024
196.443	97.8869	2.77409	1.08919	0.05652	1.055	0.0959	11.001
162.134	77.7952	2.23606	0.86086	0.055	1.095	0.1016	10.7776
129.174	92.8026	1.74953	0.71165	0.055	1.562	0.1399	11.1651
285.48	62.8289	3.81566	1.60652	0.12479	1.421	0.1144	12.4213
260.533	75.7832	4.00763	1.76754	0.08805	1.476	0.1351	10.9252
300.509	58.9949	4.08055	1.67959	0.10352	1.431	0.1407	10.1706
277.284	85.8887	3.6052	1.51022	0.13605	1.519	0.1509	10.0663
299.801	69.4947	4.20034	1.51737	0.1414	1.173	0.1002	11.7066
150.566	107.927	1.68043	3.63599	1.27672	1.261	0.1263	9.98416
135.581	108.904	1.38338	3.60633	1.39659	1.118	0.1142	9.78984
160.427	107.931	1.47683	3.97558	1.36108	1.624	0.1487	10.9213
153.038	127.321	1.94135	3.71945	1.32212	1.596	0.1505	10.6047
144.411	111.711	1.70669	3.78037	1.30863	1.619	0.157	10.3121
161.504	92.2784	2.84445	3.95647	1.19791	1.519	0.1461	10.397
141.66	105.801	2.52977	3.93767	1.50986	1.338	0.1374	9.73799
145.486	94.5886	3.52107	4.08025	2.02446	0.9996	0.1058	9.44802
151.107	83.5079	2.22712	3.91506	1.09147	1.05	0.1207	8.69925
137.827	78.1212	1.88497	3.54913	1.09152	1.058	0.1196	8.84615
276.49	71.319	7.578	1.582	0.353	0.71983	0.13012	5.53202
313.29	72.361	6.911	1.451	0.374	0.90062	0.13495	6.67353
279.372	88.002	9.167	1.925	0.412	1.0274	0.14865	6.91154
264.542	77.189	11.959	1.247	0.273	0.70259	0.12383	5.67375
244.516	85.789	6.288	1.62	0.368	0.72523	0.13568	5.34529
198.393	58.405	3.881	1.32	0.356	0.49844	0.11911	4.18463

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
233.642	72.082	3.551	1.214	0.379	0.60066	0.12891	4.65954
215.623	76.467	4.607	1.548	0.497	0.6062	0.13584	4.46247
222.947	75.317	5.001	1.346	0.395	0.53604	0.1143	4.6898
210.633	76.365	4.034	1.346	0.397	0.56662	0.11739	4.82673
192.943	93.678	4.304	1.954	0.314	1.23999	0.1842	6.73185
213.46	103.413	5.443	2.554	0.299	1.2583	0.15164	8.29789
223.479	80.023	3.999	2.048	0.269	1.39909	0.16499	8.47973
200.509	56.119	2.4	1.411	0.212	0.99799	0.15448	6.46018
192.156	64.003	2.457	1.413	0.211	1.14705	0.13615	8.42479
207.11	69.053	2.51	1.384	0.265	1.03195	0.13753	7.50345
250.186	59.705	1.912	1.235	0.162	0.90594	0.1399	6.47563
339.144	48.595	1.611	1.449	0.209	0.89708	0.15373	5.83527
233.283	30.675	1.198	0.873	0.165	0.75207	0.136	5.52977
161.418	222.345	9.321	0.735	0.474	0.8479	0.14063	6.02914
216.453	45.395	1.489	1.075	0.18	0.95341	0.14725	6.47466
178.711	212.629	11.398	0.678	0.588	0.79868	0.1359	5.87686
159.582	124.031	8.855	0.749	0.428	0.75499	0.1343	5.62179
163.691	176.815	10.658	0.714	0.449	0.72843	0.13661	5.33225
134.802	179.214	6.666	0.62	0.424	0.77277	0.13954	5.53819
143.085	209.149	3.517	0.669	0.318	0.44096	0.12362	3.56711
157.876	130.18	3.359	0.496	0.391	0.54125	0.12339	4.38634
154.064	130.323	3.24	0.603	0.264	0.43355	0.11841	3.66137
140.299	123.654	2.234	0.622	0.208	0.39613	0.13035	3.03905
126.206	132.384	1.945	0.537	0.272	0.4128	0.11956	3.45279
279.908	111.527	6	0.56	0.282	0.45555	0.12134	3.75428
162.808	122.624	7.55	0.428	0.317	0.61509	0.13682	4.4955
159.555	135.936	11.777	0.548	0.387	0.65862	0.14915	4.41572
211.811	97.293	8.796	0.556	0.284	0.71223	0.14028	5.07737
204.846	176.85	8.494	0.632	0.406	0.79041	0.15265	5.1779
217.873	158.543	3.551	0.591	0.192	0.33628	0.12867	2.61358
125.591	92.263	2.945	0.456	0.241	0.41732	0.1195	3.49215
150.138	121.657	5.265	0.509	0.209	0.36395	0.12056	3.01881
204.788	80.311	2.574	0.633	0.197	0.34177	0.1115	3.06528
173.807	172.478	2.548	0.637	0.287	0.46552	0.12679	3.67154

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
280.611	146.482	4.206	1.442	0.335	1.12324	0.13737	8.17678
316.367	140.491	3.599	1.321	0.368	1.032	0.13031	7.9198
330.872	134.654	2.743	1.112	0.259	0.95428	0.14799	6.44821
322.94	128.637	3.398	1.394	0.312	1.31968	0.14542	9.07527
294.515	118.757	2.733	1.126	0.235	0.98006	0.13886	7.05813
230.938	101.248	2.688	1.601	0.251	0.64091	0.12971	4.94104
176.622	122.349	2.096	1.655	0.236	0.49328	0.10877	4.53525
180.538	113.994	1.734	1.271	0.148	0.4617	0.11184	4.12825
228.448	117.037	2.207	1.441	0.205	0.5558	0.1132	4.90995
188.58	106.863	1.74	1.26	0.162	0.41401	0.1085	3.81589
263.558	87.452	2.947	2.952	0.577	1.0988	0.1507	7.29113
219.674	70.395	3.07	2.799	0.52	1.23131	0.1483	8.30292
335.985	87.079	3.699	2.945	0.656	1.35717	0.16957	8.0036
229.209	60.859	3.298	3.123	0.568	1.23714	0.15282	8.09532
342.628	108.208	3.664	2.93	0.567	1.42539	0.15071	9.45763
245.086	48.515	2.297	3.635	0.563	0.68677	0.11212	6.12547
224.099	60.886	2.461	3.188	0.519	0.89345	0.13477	6.62943
297.801	71.184	3.172	3.427	0.544	1.02425	0.13428	7.6276
250.415	61.264	3.169	3.594	0.637	1.00343	0.14515	6.91291
306.339	64.058	2.945	3.792	0.601	0.94067	0.1373	6.85137
136.259	262.9	3.535	1.092	0.314	0.72285	0.11892	6.07853
148.359	289.457	4.256	1.274	0.308	0.66029	0.12382	5.33264
142.181	234.164	2.971	1.011	0.228	0.69469	0.12222	5.6838
124.457	247.765	2.467	0.874	0.214	0.76279	0.13005	5.86561
126.237	237.2	2.662	0.905	0.246	0.77029	0.13451	5.72675
116.839	257.684	1.437	0.959	0.186	0.47994	0.12095	3.96809
123.001	285.938	3.004	1.073	0.252	0.54928	0.11797	4.65631
128.394	226.277	1.752	0.973	0.189	0.57399	0.11791	4.86794
124.451	215.882	1.92	0.814	0.142	0.49088	0.11671	4.20586
112.074	246.291	1.135	0.829	0.188	0.43219	0.11702	3.69339
153.115	282.597	5.124	1.299	0.358	0.95991	0.14185	6.7669
136.164	308.042	3.535	1.008	0.265	0.72007	0.12937	5.56609
152.172	405.35	2.846	1.27	0.262	0.67151	0.09951	6.74798
126.414	344.092	3.168	1.208	0.232	0.55156	0.11981	4.6037

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
147.797	284.468	2.675	1.015	0.274	0.72828	0.11014	6.61203
152.781	264.186	3.704	1.142	0.27	0.69939	0.11365	6.15388
168.072	321.504	2.756	0.987	0.188	0.56134	0.1015	5.5305
115.071	418.635	1.189	0.923	0.229	0.37551	0.09372	4.00697
139.581	346.155	4.644	1.285	0.214	0.71342	0.12203	5.84648
170.654	273.167	2.654	0.926	0.184	0.57308	0.1085	5.28179
373.378	105.973	3.254	1.451	0.431	1.06635	0.13416	7.94818
377.114	111.205	3.38	1.198	0.361	1.00148	0.13372	7.48956
353.099	111.517	2.618	1.095	0.357	1.04588	0.13046	8.01704
346.018	100.691	2.307	1.166	0.381	1.02455	0.12558	8.15858
372.113	99.557	2.873	1.091	0.386	0.98633	0.13341	7.39311
310.711	93.286	1.789	1.446	0.442	0.83269	0.11455	7.26894
368.441	96.8	3.022	1.434	0.415	0.839	0.11667	7.1911
300.296	94.605	1.606	1.36	0.333	0.60345	0.10561	5.71386
286.59	92.789	1.744	1.239	0.408	0.74522	0.11438	6.51517
303.1	104.904	1.784	1.258	0.402	0.77405	0.10356	7.47423
238.685	123.721	2.412	1.603	0.277	0.59763	0.09958	6.00161
232.834	106.889	2.653	1.714	0.263	0.66893	0.10825	6.17957
356.855	81.501	4.548	1.719	0.334	0.79602	0.10641	7.48044
236.241	94.088	3.692	1.951	0.265	0.73205	0.10455	7.00168
259.297	99.525	3.69	1.892	0.275	0.80378	0.1159	6.93527
228.044	151.343	1.818	1.619	0.262	0.57213	0.10355	5.52525
242.909	103.71	2.467	1.736	0.25	0.62807	0.09924	6.32856
374.245	81.891	4.372	1.689	0.372	0.83007	0.11452	7.24854
232.261	97.157	2.855	2.023	0.274	0.64786	0.11633	5.56924
265.006	106.52	3.461	2.029	0.332	0.76234	0.10514	7.25067
167.952	115.184	9.359	2.269	0.334	1.16818	0.10832	10.7849
140.086	98.232	6.817	1.568	0.275	0.94673	0.10921	8.66886
137.961	113.718	6.535	2.411	0.36	1.16415	0.11079	10.5076
143.896	113.569	6.273	2.326	0.344	1.24213	0.12822	9.68735
130.039	108.634	8.268	2.385	0.397	1.40253	0.13146	10.6688
120.308	76.285	2.937	1.893	0.341	0.96141	0.11538	8.33265
110.873	75.41	1.368	1.602	0.295	0.66974	0.10342	6.47617
123.77	95.207	2.046	2.468	0.469	0.93334	0.11527	8.09674

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
114.655	93.538	1.385	2.12	0.418	0.88101	0.10546	8.35413
122.537	79.9	3.101	2.513	0.477	1.10122	0.13022	8.45665
148.352	133.404	6.224	4.096	0.653	1.46507	0.13795	10.6206
143.668	122.292	4.264	2.902	0.665	1.56088	0.14649	10.6551
155.035	115.522	5.349	4.158	0.702	1.4813	0.12691	11.6721
138.941	121.781	3.803	3.318	0.742	1.48877	0.15125	9.84291
130.367	124.315	4.443	3.648	0.759	1.41257	0.14181	9.96085
157.414	98.055	4.95	3.607	0.686	1.07394	0.12606	8.51945
161.052	78.77	3.397	3.488	0.819	1.14997	0.11289	10.1864
147.311	75.15	3.933	3.255	0.678	1.00957	0.12421	8.12819
156.699	95.823	2.364	3.548	0.832	1.11642	0.13643	8.18295
136.577	85.193	2.648	3.431	0.785	1.0132	0.13074	7.74964
347.685	47.066	0.988	0.665	0.184	1.02352	0.1169	8.75575
339.686	73.025	0.854	0.835	0.187	1.07097	0.13528	7.91678
372.196	75.615	1.27	0.765	0.261	1.03453	0.12338	8.38518
396.158	57.153	1.47	0.703	0.225	1.00313	0.12944	7.7498
348.686	78.383	0.807	0.833	0.214	0.93891	0.11205	8.37919
295.713	124.788	0.687	0.615	0.144	0.80455	0.11519	6.98455
340.338	111.333	0.801	0.795	0.163	0.81666	0.11183	7.30277
349.674	159.5	0.722	0.82	0.174	0.76963	0.10687	7.20127
393.236	68.959	0.869	0.624	0.204	0.86329	0.1133	7.61936
426.418	98.83	0.959	0.499	0.221	0.85528	0.10551	8.10619
371.064	122.154	2.868	0.692	0.22	1.13704	0.1215	9.35811
374.062	150.398	2.258	0.886	0.45	1.02296	0.12051	8.48853
444.851	125.01	1.929	0.604	0.511	1.22545	0.12323	9.94415
403.797	128.413	2.837	0.858	0.449	1.16539	0.12434	9.37237
380.606	129.669	2.089	0.756	0.37	1.04023	0.10906	9.5386
290.253	221.496	1.796	0.992	0.257	0.82144	0.09032	9.09435
224.19	248.146	1.062	0.728	0.224	0.57016	0.09719	5.86653
374.202	160.74	1.312	0.587	0.365	0.92211	0.10185	9.05364
263.922	196.433	1.679	0.905	0.238	0.84712	0.09848	8.60182
204.586	253.227	1.124	0.792	0.189	0.65009	0.10253	6.34052
237.765	52.184	4.322	0.97	0.369	0.79529	0.10039	7.92198
215.149	43.813	2.297	0.91	0.273	0.88514	0.09968	8.87975

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
267.535	39.674	2.263	1.239	0.344	0.92928	0.09887	9.39929
259.054	52.669	2.78	1.238	0.317	0.84079	0.09695	8.67218
235.352	28.456	1.928	0.947	0.297	0.76343	0.08905	8.57329
260.563	42.588	1.734	1.136	0.341	0.67832	0.0944	7.18555
228.592	31.912	1.593	0.938	0.241	0.6993	0.10506	6.65628
253.956	34.967	1.671	1.324	0.266	0.63799	0.09917	6.43352
283.799	44.992	2.128	1.631	0.326	0.75079	0.09508	7.89682
221.011	23.832	1.569	1.011	0.289	0.61125	0.08949	6.83046
240.213	98.357	1.979	0.936	0.278	0.63297	0.09789	6.46634
189.256	58.199	2.155	0.975	0.211	0.70206	0.10901	6.44021
162.269	29.05	2.176	1.026	0.277	0.55505	0.09333	5.94741
181.445	76.312	2.38	1.007	0.261	0.75794	0.10776	7.03343
186.552	42.955	1.877	1.013	0.237	0.68059	0.09606	7.08495
240.154	114.418	1.795	1.009	0.323	0.5512	0.08386	6.5729
199.342	47.568	1.801	0.94	0.212	0.58299	0.08913	6.54087
180.585	24.26	1.517	1.173	0.236	0.42792	0.08316	5.1459
182.301	83.772	1.545	1.04	0.222	0.56441	0.08671	6.50904
233.996	56.045	1.923	1.223	0.285	0.63759	0.08705	7.32418
326.988	67.772	3.443	2.003	0.456	0.87179	0.0985	8.85052
272.179	51.934	4.754	1.82	0.455	0.83343	0.09673	8.61639
289.63	35.865	2.13	1.323	0.432	0.7222	0.09954	7.25555
299.65	34.73	2.423	1.272	0.37	0.64675	0.08904	7.26339
315.661	38.923	2.569	1.482	0.382	0.74118	0.1027	7.21676
336.717	53.396	2.815	2.049	0.483	0.61577	0.0883	6.97341
283.383	47.917	3.405	2.221	0.498	0.71848	0.09157	7.84659
427.267	28.403	1.895	1.131	0.399	0.57683	0.08502	6.78477
357.03	32.838	2.077	1.421	0.378	0.56335	0.09342	6.03059
472.276	32.904	2.013	1.226	0.36	0.60914	0.08559	7.1169
241.201	66.698	2.143	1.999	0.456	7.40814	0.92792	7.98364
279.173	35.963	2.503	1.295	0.428	0.90639	0.10744	8.43591
254.153	48.673	1.685	1.627	0.414	0.78585	0.10438	7.52896
221.348	50.755	1.82	1.445	0.578	0.73685	0.10249	7.18987
276.31	37.027	1.704	1.324	0.508	0.82157	0.10464	7.8511
228.917	51.049	1.745	2.148	0.409	0.59021	0.09927	5.94562

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
218.953	31.581	2.172	1.779	0.34	0.48968	0.08538	5.73559
208.601	36.956	1.465	1.726	0.285	0.5019	0.09492	5.28757
283.156	28.625	1.07	1.223	0.172	0.44068	0.08449	5.21597
234.202	35.497	1.492	1.713	0.327	0.58065	0.08735	6.64765
208.772	82.914	5.136	2.389	0.338	0.88876	0.09445	9.40959
257.93	86.842	3.6	2.474	0.378	0.83019	0.10493	7.91187
294.572	74.683	6.002	2.599	0.373	1.0494	0.10184	10.3045
347.531	61.844	4.621	3.279	0.502	1.0556	0.11585	9.11155
322.291	78.005	10.97	3.799	0.534	1.36766	0.11298	12.1055
175.172	76.175	2.974	2.673	0.376	0.68523	0.08921	7.68091
207.126	77.007	1.598	2.11	0.471	0.58444	0.08835	6.61529
214.204	82.286	2.387	2.285	0.369	0.64408	0.08144	7.90898
346.58	57.068	2.667	2.925	0.596	0.69143	0.09128	7.57454
268.746	73.63	3.046	3.098	0.568	0.72489	0.09665	7.50027
177.853	32.57	1.594	0.698	0.071	0.4074	0.08621	4.72539
184.485	56.997	3.238	1.393	0.237	0.69453	0.09052	7.67287
179.773	41.448	2.769	0.735	0.107	0.46264	0.08484	5.45314
304.552	57.093	2.432	1.069	0.138	0.62247	0.083	7.50007
179.774	26.286	1.853	0.5	0.127	0.3975	0.07779	5.10974
145.527	31.34	1.003	0.551	0.044	0.18859	0.06542	2.88282
128.862	51.672	1.795	1.283	0.238	0.43508	0.07704	5.64743
206.944	35.528	1.913	0.815	0.064	0.27496	0.07318	3.75748
223.354	64.549	1.925	1.166	0.094	0.35184	0.07788	4.51769
191.858	24.429	1.017	0.502	0.068	0.24634	0.07524	3.27403
262.343	251.403	2.225	1.668	0.151	1.06898	0.11721	9.12009
348.441	83.333	52.585	2.929	0.403	1.24392	0.11153	11.1537
420.238	128.731	3.809	0.996	0.24	0.79596	0.1022	7.78795
400.888	85.145	3.926	1.34	0.206	0.8135	0.09874	8.23918
387.496	91.602	2.911	1.294	0.211	0.77709	0.09622	8.07638
478.135	71.928	9.711	1.302	0.236	0.86992	0.10015	8.68661
347.094	62.585	30.143	1.983	0.181	0.76792	0.10061	7.63271
306.051	158.371	2.92	1.037	0.101	0.47457	0.09952	4.76862
351.866	98.544	2.725	1.362	0.132	0.47187	0.09421	5.00862
345	86.365	1.7	1.22	0.122	0.47332	0.09417	5.02644

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
422.939	69.097	7.917	1.578	0.195	0.68929	0.1078	6.3942
262.404	393.158	2.426	1.706	0.117	1.26915	0.11944	10.626
207.688	328.175	2.189	1.444	0.089	1.1258	0.12628	8.91483
280.169	268.884	1.872	1.188	0.112	1.10041	0.12713	8.65582
240.691	232.691	2.234	1.342	0.097	1.20037	0.1341	8.95116
187.508	75.151	1.433	1.44	0.009	0.48348	0.10803	4.4755
231.819	294.818	2.182	1.645	0.02	0.8951	0.1079	8.29583
184.326	233.626	1.686	1.511	0.066	0.68626	0.08428	8.14289
249.704	246.935	1.46	1.238	0.042	0.76147	0.10064	7.5663
216.574	144.574	1.477	1.411	0.049	0.73441	0.11165	6.57804
235.656	151.392	2.212	1.866	0.351	1.3279	0.12151	10.9283
248.475	104.737	2.663	1.956	0.208	1.19232	0.12713	9.3786
179.958	58.863	1.544	1.587	0.323	1.16356	0.1273	9.1402
204.524	41.051	1.695	1.363	0.317	1.21073	0.1118	10.8294
216.732	84.376	2.186	1.946	0.273	1.30324	0.12105	10.7664
210.348	220.854	1.944	1.902	0.284	1.03599	0.10514	9.85362
248.453	98.012	3.012	1.988	0.141	1.0115	0.1095	9.23755
178.901	46.797	1.409	1.688	0.278	1.00132	0.11754	8.51916
232.645	40.288	1.343	1.591	0.262	0.98011	0.12434	7.88248
222.204	67.374	1.997	2.045	0.285	1.20836	0.11445	10.5583
283.86	63.333	2.01	1.128	0.557	0.90714	0.11819	7.67554
195.296	99.522	1.791	1.251	0.538	1.14198	0.12505	9.13203
247.493	112.566	2.289	1.52	0.508	1.25305	0.13467	9.30477
261.199	85.836	1.84	1.288	0.73	1.18219	0.10594	11.1591
218.149	88.666	1.905	1.279	0.436	1.11838	0.11021	10.1477
252.028	115.332	1.457	1.026	0.577	0.71218	0.10307	6.90984
203.614	67.463	1.654	1.312	0.519	0.9233	0.10697	8.63182
241.562	167.704	1.841	1.354	0.29	0.71029	0.097	7.32284
306.84	89.705	1.915	1.36	0.592	1.00534	0.11023	9.12037
229.594	107.854	1.365	1.4	0.231	0.55534	0.09285	5.98123
175.037	105.042	2.57	1.136	0.032	0.76749	0.09104	8.43039
174.757	35.876	2.391	1.077	0.014	0.73454	0.09845	7.46089
173.341	71.803	3.067	1.166	0.049	0.95617	0.0987	9.68759
167.574	74.188	1.945	0.899	0.008	0.63859	0.1006	6.34787

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
161.758	155.014	3.03	1.005	0.02	0.71066	0.09708	7.3204
165.068	142.313	1.566	0.832	0.055	0.46922	0.09028	5.19725
153.555	40.877	1.134	0.856	0.055	0.41311	0.09391	4.39893
159.934	67.396	1.586	1.042	0.066	0.53366	0.09548	5.58925
139.837	116.377	0.772	0.617	0.066	0.3146	0.08285	3.79729
141.413	260.371	1.345	0.789	0.066	0.4225	0.09388	4.50035
188.554	117.804	2.575	0.979	0.066	0.61934	0.10519	5.88775
161.537	137.284	1.934	1.02	0.066	0.61955	0.0961	6.44704
207.798	128.262	3.483	0.927	0.066	0.80938	0.10327	7.83784
204.863	70.541	2.162	1.032	0.066	0.75647	0.10772	7.02241
143.772	77.955	1.159	0.847	0.066	0.53913	0.09896	5.44804
183.254	255.979	1.125	0.698	0.066	0.40762	0.09622	4.23652
141.581	321.466	0.879	0.593	0.066	0.35168	0.09534	3.68852
200.277	185.975	1.185	0.697	0.017	0.42103	0.09848	4.27542
178.535	193.257	1.241	0.829	0.02	0.50685	0.1034	4.90178
143.211	197.023	0.621	0.447	0.003	0.35809	0.09599	3.73047
467.538	61.603	5.155	1.137	0.178	0.73823	0.10722	6.88495
399.421	58.987	6.094	1.708	0.198	0.91187	0.10217	8.925
397.2	37.144	7.085	1.729	0.202	0.89747	0.10729	8.36486
414.536	62.949	11.534	1.222	0.15	0.7697	0.1114	6.90936
412.417	46.962	5.372	2.483	0.151	0.85569	0.10619	8.05796
377.577	135.834	1.613	1.03	0.076	0.48359	0.09784	4.94277
349.003	107.675	1.409	1.648	0.119	0.70177	0.10278	6.82796
318.904	128.747	1.74	1.413	0.102	0.61256	0.09893	6.1918
415.422	69.907	1.544	1.287	0.109	0.81681	0.10508	7.77296
362.35	123.604	1.209	1.3	0.078	0.55416	0.09122	6.07482
482.261	48.472	5.873	0.948	0.188	0.84214	0.09513	8.8525
413.224	72.38	5.759	1.032	0.156	0.77523	0.11204	6.91901
389.371	52.663	4.99	1.326	0.121	0.7406	0.09683	7.6484
385.751	83.341	5.505	1.926	0.101	0.8158	0.11223	7.26933
410.038	67.764	5.927	1.478	0.138	1.02368	0.11182	9.15458
401.999	58.823	0.843	1.056	0.04	0.4212	0.09905	4.25233
407.144	61.248	0.982	0.705	0.035	0.45119	0.09668	4.66668
306.9	145.321	1.264	0.963	0.05	0.53915	0.09959	5.41395

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Fe (mg kg-1)	Mn (mg kg-1)	Zn (mg kg-1)	Cu (mg kg-1)	B (mg kg-1)	TC	TN	C:N
340.751	115.775	1.44	1.461	0.053	0.67974	0.11569	5.87553
313.69	153.827	2.158	1.439	0.079	0.78398	0.09731	8.05698

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
14592.2	67.796	106.384	1264.88	130.772	8.7846	27.4123	368.418
17483.9	89.1438	82.1367	884.124	101.325	11.591	25.6192	448.999
15382.5	95.6462	99.165	1173.33	125.503	9.21385	25.0951	383.231
16045.3	50.8951	96.4044	1011	112.01	10.9976	21.7193	300.28
18497.3	98.911	77.076	1235.98	129.561	9.5717	30.3767	490.975
16663.7	67.2283	193.974	2400.78	819.346	14.628	112.168	374.909
18318.2	19.1925	139.252	1493.52	684.117	10.9895	71.2563	294.876
13837.7	35.2153	123.536	1457.91	588.782	6.93092	68.5793	317.756
15829.3	29.8158	82.5522	1469.02	275.006	8.4217	36.2549	278.028
13028.8	45.2157	87.5276	1331.24	273.292	7.23836	37.975	263.714
13428.4	22.8577	74.5945	1321.49	135.55	12.527	44.7241	268.91
16901.7	25.3293	60.2363	1161.64	115.555	11.2888	30.5912	317.948
14456.1	19.7472	64.5702	1154.26	111.085	12.7281	26.767	226.259
14504.8	17.0185	58.6494	1164.8	117.065	7.61631	23.6138	229.879
13860.8	18.3447	54.188	1470.87	146.676	13.3548	46.0118	255.303
15139.7	52.3411	151.656	1129.47	117.813	14.5329	26.4073	237.286
17393.5	57.8879	204.791	1433.41	141.382	17.7686	28.2769	424.286
12706.4	75.3391	139.313	1298.66	137.536	9.30906	23.1345	430.535
15740.3	93.2152	147.636	1353.94	125.365	11.5156	15.9842	528.573
15725.5	45.3231	159.711	1237.33	126.716	8.95409	21.4453	416.058
22803.2	9.97321	219.88	4137.92	742.433	20.0538	153.453	236.755
17139.7	7.38778	89.7559	2414.95	352.62	17.4947	72.3589	201.683
21207.1	8.9967	148.839	2973.29	535.406	12.3416	75.0256	205.12
25577.9	30.1974	64.8468	2413.57	354.867	15.9402	61.0789	411.866
17516.2	20.6797	122.22	2698.2	496.761	14.8033	82.2342	273.363
16963.3	21.5629	104.783	2430.47	367.938	8.63216	37.8648	425.241
18874	7.97669	132.499	2675.51	395.273	10.3765	33.848	175.044
18084.5	6.10842	111.6	2474.99	381.053	9.01808	32.3039	177.402

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
19649.5	5.8527	216.592	4324.18	701.769	7.16267	61.2383	127.187
17328.7	6.22563	134.797	2969.29	438.68	8.61274	40.7871	192.098
17094.1	63.2978	102.655	1429.48	198.903	17.4928	29.2367	241.769
12604.5	20.8383	77.0507	952.494	147.931	10.6577	24.2182	153.655
11115	24.5824	69.9516	872.273	120.059	14.7366	30.8135	169.178
11518.7	14.9971	55.6197	1171.81	158.494	11.19	31.3481	200.964
12007	13.3417	62.3618	917.506	118.289	13.2267	27.4737	188.203
14886.9	71.8259	102.234	1188.73	204.383	18.4553	36.8341	345.174
19095	42.3276	88.2312	1799.27	302.051	22.33	66.3054	300.548
21289.3	23.4154	130.01	2293.01	685.425	12.5543	121.029	239.449
17030	25.0013	78.3191	1659.98	296.967	19.4649	57.4486	277.708
16519.3	30.1178	70.64	1449.21	251.424	16.733	52.575	288.186
11934.9	132.123	374.447	1707.3	250.415	6.67652	9.09331	383.429
7212.5	99.1192	297	1012.33	151.961	5.84033	13.019	336.713
13336.8	30.316	196.029	1600.98	287.77	7.41578	12.4899	269.743
11185.4	54.6445	238.285	1374.32	224.505	8.25012	14.6255	294.547
9593.84	86.3047	309.421	1261.92	213.672	7.2019	14.3929	314.691
27149.3	35.9155	219.672	3104.91	448.014	16.9146	26.1882	338.062
23579.7	26.8057	227.732	3564.23	517.665	12.6972	29.3827	299.898
31315.5	65.2078	296.465	3883.26	667.67	9.77227	30.3792	424.737
29350.7	45.3034	291.103	4061.36	680.331	7.96802	33.9864	378.874
32090.3	43.8956	262.181	3959.99	607.337	12.5252	35.4606	329.537
21610	37.7415	191.375	1486	219.099	9.2418	38.1974	227.866
16991.2	32.9941	122.788	1349.6	166.124	6.11336	35.2187	228.325
18660.3	61.7263	141.865	1427.99	170.099	7.85916	35.6448	258.321
17945.3	34.6453	159.137	1330.34	176.11	7.15743	31.7265	225.327
16965.7	63.2712	200.601	1348.4	187.482	6.72873	30.3629	250.572
19255.3	51.9038	295.745	1252.41	156.917	10.9457	14.427	215.611
15527.1	17.5698	170.41	1637.25	139.268	10.0737	27.148	193.964
16442	39.5689	149.964	1273.89	115.365	7.12192	22.8128	194.632
16346.1	39.2254	181.103	1543.28	124.496	7.90716	20.8034	214.203
19799.6	23.5849	169.282	1713.29	138.317	7.20154	31.0612	204.912
29635	195.275	192.809	3101.06	295.935	40.7309	51.9374	658.307
21289.1	59.6965	62.1213	2258.72	245.411	29.3543	36.8849	520.879
14769.1	10.7116	40.3327	1997.55	235.259	30.3663	62.0757	229.909

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
22458.2	46.6126	44.7616	2340.33	242.605	34.3805	54.7269	432.376
24435.2	70.1358	62.8902	2403.36	245.16	44.2878	47.8927	456.317
24006.5	41.6304	70.007	2446.46	231.237	29.2449	40.8717	479.284
25268.7	9.72583	42.6489	2719.83	231.89	49.681	55.2973	355.301
21975.9	16.2058	60.2685	1769.34	246.032	37.5894	62.6215	437.382
24330.4	8.7392	46.3799	2190.83	246.218	26.9578	48.0831	205.192
26034	11.6961	52.0004	2481.39	263.528	33.2458	48.2818	269.39
21869.5	133.557	139.143	784.176	100.499	14.9219	19.7649	368.1
23013.7	89.0906	110.868	984.163	110.724	14.3118	19.0499	242.51
21370.4	66.1563	148.859	984.958	109.221	10.6903	14.6795	233.017
19236.2	39.8378	99.3046	1062.72	123.064	12.7074	21.1421	249.618
19411.4	77.6497	122.008	985.064	109.115	12.5211	17.3743	251.343
19805.7	124.272	111.473	1094.27	73.1768	17.3728	26.0028	346.244
18985	105.162	165.161	870.117	75.4608	12.2966	16.3301	253.875
19803.2	72.2898	141.43	878.695	85.5519	11.026	17.6868	251.556
18033.4	98.9374	77.0796	881.788	77.446	12.8162	24.5829	274.234
16991	53.1126	121.16	869.98	73.4783	10.3004	18.2591	258.622
16087.3	23.7776	98.6318	1416.83	62.5423	10.1551	19.0179	191.271
15792.5	30.4155	104.428	1496.68	80.8892	8.55042	16.2724	163.996
15461.5	25.0832	71.0819	1010.16	64.6155	8.63617	8.88556	167.522
9577.16	39.2669	101.416	473.512	34.2477	6.85828	5.83125	123.281
17946.9	24.8136	88.2379	1057.9	76.7518	9.38269	10.9557	183.486
14641.7	60.3349	142.165	1307.61	53.6242	7.06736	7.95199	157.348
15771	41.0936	97.6295	738.586	70.3185	6.87251	9.21695	150.707
18555.3	37.0143	115.875	1093.41	51.5575	10.3586	7.7648	180.653
10537.2	36.3953	115.961	712.419	47.9359	6.58381	7.22087	116.968
10472.5	52.056	126.133	723.702	36.6179	6.53638	6.46403	148.7
20345.6	15.3877	146.884	2462.54	439.769	40.1178	92.5884	167.802
20363.6	42.9084	147.717	2128.46	354.576	12.9949	46.5096	198.58
18992.5	47.6425	101.446	1901.08	314.233	10.2671	34.6069	232.815
16972	20.4312	114.884	2061.54	372.7	9.14813	30.886	175.591
19662.6	40.2973	186.109	4201.25	686.756	29.2593	90.6318	240.353
36441.9	12.5585	322.292	5135.27	892.6	7.76246	46.8032	240.539
37073.2	10.2139	322.306	5030.04	891.988	8.10821	42.5135	235.785
36529.6	8.78646	322.783	5111.4	864.954	13.8827	42.3808	230.347

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
37248.7	9.94952	317.432	4927.39	894.119	7.66254	42.194	245.055
40380.4	9.05689	307.047	4689.65	851.678	7.57908	41.3992	218.144
14033.3	41.8163	97.1417	1113.86	245.051	15.3373	32.9714	218.664
20014.3	31.9815	104.256	976.017	177.605	10.9039	24.0354	204.555
18129.9	33.3216	94.7527	1144.85	170.891	9.68378	22.7135	211.3
20654	46.435	125.911	1220.19	166.176	11.791	26.4928	248.734
21578.2	43.7728	106.083	1329.31	217.788	14.6592	29.1223	249.034
17876.5	31.4605	75.1388	849.769	157.828	10.3377	29.5988	370.825
20039.9	32.5447	118.988	855.972	159.689	17.46	27.3709	345.62
23076.1	43.1613	121.63	969.725	196.904	18.7616	29.7655	378.212
19579.1	24.0512	64.2055	981.057	190.179	12.0552	35.5613	288.957
19144.8	40.9279	96.2025	1004.97	198.691	18.9749	40.0196	421.531
12968.1	48.9682	236.768	837.899	108.073	8.12186	12.8681	209.241
13846.8	67.0148	341.38	983.468	115.561	7.93019	10.747	245.3
12406.1	17.4684	205.562	702.5	125.488	7.83754	10.0647	146.552
15517.6	50.8183	208.022	887.704	100.522	10.3661	12.5891	216.007
11677.2	30.0505	164.542	744.917	86.5639	7.792	14.6364	173.551
16616.6	65.576	230.122	1055.95	163.856	7.56144	12.3501	291.145
18829.4	34.6889	169.802	937.255	154.231	9.57704	10.8309	222.017
16354.4	94.0857	116.182	1339.95	215.42	7.37179	18.3702	317.971
16352.7	87.8032	165.118	851.836	99.0509	9.02546	7.44042	261.505
16642.7	100.805	144.396	1077.66	158.44	7.34296	14.1287	235.402
18800.4	35.0457	95.4945	1480.89	200.938	10.8029	17.5855	254.548
14862.5	9.40622	64.0496	1524.14	208.707	6.72446	15.1343	220.529
20876.8	23.0673	84.2474	1764.76	233.309	10.0061	16.9409	279.17
16313.1	12.1141	65.8827	1640.35	184.481	9.47125	21.3398	213.753
20144.8	15.1873	87.0809	1609.64	208.08	9.42774	19.7677	166.1
23685.6	49.0089	126.115	2178.18	333.243	9.46489	17.4714	381.998
20872.7	41.4456	93.4067	2091.46	347.486	8.08345	12.7853	350.416
22344.8	47.302	120.125	1965.2	303.965	13.4854	18.2992	359.621
21532.5	61.5209	91.372	1972.93	314.182	11.1866	23.022	405.027
23455.9	63.4757	93.09	1664.69	254.068	8.93102	12.9248	372.894
30019	17.0126	306.579	8071.2	880.092	47.5129	163.022	209.191
41728.4	14.0319	345.176	6050.36	1174.5	6.72206	40.0771	231.688
35101.8	15.3195	311.053	5269.69	1061.18	6.09171	27.2018	222.791

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
33646.3	15.2063	316.48	5404.16	1030.25	7.6802	31.2823	210.566
37823.4	11.7431	345.551	5456.07	1251.76	7.08231	40.6334	214.361
35273.2	20.6193	342.83	5292.45	1152.7	8.02672	32.0735	205.076
16632.8	103.875	198.401	1094.85	123.655	11.9684	29.6827	471.865
18205.5	123.621	163.066	1076.86	118.866	13.2549	24.6844	463.414
16405.8	114.105	185.167	1060.7	132.371	15.7074	21.7906	390.609
17650.7	110.964	177.037	876.01	101.201	12.2312	22.6172	364.635
18863.2	81.8745	179.007	1035.8	108.243	12.7167	22.147	408.199
26819.7	67.5826	162.394	1454.68	441.932	18.1285	41.2671	420.591
27899.6	51.6609	183.085	1098.16	372.942	17.5372	30.8839	377.724
24814.6	31.6191	123.526	1227.54	385.255	11.8744	40.5907	398.239
25421.4	38.65	126.756	1502.45	348.494	14.6569	38.1464	422.543
25403.8	41.7281	107.106	1070.34	287.164	13.2421	33.3283	401.249
21286.2	76.9044	254.055	1356.87	132.064	13.5316	25.3264	440.096
21461.1	64.5653	220.098	1175.17	106.117	11.4849	13.075	364.76
18403.5	47.7887	210.481	959.462	93.6391	11.8875	17.1962	269.783
19177.2	35.8468	133.361	1120.81	112.709	9.98581	15.8373	294.143
21588.7	77.5559	164.889	1251.06	108.526	11.3515	15.7105	417.731
15619.1	77.1711	240.439	881.164	86.4925	10.4749	10.2092	278.5
20974.6	86.4308	244.078	1078.04	103.913	13.3877	15.4694	414.929
17734.7	100.054	221.211	1027.86	106.46	9.74742	13.5095	441.257
14826.8	76.2146	170.019	811.76	81.0039	7.8773	8.88853	348.664
17291.3	66.7828	201.011	963.138	95.58	9.05143	8.84965	358.239
29440.3	37.616	154.524	2711.8	487.879	19.0082	87.3231	413.786
26524.4	15.5354	123.462	1999.07	320.69	15.8548	40.6507	281.386
24429.5	30.5989	115.522	1960.99	312.269	13.458	34.1451	278.825
24216.4	22.005	106.397	2087.67	349.527	16.4484	57.8837	375.429
26480.2	32.9001	90.384	1621.84	264.289	17.6402	56.1609	324.965
27263.9	45.7831	136.704	1991.14	309.871	15.4137	20.8835	399.068
22907.2	41.5912	149.507	1710.95	266.264	13.986	13.1845	226.253
24601.3	20.3477	117.561	1957.42	299.073	11.308	18.409	211.152
20124.2	17.7442	236.099	3649.4	610.321	7.9835	40.1176	128.002
19932.3	19.7959	137.548	2059.39	321.795	8.3692	18.6736	180.445
35110.4	141.34	217.205	1856.58	246.214	23.7486	31.6202	244.716
10818.5	48.3029	145.321	699.539	98.238	11.3443	24.732	161.256

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
12801.9	52.6976	123.265	829.306	123.561	11.339	26.8218	175.445
12018.8	54.3315	137.011	1027.43	137.668	11.4472	22.8267	211.662
15935.6	56.9825	193.818	840.209	117.616	13.1052	21.9536	186.447
18143.7	94.2924	130.684	1204.95	195.409	14.494	36.6008	324.253
22438.8	247.249	168.486	1609.46	342.268	29.3964	54.8184	246.146
21429.8	56.7286	105.472	1642.71	344.116	10.4826	38.3984	226.012
20506.8	100.654	175.616	1540.26	260.842	25.2989	47.3957	240.704
17027.3	65.115	144.348	1333.78	234.744	16.393	39.7157	239.744
26002.2	179.972	392.925	1884.41	132.264	8.8574	10.1452	346.617
12432.3	100.711	357.035	957.318	101.41	6.0766	7.74161	362.494
22485.8	89.4196	228.328	1317.11	168.425	9.25409	13.7864	294.852
22041.7	137.336	308.477	1249.05	157.841	11.7344	16.4249	485.053
18504.6	151.946	430.75	1315.75	142.455	8.67391	13.9793	347.589
27920.7	53.6705	247.982	2917.09	461.449	11.8278	28.581	254.114
27368.4	58.0303	211.695	2478.92	384.671	9.13146	17.0377	241.97
25505	55.8253	239.593	2539.04	443.174	7.04138	17.0223	236.776
30121.4	50.4734	257.658	2876.16	496.248	7.83466	22.4568	237.136
29316.3	65.1162	247.883	2823.11	464.584	11.4642	27.2158	261.311
23154.3	73.6702	299.934	1224.9	170.991	10.002	17.1343	225.142
19857.4	74.0881	202.866	1222.47	150.49	8.01747	21.3196	238.704
23406.6	85.5582	249.78	1588.92	193.277	9.54765	21.929	235.665
22696.5	80.807	259.028	1176.17	155.974	7.60729	13.7587	208.824
27368.5	117.002	373.711	1511.78	196.639	8.96025	21.8167	294.238
25256.3	91.53	412.55	1282.42	170.12	12.8744	12.5741	270.89
18666.7	62.7676	236.356	1109.45	117.703	6.55171	13.2927	203.501
20299.9	77.0404	408.219	1127.79	146.718	9.27734	12.7573	185.814
20458.4	81.1286	375.384	1096.06	125.151	8.59217	11.6376	213.03
18979.4	53.6918	419.446	1124.13	155.222	6.18727	15.0005	180.897
32298.7	190.978	292.935	2630.62	268.137	47.2049	36.0942	637.998
23638.8	78.7168	115.059	2052.06	242.301	25.6317	35.7456	520.145
23998.8	41.8093	83.0532	1965.28	251.893	30.795	48.163	404.371
25640.1	72.3778	101.791	2229.02	268.009	32.6643	44.3877	506.418
25521.8	70.7028	75.7552	2330.18	251.821	48.9394	58.2145	453.593
27052.7	58.1481	89.635	2203.02	221.816	24.0978	40.9684	536.841
25883.2	19.0507	75.2138	2295.51	259.498	36.0662	44.3054	403.346

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
22912.5	26.6837	124.726	1727.49	264.831	41.275	62.4169	357.695
26871.6	16.7731	94.4665	1989.99	237.384	19.827	35.8502	260.11
26115.4	18.8674	94.5798	2220.7	266.732	27.1908	42.8399	320.064
22241.9	121.184	283.372	710.908	95.1254	18.3451	15.0467	301.813
23830.7	77.2962	247.89	960.966	112.225	14.3633	20.1415	254.443
22973.3	83.3104	353.807	752.945	97.1808	15.1318	10.8362	220.272
23787.8	52.0583	192.558	1019.56	120.334	15.9726	19.418	237.823
26784.5	54.124	254.466	788.696	108.137	12.5416	13.4432	199.104
24261.9	176.008	226.637	848.221	74.3622	20.4297	21.9077	362.775
19652.9	106.992	244.42	648.201	68.8113	13.0473	11.6592	247.349
21756.8	101.418	239.523	623.332	68.9312	13.5569	12.2242	215.912
22574.6	85.5179	208.066	703.486	79.8208	14.5135	13.8605	251.822
22560.6	105.668	234.313	706.418	78.275	13.1302	12.0804	250.972
16567.7	32.6396	154.642	1339.35	83.9386	8.36381	16.8408	150.423
17700.7	75.246	130.133	1361.83	91.8823	8.37458	7.9648	163.847
16622.5	99.8214	184.877	861.647	87.5634	9.29115	8.18267	170.884
11312.5	52.433	106.017	441.606	58.7246	6.35082	5.68315	117.871
17134.6	65.5908	179.338	821.342	81.3214	9.75476	8.97066	161.705
28013	71.1019	140.97	1082.94	69.9016	6.58791	7.19799	139.481
17029.4	57.5764	115.157	776.47	91.2483	7.13989	6.2277	144.656
22146.3	77.8041	239.264	941.668	79.6776	9.66496	6.89121	181.874
15597.3	91.927	100.747	552.358	69.5736	6.03332	4.70909	133.285
15170.5	87.148	145.244	767.734	64.3578	5.98688	5.7339	149.993
28182.1	184.874	278.843	2450.91	451.992	32.7841	72.5932	206.87
25394.5	133.329	190.314	1867.65	330.954	15.1497	33.5557	218.879
25642.9	116.457	191.302	2004.93	338.032	15.212	31.6088	251.209
25835.2	57.5474	167.295	1996.26	355.316	13.8377	29.7272	198.448
27828.3	99.6135	201.249	2170.55	372.912	18.7581	36.3733	215.999
42438.3	22.6546	270.237	4433.07	786.906	14.3553	41.2049	195.157
40200.4	14.399	244.743	4119.37	745.208	12.4925	35.4847	178.287
42420	17.6355	283.527	4361.16	793.058	13.366	32.7173	190.825
38075.8	14.9419	291.622	4255.51	803.119	13.8875	34.0084	178.867
43329.8	16.6457	247.544	4313.5	776.799	12.936	35.0732	191.931
19604.8	42.3632	121.941	1055.04	210.624	12.6965	23.7539	216.531
17298.7	34.767	115.719	806.877	151.55	10.2773	18.449	164.737

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
18671.7	62.3432	164.865	1016.84	165.028	10.6275	20.0113	183.849
20913.1	72.9566	177.58	1121.47	173.634	14.1445	23.2888	206.097
42012.8	68.3357	187.732	1201.64	208.595	14.0653	20.1827	226.759
20547	33.9709	121.699	712.827	137.872	11.2064	18.1971	259.565
18185.4	41.0916	279.192	672.837	137.48	12.401	17.9954	227.552
22562.6	54.4822	215.386	763.041	154.817	14.999	19.2784	275.107
18573.9	29.6394	155.719	774.72	158.677	10.4804	20.8805	211.714
21252.4	41.6568	186.088	912.429	190.502	10.8875	22.297	272.737
17054.7	82.4882	353.249	696.321	91.4921	9.06864	11.6878	261.599
24396.8	91.0975	523.649	634.157	77.1743	12.3488	13.7211	238.147
20079.5	46.028	369.648	597.745	99.72	9.61057	9.13524	166.229
19752.9	58.9822	327.015	733.043	86.6418	10.9776	11.8627	222.98
17838.3	47.3981	394.522	664.662	73.2158	9.84002	15.2855	185.58
19925.5	86.7063	339.629	832.75	119.782	8.91711	11.2055	282.249
25456.7	47.8147	339.566	889.501	149.971	13.7912	11.61	203.047
19025.2	86.7443	180.195	978.131	146.64	9.65676	9.03634	251.696
19749.9	95.7974	291.571	729.396	92.8847	8.3472	9.01772	257.153
18871.8	104.166	342.933	777.813	96.3639	9.81671	10.2931	257.173
19768.1	79.9442	199.202	1433.82	203.024	11.0011	13.622	266.626
19005	16.7988	78.5122	1368.67	185.646	8.9601	9.61629	242.263
17148.6	61.4679	142.346	1020.57	158.126	9.34307	10.8175	170.557
21832.3	64.2416	156.42	1490.18	209.162	11.0165	15.355	205.311
19885.6	52.9651	168.164	1299.23	188.403	13.7	13.106	159.209
21090.9	62.9477	205.155	1453.39	241.803	8.1766	10.5091	288.236
24061.1	78.7593	160.585	1719.05	257.859	10.2081	12.0084	293.363
27835	74.4826	177.624	1781.94	272.505	9.35361	13.3767	358.375
20568.1	95.186	160.564	1603.27	238.854	9.14278	15.0713	306.897
27288.5	121.335	276.578	1711.98	275.304	10.053	9.54593	375.726
34886.4	56.7703	344.14	4276.12	920.378	13.2182	42.5171	178.504
27554.8	45.0807	251.237	5359.17	677.241	17.8803	110.217	153.166
32123.9	51.4077	325.436	5143.66	864.479	19.105	64.562	190.194
38552.1	57.2537	407.366	4227.54	1065.45	9.89174	22.8237	198.708
35010.6	69.4698	389.107	3745.52	964.13	8.24616	19.8031	162.971
39091.2	83.1107	402.706	4286.98	1132.28	9.55742	22.5804	203.652
37859.3	67.0464	375.707	4483.54	1076.52	8.83036	23.9405	169.524

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
41444	112.935	450.059	4263.53	1106.81	12.0494	23.3817	183.453
39208	77.7471	388.19	4140.74	1095.17	9.56073	25.5303	190.082
38347.2	54.8861	376.641	4397.67	1066.28	9.93941	25.5801	183.072
18312	59.8784	103.906	1263.61	143.199	10.5556	18.2554	349.521
23093.7	51.4533	65.0986	1396.08	150.236	8.39213	28.1092	377.646
23935	73.3037	118.454	1496.81	176.714	21.4414	17.0186	325.585
18939.9	29.1777	60.6257	1173.44	140.924	18.8044	23.8867	328.723
19438.8	37.7523	66.3069	1428.18	165.883	14.632	32.9064	299.068
15653.3	26.7911	81.7353	1566.83	209.479	10.7534	28.4166	278.004
16951	29.9316	60.0883	1543.94	186.22	6.38976	32.2644	311.089
18037.8	37.4437	120.347	1899.21	245.254	16.9922	27.8834	286.109
16548.2	25.6043	72.1514	1633.29	212.88	7.01395	37.3127	294.323
17444.3	20.9434	68.9408	1620.74	211.278	8.04935	38.1881	268.822
30216.3	89.1282	78.0679	1929.56	189.207	19.0738	42.9317	228.652
30382.5	131.945	120.521	2307.1	269.559	14.2238	35.3284	245.49
35635.2	69.267	162.616	2878.2	513.135	14.5405	44.2767	258.245
26870.2	40.6455	107.654	1891.81	263.536	13.5676	34.3027	244.621
28197.3	41.8034	97.9259	1982.67	240.73	12.6955	41.6178	236.181
26504	69.0978	70.9527	1953.44	207.642	16.8692	57.0028	266.233
28733.2	79.272	118.483	2013	336.774	31.6452	81.0651	355.19
30096.5	48.6859	164.056	2104.51	519.134	21.5152	57.4903	446.668
22679.3	28.1784	82.1415	1641.35	252.027	13.778	48.6384	305.647
21472.6	76.0392	210.394	1439.45	234.029	10.4461	27.3926	207.736
27130.4	33.3397	91.8184	2117.95	248.618	13.0043	59.3509	288.256
20501.9	65.7449	194.018	1242.99	200.7	12.6747	18.5799	240.943
18835.6	44.4965	164.536	1157.17	200.591	7.30325	8.76155	208.156
19776.2	86.8475	212.386	1344.06	213.577	9.03415	11.3224	231.643
18780.2	41.5831	178.905	1313.86	216.445	9.65987	23.3853	189.765
14694.7	35.5366	209.194	1233.52	217.754	6.20271	19.6202	202.814
13716.3	57.0893	156.866	1071.83	176.842	7.54694	17.9441	230.997
14491.1	47.0657	187.199	969.503	172.216	5.85969	9.92297	219.651
12330.4	36.0557	154.549	987.21	159.857	5.69316	16.182	207.09
14189.3	23.8075	154.593	1076.93	190.53	6.35868	19.1154	184.018
14842.5	90.5876	106.695	1023.57	164.687	5.02185	30.8652	388.41
18567	37.0359	142.465	884.128	112.609	9.24461	19.3714	217.625

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
23355.6	36.0179	174.047	918.896	118.922	6.87554	9.0852	213.804
20186.5	79.0189	109.921	1080	143.128	7.73187	17.5046	300.605
25074.6	40.2221	151.789	1141.4	161.683	9.45094	29.1867	266.481
13403.9	117.958	190.935	924.045	147.001	8.8712	29.9339	327.926
13191.6	21.1076	144.274	856.927	119.311	7.04856	19.0804	183.697
12879.7	31.0541	152.827	779.605	111.401	4.67415	11.3471	221.797
12133	94.9617	80.542	1120.8	155.339	4.67483	21.8825	319.863
14205.1	30.9967	149.459	1119.62	173.215	7.13569	24.9065	250.299
26446.9	54.3774	147.169	1273.25	150.771	10.6816	10.0449	314.519
31225.7	54.4939	133.991	1050.97	124.288	10.7785	9.31683	375.339
23953.5	52.8217	78.4892	671.584	94.8854	12.706	9.10388	364.367
26200.2	46.8421	81.9916	1085.94	114.503	12.3288	12.9571	362.345
22083	43.8767	97.8189	771.406	97.6929	11.9363	11.2382	334.325
17417.8	45.234	112.227	1394.98	115.708	8.65609	10.833	298.183
15342.9	27.4197	86.1283	1356.88	116.108	8.37353	10.206	240.284
14430.6	31.7889	71.9154	988.807	91.3809	9.56169	10.6589	224.596
16462.4	47.8589	80.9447	1309.49	99.1768	9.38656	11.4154	312.951
11661.7	33.3267	95.1043	1044.16	85.4677	9.27372	13.1557	238.456
34678	51.8747	239.58	3430.01	578.875	10.0771	25.2091	346.767
37135.6	59.7505	251.471	3162.62	499.889	12.516	25.7583	276.021
39358.4	79.4982	293.669	3263.72	586.102	11.6364	19.8216	418.459
46592.6	60.3991	286.003	3812.93	643.602	9.86909	24.396	302.014
40807.4	69.8716	285.674	3163.86	568.594	12.7914	21.2514	413.5
26101.7	36.5055	226.722	3962.34	685.668	4.13048	36.3039	325.192
31791	44.9163	234.192	3801.14	599.907	12.3344	33.8999	314.533
30330.8	57.14	242.429	3345.83	609.808	9.92872	25.5288	358.051
35045.1	51.4839	277.142	4209.21	697.854	8.59401	32.4991	346.103
33784	56.7058	297.265	4291.09	777.16	7.5874	33.0651	429.237
20420.9	72.3709	171.983	712.288	68.8189	10.5387	10.2348	169.76
23388.6	78.3577	174.666	1125.63	64.1018	12.1758	15.0799	205.459
16678.8	32.0154	216.811	620.076	65.916	9.18088	10.1802	175.191
21236.5	27.0566	98.7567	677.891	71.5605	12.8374	12.087	159.372
17730	30.3473	200.463	704.522	72.2741	10.7068	10.0666	167.671
14231.9	20.4464	153.05	689.474	81.4265	7.07427	14.5952	162.579
15806.8	25.5309	181.725	1096.13	49.4425	8.11167	12.3172	179.612

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
15473.2	18.4694	245.304	648.873	30.4496	7.03651	11.4119	168.146
12503.8	15.5052	78.0982	526.746	37.2833	11.9453	12.9941	167.561
13241.6	12.8379	156.353	805.454	58.543	8.61043	12.7178	158.405
23264	83.0659	102.155	893.979	154.9	13.9457	15.5924	197.292
21883.7	44.7398	132.139	842.636	165.93	8.18156	14.2519	174.86
17478.1	51.3511	153.278	1059.73	215.746	9.50013	14.8468	204.015
16899.8	24.1778	85.4059	857.902	161.758	6.91174	16.74	159.879
18159.1	43.5307	127.953	869.844	194.708	16.8898	20.4343	204.076
27169.5	75.2112	108.121	654.71	90.9372	12.1176	14.4394	202.243
16970.8	66.3965	168.919	612.317	85.7495	9.32817	14.9145	239.946
11630.4	26.5797	204.906	966.333	183.846	6.942	14.3715	156.264
17284.2	37.0755	111.336	753.948	133.037	7.77413	12.2824	172.214
20848.7	66.6608	126.968	547.093	90.649	11.305	12.7872	236.629
22268	122.15	200.785	1659.76	174.405	34.6673	17.5303	457.434
27831.3	126.462	178.018	1101.25	114.686	59.556	21.1434	428.312
18947.6	88.2815	129.361	1063.97	107.994	28.1155	17.9892	395.836
23139.9	79.4511	142.621	1339.99	140.232	38.5734	29.6754	412.494
23602.9	99.8289	167.861	1211.47	131.432	33.249	19.1922	429.91
23694.9	109.532	193.393	2005.12	223.057	39.8051	24.934	425.276
27898.5	132.281	151.112	1435.48	144.798	24.7368	21.9442	450.877
13954.4	71.193	110.929	1330.55	134.13	18.5185	22.2361	371.627
24425.1	75.8841	125.723	1575.53	168.005	24.0243	27.9848	359.875
16374.8	82.6256	115.35	1555.15	164.204	21.2914	22.8131	385.325
16608.1	51.5038	114.676	1665.74	234.517	9.95594	56.3505	295.417
18768.1	42.4161	103.541	1765.52	303.695	9.67193	130.043	303.212
23725.1	92.3137	178.76	1584.98	202.562	12.6344	23.44	448.846
22428.5	55.0214	119.38	1699.94	341.312	13.9669	95.3518	277.67
22154.1	68.0944	141.91	1917.98	342.077	15.0024	93.0375	340.101
19104	38.9573	94.6279	2057.04	286.071	9.51667	60.5006	302.681
22224.1	37.417	79.6504	1760.53	310.826	9.77932	99.1714	304.354
31697.9	98.055	193.073	1935.01	249.632	12.757	43.5234	513.361
22379.8	55.074	120.937	2291.24	564.383	11.2652	123.856	305.52
26892.7	67.8465	124.075	2266.88	410.737	18.6562	156.377	374.063
39171.7	31.149	198.552	2720.77	537.564	21.3571	45.3621	246.782
29710.7	20.3256	152.631	2276.21	443.499	16.7482	42.9124	205.554

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
36744.9	25.7201	229.012	3005.83	604.452	16.549	38.95	201.28
41328.5	22.2328	240.637	3044.71	647.03	14.7761	33.9826	207.862
47267.5	32.4541	309.227	2727.88	558.313	20.0829	29.2309	185.296
32848.8	14.1598	163.718	3084.12	618.775	15.9836	40.3791	183.769
44840	8.64578	143.565	2841.16	592.737	21.6842	49.9339	173.814
31746	11.0474	174.492	3390	706.278	15.2522	42.7983	179.582
33206.8	7.81346	180.137	3642.37	783.134	11.8831	35.8006	178.777
36047.5	13.762	199.723	3313.57	705.099	16.1344	34.1819	181.017
46605.3	41.2275	224.069	4594.46	812.471	16.5922	54.3274	200.268
45410	21.708	210.922	3934.14	760.674	11.0659	38.7427	174.935
46140.3	52.5711	267.754	4476.39	889.411	19.4658	62.5973	216.041
43890.1	16.0125	249.26	4536.71	884.141	12.5725	49.3853	175.333
43024.2	26.819	255.284	4587	877.065	12.3961	45.4189	165.765
36505.7	12.6108	234.921	4846.85	847.633	14.9355	55.9103	205.584
38553.2	11.1516	257.948	4973.29	948.107	10.0917	53.4824	203.695
40660.7	13.6051	272.44	5331.89	1012.09	18.0599	64.2038	221.554
36411.7	6.69799	270.575	4921.47	961.221	9.39054	54.7598	183.523
37778.3	5.42655	257.95	5091.45	956.997	9.55067	56.3826	163.643
29612.3	28.8207	84.2717	1657.55	243.822	31.0201	52.9778	451.151
26713.4	14.5795	81.8792	1659.23	265.166	56.509	78.4858	419.772
29446.2	34.8707	125.201	1965.5	282.067	97.6354	97.6304	470.159
28580.6	27.9625	96.2132	1683.67	260.287	32.3445	47.3227	489.421
25318	23.3585	112.802	1736.19	259.001	79.5157	69.8137	428.764
24125.7	14.9882	67.5065	1997.27	284.572	47.3108	85.9904	409.555
25757.8	9.24839	62.5718	2102.06	295.208	144.973	136.454	462.675
25054.1	11.9273	78.8251	2470.41	336.888	95.1677	100.787	501.102
24931.5	23.4559	76.5342	1848.52	275.155	52.7149	65.4737	501.424
26877.6	24.4398	112.703	2241.54	319.056	111.858	108.695	600.01
30562.1	32.4142	84.5313	1950.65	263.414	16.4768	37.0505	459.004
25521.3	15.7498	76.3548	2436.78	260.897	32.4959	44.1802	435.368
31763.7	34.1453	106.48	3208.56	231.826	25.5176	36.6599	541.71
30075.6	36.5286	84.6842	2519.18	264.205	12.2515	31.1087	487.64
31265	30.7415	66.4688	2606.42	293.991	77.6246	91.3846	509.843
8820.81	19.3598	74.0144	2400.78	315.886	35.4964	68.0604	398.104
23276.7	8.51215	37.9892	2891.61	330.879	95.5785	129.356	334.385

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
36464.2	23.7859	48.2743	3207.85	259.811	27.9525	55.1083	503.606
25264.6	16.6167	47.1205	2555.94	277.679	37.5357	78.0319	348.195
24623.4	11.6588	42.8664	2546.02	294.072	67.2616	120.479	297.93
26128.1	62.5161	137.569	1226.85	153.301	14.4524	16.7368	327.39
26462.2	50.5353	101.383	1191.42	146.468	11.5059	13.2782	288.215
27156.6	54.9356	99.422	1563.68	205.189	14.4384	19.0029	371.742
27094.8	62.8285	116.666	1351.9	176.637	11.9625	15.251	361.897
21259.7	50.4103	105.191	1328.68	157.996	13.5901	18.4108	332.032
22294.4	54.1907	75.7765	1411.92	189.558	26.5382	27.1741	376.546
20845.4	47.1991	67.2964	1149.79	147.589	10.5577	15.2929	322.821
26363.7	42.2658	72.1759	1708.02	234.833	14.7076	25.0055	380.896
22674.7	64.666	88.3076	1904.18	258.945	11.8776	22.8091	429.571
19252.2	46.2556	68.227	1620.84	204.084	13.3245	24.5952	328.925
25234.3	64.7962	68.2652	1235.11	159.627	10.9026	23.771	341.943
22170.7	49.3115	58.4722	1439.9	174.166	12.9139	21.1483	268.044
20114.9	60.4985	125.508	933.316	115.849	7.64481	8.28927	208.735
20342.4	54.9907	51.3869	1256.38	149.719	19.423	18.2764	239.954
20741.1	60.3125	59.142	1201.66	127.337	13.6944	18.7738	264.683
23203.5	72.431	45.1823	1504.62	214.999	31.3777	49.6684	379.621
18799.1	49.1859	44.512	1295.74	159.085	10.9746	26.6469	296.155
15023.5	56.7191	77.5445	1214.63	175.942	7.5283	14.1215	259.793
20210.5	43.2738	40.8463	1163.57	150.502	11.6516	23.9245	248.899
20375.7	67.1469	43.315	1492.87	185.999	10.7956	24.5181	340.908
24674	42.6767	193.92	1862.66	354.598	13.8407	32.9981	384.122
23550.7	61.2085	198.632	1894.55	328.107	12.5911	28.9917	340.626
19789.6	47.5181	190.316	1510.37	274.284	13.477	21.4246	358.599
19241.6	55.5193	207.276	1342.3	236.159	12.7894	23.4572	374.179
21611.2	52.9782	215.786	1493.23	275.216	13.7904	21.3254	396.349
21109.2	41.1449	182.471	2032.37	373.961	11.7321	31.9287	441.68
21060.8	63.0643	188.933	2008.08	334.384	14.4357	30.0808	379.943
17964.5	76.3605	163.411	1401.13	254.246	15.4075	26.2263	569.275
17676.6	69.1987	204.919	1517.59	263.998	12.7889	20.9605	484.717
17621.4	75.6579	187.637	1533.34	284.202	13.9855	22.2296	629.407
21985.6	40.001	196.33	1927.75	373.339	16.1226	33.907	302.511
27453.3	68.3177	258.189	1429.15	243.312	14.4524	16.1742	337.07

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
22892	46.7023	198.452	1610.6	312.288	15.3645	19.8314	320.971
23561.6	47.9002	222.628	1695.31	337.902	13.3865	24.5297	281.341
28573.1	57.2543	213.255	1485.19	281.629	17.8767	20.6502	332.47
19777.2	32.841	170.814	2072.86	407.609	12.3926	32.1893	310.143
16987.6	33.3621	236.681	1674.71	295.848	9.90956	20.2127	293.127
16595.2	25.4683	182.648	1739.39	353.508	10.7845	25.4326	298.166
15389.7	43.8466	178.74	1248.64	261.968	19.7237	26.3707	407.745
19427.7	34.8254	191.088	1819.91	359.228	12.2492	24.9773	322.264
27836.7	101.23	192.552	2204.69	693.471	16.5924	48.1384	300.097
26970.2	76.1377	206.969	2317.69	656.375	16.0574	51.5519	368.281
31103.2	108.732	223.682	2234.83	538.506	17.4286	35.1223	413.329
32867.3	125.288	395.724	2943.16	688.138	14.1064	38.1239	513.935
39013.5	238.465	343.906	2652.94	669.204	18.6641	36.4349	447.73
21779.5	41.9555	194.479	2339.12	662.839	12.8998	48.616	246.716
21954.8	28.5677	218.497	2524.35	752.07	14.7941	70.8514	321.739
22995.6	36.332	244.342	2556.01	642.007	15.2952	47.9473	340.5
25298.1	83.1948	331.623	2965.06	777.569	10.3401	61.0602	535.116
27792.5	63.3106	400.507	3234.47	815.841	13.1238	51.392	427.875
11689.9	80.976	139.164	368.571	137.498	9.54453	10.333	249.967
21218.7	54.5009	92.7061	1449.73	310.593	15.0166	35.7304	252.654
13757.6	87.582	82.2771	518.298	112.287	7.64692	13.8674	235.476
17222.5	97.2643	155.87	586.168	180.074	13.2654	12.491	408.04
12732.8	81.376	90.1805	629.705	119.14	8.77087	16.7903	232.528
6752.97	46.4647	92.5672	445.903	141.754	6.90442	8.12372	216.921
14068.7	19.2564	111.526	1565.48	368.55	12.0075	42.5441	188.215
10016.4	65.556	65.0888	340.081	86.1347	9.04603	16.2857	293.881
82925.9	49.8317	124.511	744.887	214.732	14.2267	12.4448	335.295
7480.74	72.5353	75.2651	412.435	111.531	8.4192	17.5663	263.98
30742.9	53.3851	129.618	1115.97	314.148	23.4611	20.5986	313.687
28885.7	144.524	104.156	1927.88	298.931	12.2564	81.1185	418.524
22556.1	73.0836	68.279	1478.16	239.349	9.20667	27.5581	520.515
21698.4	65.8741	63.6772	1540.11	261.655	6.93521	24.5815	493.388
21576.7	55.8452	60.2155	1503.33	264.059	6.55612	29.9705	448.846
26360.2	110.304	81.8857	1717.11	279.821	8.90761	30.2452	627.252
19188.1	118.884	83.4399	1310.43	202.949	7.90403	100.471	464.439

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
16840.3	61.5282	96.6751	1726.32	357.159	6.67819	32.039	455.658
16544.2	50.1851	82.6424	1654.32	327.71	6.01491	45.1588	449.945
18225.6	85.0537	69.5392	1590.12	290.168	7.18881	31.7073	496.235
35104.9	73.6257	101.301	872.773	262.462	30.4217	16.4792	316.514
28977.5	47.9067	91.3249	814.168	250.256	25.231	15.8298	246.156
27938.4	47.6591	110.946	806.818	288.16	20.6934	34.6174	338.135
31878.7	49.6696	116.073	1073.9	355.132	14.927	26.5232	285.391
20469.5	36.5791	114.73	1204.48	355.237	15.4427	34.5493	256.637
28837.8	57.3188	95.2047	1096.17	303.036	29.9919	27.6877	296.591
23512.8	36.5136	76.7658	1014.71	259.024	25.7528	21.3236	238.371
23499	40.2794	81.7885	877.328	302.783	26.7921	56.0115	318.834
25357	36.0451	96.4391	1349.49	404.982	17.9553	55.331	291.393
30375	54.8846	96.1007	1791.79	267.771	13.2665	20.4827	272.258
27390.9	60.507	93.5117	1463.03	211.894	10.4416	18.7093	278.855
27094.5	39.9737	163.872	1239.74	170.321	11.5507	13.1291	210.241
27844.9	78.3312	158.219	1443.53	210.872	10.1395	12.2044	239.686
27413.6	47.7458	133.646	1315.11	197.876	11.571	14.3247	234.135
31024.3	40.5389	91.7447	2014.25	310.128	12.7126	26.5868	264.158
23547.9	43.1401	72.8158	1571.31	241.224	9.37296	28.0073	294.815
24817.6	29.6124	86.3133	1314.14	182.619	10.1979	17.4901	221.115
25290.1	68.8586	114.746	1602.35	263.294	11.0167	27.6461	300.043
26588	47.1321	78.0324	1553.15	209.591	11.7274	15.3359	264.368
18803.5	73.7475	107.554	1387.44	232.916	27.6422	48.0365	330.033
23068.8	44.0849	103.627	1734	293.347	28.3264	57.3194	237.559
24174.7	46.0925	79.896	1667.63	293.627	14.6405	50.1299	277.253
22694.1	42.4337	93.5915	1602.51	276.553	22.9189	76.5203	302.939
21166.3	37.7334	55.4293	1591.33	267.649	17.9036	47.6984	248.926
15656.6	51.5649	80.4373	1393.52	270.631	37.3162	88.2316	311.807
24197.8	49.154	88.9073	1742.61	298.23	20.9652	63.6272	263.685
17915.8	43.632	58.714	1762.94	295.19	17.9834	69.8791	310.937
22551.4	59.3445	72.5157	1822.79	311.723	25.5262	79.0388	384.17
13422.6	22.1244	43.2485	1479.46	272.427	12.5125	54.6985	280.41
22721.5	46.1283	79.3661	899.217	110.664	10.7187	20.383	250.424
22726.9	60.6075	66.6809	598.451	87.4387	11.3498	18.7324	247.346
27042.8	68.57	103.373	699.852	86.3883	12.7431	20.8252	236.171

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
18633.9	50.3252	112.227	404.264	54.2727	10.6879	9.7226	230.088
20013.3	43.8395	74.1532	665.23	87.936	10.6844	18.7308	212.19
15412.3	32.0943	52.3586	790.37	85.8729	10.9703	26.1977	253.408
13203.6	28.6151	52.1574	601.955	85.5469	8.56219	24.0251	230.257
15685.3	41.2544	72.2624	659.376	81.7706	9.37442	17.9983	220.646
11135.7	19.6278	84.3323	440.069	50.7849	7.00678	10.1778	205.195
14802.3	29.5878	55.2058	704.843	81.2417	10.1367	21.3603	216.501
19644	54.0186	92.3935	417.605	58.2764	13.0178	10.5134	263.223
18417	42.2222	62.7083	656.547	89.6092	9.12891	12.4874	215.027
23991.3	72.7442	52.0704	679.004	83.4429	10.7399	17.6857	276.341
24289.5	52.7782	58.1522	462.165	68.7013	14.3423	14.8733	278.927
16031.8	30.7495	66.3729	643.383	95.5734	8.25573	16.4101	194.326
13989	23.288	63.6638	414.922	45.1748	12.8621	11.4051	269.438
12607.6	24.1457	42.083	621.329	74.2379	14.0815	15.5267	211.597
15905.4	49.9652	32.426	675.766	72.7652	13.7444	23.2133	314.701
17606.1	35.3329	35.8222	500.775	47.0694	15.3556	17.4225	267.987
13427.1	21.1026	36.1003	529.492	69.3548	13.5175	17.9537	207.621
20629.8	187.589	166.549	1080.8	144.029	17.6191	86.0501	601.811
24503.1	235.822	228.859	1213.17	156.99	26.3716	93.5261	531.21
23377	262.39	195.261	1313.29	159.739	15.7034	68.3964	522.132
21781.2	228.337	162.44	1067.19	162.889	19.2044	99.755	550.128
24267.7	199.53	145.592	1075.36	143.629	17.8994	85.0018	498.212
17793.2	114.694	150.767	1229.48	172.313	21.481	88.7437	553.104
21987.2	161.862	180.351	1271.67	157.676	14.8467	53.2812	487.401
19742.2	153.358	149.323	1334.03	160.243	14.2167	67.593	445.099
21197.1	197.457	136.767	1139.29	154.065	26.4173	103.375	587.648
16843.7	139.882	133.78	1116.56	143.127	16.3743	83.4358	505.255
22277.5	244.304	197.543	1247.25	175.702	15.619	72.9633	638.343
23486.6	242.387	228.284	1135.98	177.532	19.5103	87.4186	535.583
18623.7	216.981	164.918	1112.84	161.095	13.1766	70.8707	513.624
21009.1	188.353	115.856	1080.92	150.014	21.7579	116.288	465.562
25261.9	192.076	158.062	1258.64	173.161	18.1924	89.4491	506.043
13851.3	142.699	131.841	1013.94	141.967	14.4565	84.3677	570.482
17446.4	165.739	196.126	954.696	180.389	24.0101	65.0569	592.244
16751.5	115.778	120.167	1187.38	186.947	14.0753	63.8753	429.267

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

SOM (kg/ha)	P (kg ha-1)	K (kg ha-1)	Ca (kg ha-1)	Mg (kg ha-1)	S (kg ha-1)	Na (kg ha-1)	Fe (kg ha-1)
20358.7	114.084	111.259	1336.46	193.621	16.2377	83.385	475.222
24656.6	117.765	157.159	1798.54	242.728	18.0424	84.7012	448.082

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
151.229	4.92202	1.94425	0.36398	12028.5	1307.88	0.82431	0.08963
154.423	7.20114	1.9941	0.29623	10912.2	1161.25	0.62413	0.06642
155.72	5.61814	2.28354	0.35113	9448.56	1102.45	0.61424	0.07167
118.257	3.40376	1.70503	0.25862	10891.7	1219.44	0.67881	0.076
152.869	5.92961	1.86448	0.42679	9448.79	1088.73	0.51082	0.05886
237.318	1.52135	2.43506	0.32483	7153.19	873.99	0.42927	0.05245
93.523	1.7283	1.78601	0.2272	10175.6	1222.2	0.55549	0.06672
95.2501	0.74752	1.28886	0.21989	7112.31	892.324	0.51398	0.06449
260.403	2.49946	1.99416	0.2451	7872.61	970.811	0.49734	0.06133
269.68	1.26513	1.1472	0.20931	11507	1273.88	0.8832	0.09777
126.034	0.81703	1.37285	0.2994	12426.6	1430.95	0.92539	0.10656
122.533	0.94208	1.12248	0.33193	14659.8	1519.77	0.86736	0.08992
115.601	0.6993	1.13488	0.25449	11728.4	1376.68	0.81132	0.09523
143.315	1.39116	1.23326	0.29851	10500.1	1284.85	0.7239	0.08858
170.014	0.84683	1.47432	0.32035	12629.9	1525.17	0.9112	0.11003
50.2526	1.58288	0.89733	0.31627	3743.72	721.479	0.24728	0.04765
43.5575	1.22388	0.95166	0.77929	4368.93	736.566	0.25118	0.04235
59.6619	1.17624	1.08488	0.44386	2905.68	587.91	0.22868	0.04627
46.7929	1.63786	0.98588	0.55194	5334.59	855.034	0.33891	0.05432
26.8128	1.10167	1.04351	0.49388	2371.51	616.199	0.15081	0.03918
232.602	79.0819	0.53759	2.0293	12740.7	1327.19	0.55873	0.0582
203.301	555.959	0.58166	1.43962	15138.5	1527.9	0.88324	0.08914
204.613	176.058	0.68263	2.05702	8309.17	951.334	0.39181	0.04486
411.288	105.624	1.84112	2.07621	11657.8	1254.99	0.45578	0.04907
274.967	84.2763	0.86695	2.26572	13862	1357.27	0.79138	0.07749
423.175	218.254	1.15905	2.52574	7299.48	885.458	0.43031	0.0522
175.921	273.329	0.35738	1.84078	10807.1	1206.78	0.57259	0.06394
178.195	181.202	0.47995	1.95337	6598.91	831.084	0.36489	0.04596
124.607	177.741	0.50606	1.7319	8211.54	956.958	0.4179	0.0487

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
192.534	333.706	3.37381	1.95378	6606.59	787.613	0.38125	0.04545
241.833	134.187	5.44114	1.64111	9978.44	1094.95	0.58374	0.06405
154.977	85.1812	2.79414	1.08209	16796.4	1350.12	1.33257	0.10711
168.962	112.798	3.3629	0.93498	13250.6	1382	1.19214	0.12434
202.359	125.544	2.91496	1.22801	13651.3	1293.84	1.18515	0.11233
190.934	161.609	3.36239	1.02655	14311.5	1458.33	1.19193	0.12146
341.284	93.0152	4.13191	1.44477	8322.77	894.038	0.55907	0.06006
297.773	73.338	4.68914	1.61667	11263	1189.28	0.58984	0.06228
236.265	60.4281	2.4219	1.418	6270.38	779.033	0.29453	0.03659
277.214	91.8158	3.35731	1.47849	9799.67	992.323	0.57544	0.05827
289.449	65.6116	2.83311	1.16329	10248.8	1110.45	0.62042	0.06722
377.751	110.187	5.69344	2.4593	15111.8	1534.99	1.26619	0.12861
340.108	31.7621	4.42508	0.93938	12370	1323.89	1.71508	0.18356
267.527	41.3408	3.04401	2.25272	16273	1656.48	1.22016	0.1242
294.319	31.593	3.83943	1.76288	15871.3	1659	1.41893	0.14832
309.303	51.9743	5.02882	1.49005	19434.5	1922.66	2.02572	0.20041
339.167	160.887	3.48554	3.88827	5513.69	857.995	0.20309	0.0316
296.69	100.975	2.8381	4.21551	6001.7	867.934	0.25453	0.03681
424.522	72.5788	3.89493	4.58174	8281.71	1040.59	0.26446	0.03323
379.09	87.5098	4.13474	4.89724	12924.8	1373.6	0.44036	0.0468
328.706	72.1669	4.17291	4.90068	8425.8	1041.53	0.26257	0.03246
346.744	1.76677	1.98437	0.70073	15219.1	1591.95	0.70426	0.07367
410.402	2.2203	1.85167	0.44745	13251.6	1474.34	0.77991	0.08677
471.205	3.33913	2.14939	0.41463	12940.8	1472.1	0.69349	0.07889
341.549	1.96568	1.79473	0.51715	7750.67	1103.13	0.43191	0.06147
350.649	2.27128	1.84946	0.88296	10896.4	1287.26	0.64226	0.07587
262.106	1.27465	1.58585	0.6516	6651.1	840.916	0.34542	0.04367
191.28	0.46375	1.58502	0.66968	4498.98	708.137	0.28975	0.04561
282.616	1.17138	1.60835	0.78837	8222.91	988.278	0.50012	0.06011
374.024	1.43386	1.87399	0.55218	4004.61	685.936	0.24499	0.04196
322.74	0.94111	1.73824	0.83177	5711.79	836.041	0.28848	0.04223
170.296	20.3797	2.96826	1.76871	25675	2328.23	0.86637	0.07856
259.579	2.71072	1.23696	1.00678	6792.86	828.069	0.31908	0.0389
270.675	0.80039	0.68099	0.3963	6748.26	803.682	0.45692	0.05442
272.039	3.0508	1.24388	0.4207	11132.9	1176.52	0.49572	0.05239

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
170.227	3.8577	1.47951	0.55239	8932.1	1005.7	0.36554	0.04116
280.288	0.78496	0.88683	0.49561	8137.19	1032	0.33896	0.04299
325.216	1.2628	1.17206	0.51942	4625.02	721.321	0.18303	0.02855
107.277	1.07534	0.89702	0.37635	4405.38	664.698	0.20046	0.03025
342.917	0.85763	1.31322	0.47791	5428.78	836.302	0.22313	0.03437
340.467	1.15595	1.33229	0.51546	5684.38	832.972	0.21834	0.032
397.267	3.05476	1.78332	0.07582	11737.5	1278.01	0.53671	0.05844
462.885	3.42955	1.89581	0.10996	18787.2	1795.42	0.81635	0.07802
430.912	3.21613	1.65975	0.12892	15314.6	1457.24	0.71663	0.06819
472.741	1.49931	1.32336	0.04068	14831.9	1538.76	0.77104	0.07999
513.066	2.77753	1.77509	0.08468	13151.3	1359.63	0.67751	0.07004
380.668	4.26253	2.10834	0.10617	8396.7	1069.23	0.42395	0.05399
453.162	3.97753	1.71012	0.15827	11340.7	1251.97	0.59735	0.06595
311.154	2.80469	1.43704	0.14381	11443.2	1252.92	0.57784	0.06327
326.176	2.97644	1.71302	0.0795	10256.5	1176.61	0.56875	0.06525
379.104	2.38717	1.49061	0.1154	8213.3	1030.58	0.48339	0.06065
474.322	2.82594	2.81195	0.09881	20394.4	1971.79	1.26774	0.12257
403.597	2.64536	2.76811	0.16169	8593.58	1087.27	0.54416	0.06885
373.142	2.86745	3.11971	0.08209	16194.3	1676.15	1.04739	0.10841
169.264	1.2236	1.47518	0.0772	11520.3	1337.58	1.20289	0.13966
423.406	4.10779	4.71161	0.14688	11929.4	1307.46	0.66471	0.07285
252.941	2.11087	1.66871	0.09926	8206.19	952.033	0.56047	0.06502
224.229	1.82767	1.55763	0.07788	3379.78	624.417	0.2143	0.03959
332.538	2.77444	2.78244	0.09777	6984.83	962.367	0.37643	0.05186
140.223	0.93228	0.96638	0.07944	5117.45	847.854	0.48565	0.08046
229.926	1.8487	2.30637	0.0808	5548.65	857.933	0.52983	0.08192
147.019	1.87729	2.14351	0.19954	19840.3	1949	0.97516	0.09579
151.172	4.35497	2.42539	0.27486	21688.1	2186.41	1.06504	0.10737
167.367	5.14365	2.28334	0.24458	21693.1	2076.75	1.14219	0.10935
83.3462	2.37723	1.78218	0.10546	23774.7	2238.62	1.40082	0.1319
230.652	5.26566	3.73993	0.71173	18534	1933.2	0.9426	0.09832
113.59	5.44336	4.80621	0.77452	13026.1	1485.32	0.35745	0.04076
154.499	7.12607	4.63293	0.79236	10817.2	1347.21	0.29178	0.03634
156.639	6.18478	4.82161	0.84459	14742.1	1686.89	0.40357	0.04618
140.173	6.87509	5.16241	0.88539	13515.6	1552.87	0.36285	0.04169

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
127.069	6.4963	4.85702	0.83743	13966.7	1606.3	0.34588	0.03978
231.108	0.71124	1.01112	0.07332	12330.8	1570.34	0.87868	0.1119
211.95	1.67417	1.50588	0.06397	9560.71	1154.96	0.47769	0.05771
291.604	1.61784	1.49977	0.07353	14866.8	1517.43	0.82002	0.0837
248.138	1.46292	1.61494	0.06879	10829.3	1298.16	0.52432	0.06285
218.819	1.67258	1.74377	0.07075	12112.3	1399.55	0.56132	0.06486
75.8233	1.51283	1.29912	0.06805	6961.27	1080.2	0.38941	0.06043
137.715	1.7593	1.38235	0.07287	5268.84	955.201	0.26292	0.04766
159.639	2.2343	1.60927	0.07134	7631.09	1041.61	0.33069	0.04514
167.857	2.03864	1.40345	0.06851	6309.04	994.001	0.32223	0.05077
82.6495	1.83761	4.71697	0.07443	6594.39	1005.47	0.34445	0.05252
269.536	3.35322	1.06108	0.16149	11231.5	1512.11	0.86609	0.1166
341.446	3.4097	1.06477	0.5956	10239.7	1349.98	0.73949	0.09749
168.555	1.33214	0.73999	0.09442	11923.2	1503.78	0.96108	0.12121
272.664	2.76869	1.06843	0.14551	10318.4	1333.58	0.66495	0.08594
236.243	2.59583	0.85791	0.10036	8968.23	1125.81	0.76801	0.09641
182.216	4.11719	1.26784	0.11472	8734.41	1314.04	0.52564	0.07908
207.14	2.65271	1.0448	0.09215	4510.84	956.968	0.23956	0.05082
114.264	3.77693	1.29705	0.08219	6918.77	1165.58	0.42305	0.07127
137.355	4.74896	1.07376	0.05294	4159.44	924.319	0.25436	0.05652
121.05	4.18149	1.22458	0.06978	6215.59	1022.67	0.37347	0.06145
30.868	5.54494	2.01087	0.07005	16137.7	1704.2	0.85837	0.09065
204.773	1.22437	1.27819	0.07082	12806.3	1483.3	0.86165	0.0998
133.707	2.92031	1.87795	0.07316	12694.1	1547.02	0.60805	0.0741
86.169	1.73557	1.1462	0.07428	17070.2	1766.44	1.04641	0.10828
132.847	1.87653	0.97411	0.07331	14902.4	1648.87	0.73977	0.08185
80.1984	4.78604	2.59065	0.08161	15393.6	1697.66	0.64991	0.07167
96.2225	5.06327	2.71414	0.08098	10668.8	1339.2	0.51114	0.06416
71.5818	5.52881	2.40721	0.07249	5257.67	914.553	0.2353	0.04093
88.1409	4.9503	2.43952	0.10636	11618.7	1388.79	0.53959	0.0645
76.4538	4.67339	2.12042	0.06645	13969.1	1505.42	0.59555	0.06418
94.1984	1.26455	5.78004	1.65045	14840.7	1659.45	0.49438	0.05528
94.8979	0.98955	5.57891	2.06175	14136.1	1611.96	0.33876	0.03863
78.4685	0.97973	4.48644	1.63324	12075.3	1469.27	0.34401	0.04186
76.9578	1.05708	4.56759	1.6931	14811.3	1610.09	0.4402	0.04785

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
47.5538	0.9919	4.11877	1.65774	13481	1537.19	0.35642	0.04064
78.4417	1.5608	4.91268	1.65485	10513.8	1408.49	0.29807	0.03993
138.513	8.64679	1.49844	0.45026	11929	1340.69	0.7172	0.08061
161.687	8.50812	1.80715	0.44168	11049.7	1375.25	0.60694	0.07554
142.226	7.31428	1.69211	0.4855	9470.95	1229.23	0.57729	0.07493
115.892	4.74614	1.2598	0.33279	11321.8	1312.26	0.64144	0.07435
176.797	7.49588	1.78023	0.39432	16031.9	1782.28	0.8499	0.09448
123.087	9.61561	3.25321	0.33159	11575.5	1513.21	0.4316	0.05642
67.7291	6.03483	2.08067	0.27452	11264.6	1320.41	0.40375	0.04733
47.11	2.73002	2.10823	0.27707	10146.3	1396.19	0.40888	0.05626
89.9036	3.46184	2.41936	0.25771	15990.6	1583.01	0.62902	0.06227
93.8748	2.73665	1.94459	0.23026	9947.84	1366.15	0.39159	0.05378
103.717	1.48459	1.11509	0.64008	10851.5	1320.36	0.50979	0.06203
101.56	1.33874	0.91963	0.59158	9408.09	1186.73	0.43838	0.0553
105.252	1.00134	0.87431	0.35309	6828.39	1012.64	0.37104	0.05502
131.473	1.0397	1.16608	0.40964	7675.46	1076.15	0.40024	0.05612
129.374	1.45746	0.98267	0.55484	11516.1	1489.5	0.53344	0.06899
64.8451	2.26968	0.68439	0.29111	9976.55	1231.03	0.63874	0.07882
35.2992	2.19373	0.61654	0.46629	11030.2	1192.43	0.52588	0.05685
38.8099	1.98419	0.67893	0.4463	12118.8	1361.37	0.68334	0.07676
34.872	1.59578	0.495	0.32777	7897.17	898.844	0.53263	0.06062
35.1137	1.74761	0.67375	0.4459	6995.36	938.437	0.40456	0.05427
159.276	2.9621	2.34489	0.47427	8015.05	1114.6	0.27225	0.03786
242.882	1.92454	1.74284	0.38657	10580.6	1318.1	0.3989	0.04969
167.66	1.40354	1.90587	0.31534	6906.42	998.332	0.28271	0.04087
171.936	1.70107	1.89427	0.37111	6903.87	1021.69	0.28509	0.04219
325.566	94.4235	2.01103	1.77446	9178.91	992.527	0.34663	0.03748
400.817	164.004	3.65928	2.92148	8977.77	1059.53	0.32929	0.03886
225.646	146.472	1.16125	1.74028	10557.5	1139.44	0.46088	0.04974
210.43	138.208	1.48128	1.97288	5324.06	715.374	0.21641	0.02908
125.68	130.232	1.3634	1.72772	9193.5	1097.81	0.45684	0.05455
179.574	188.368	1.42275	1.93942	6405.6	806.866	0.32137	0.04048
240.712	181.647	13.5701	2.87567	6424.94	792.749	0.18299	0.02258
160.08	91.715	4.7419	1.20309	6738.91	816.991	0.62291	0.07552
177.703	111.561	4.11662	1.02602	3997.38	620.261	0.31225	0.04845

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
210.191	95.1566	6.50394	1.41911	6381.13	825.136	0.53093	0.06865
187.229	127.538	5.70754	1.21613	6752.89	804.032	0.42376	0.05046
323.778	92.7772	5.15465	1.60954	7094.77	805.633	0.39103	0.0444
244.805	78.61	9.92444	2.6396	7964.12	797.636	0.35493	0.03555
226.292	85.2114	4.21175	1.6143	3568.54	514.103	0.16652	0.02399
238.953	100.515	7.83233	2.06354	6093.79	678.878	0.29716	0.03311
238.944	71.2556	4.90343	1.79005	6944.92	647.707	0.40787	0.03804
348.229	85.6011	8.6284	2.21839	7759.57	829.698	0.29842	0.03191
356.629	50.9985	4.7509	0.88013	7570.28	861.383	0.60892	0.06929
290.408	63.7183	5.09413	1.94608	3959.15	651.745	0.17607	0.02898
485.361	70.8637	6.17578	1.82431	3737.84	551.764	0.16958	0.02503
349.596	65.8935	7.57968	1.81365	13894.5	1634.08	0.75087	0.08831
253.061	123.086	3.84886	2.96439	12365.1	1361.37	0.44287	0.04876
242.216	70.429	3.26138	2.58381	10420.4	1147.81	0.38075	0.04194
237.35	37.2973	2.94262	2.84913	10068.3	1030.83	0.39476	0.04042
240.18	57.0224	3.31286	3.19411	12228.3	1350.71	0.40597	0.04484
264.218	66.1772	3.57524	3.27136	6383.85	831.225	0.21776	0.02835
223.993	335.781	2.44471	1.60054	9281.51	1058.96	0.40085	0.04573
438.096	2.4965	1.59547	0.50677	8075.28	936.861	0.40666	0.04718
500.425	3.549	2.0087	0.6235	6973.09	934.779	0.29791	0.03994
310.191	2.06403	1.45662	0.49808	9304.16	982.319	0.40994	0.04328
399.177	2.92402	1.79833	1.03248	23002.2	2219.11	0.84046	0.08108
357.5	2.30236	1.89865	0.68835	23456.8	2324.55	0.92875	0.09204
356.879	2.17302	1.4991	0.7145	20494.2	1933.7	1.0979	0.10359
351.347	1.77099	1.49889	0.85608	18311.3	1926.05	0.90204	0.09488
460.582	3.31147	1.61923	0.82374	22502.7	2163.52	1.09993	0.10575
371.242	1.8905	1.45109	0.89958	12856.1	1362.31	0.67737	0.07178
160.276	15.054	2.61557	1.64241	13437.3	1489.61	0.41603	0.04612
174.867	3.10917	1.27073	1.10154	14093.7	1546.4	0.59621	0.06542
167.337	1.95664	1.02952	0.82493	14242.2	1512.83	0.59345	0.06304
184.407	3.9367	1.38962	0.61747	15095.8	1633.4	0.58876	0.0637
168.245	3.21468	1.30148	0.56167	10174.6	1363.35	0.39866	0.05342
173.744	1.65502	0.83742	0.64722	13396.1	1578.83	0.49518	0.05836
246.609	1.57949	1.14679	0.61639	12419.5	1515.09	0.47983	0.05854
127.932	1.38741	0.83094	0.38185	14654.9	1619.14	0.6396	0.07067

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
285.275	1.38474	1.34744	0.51563	15258.3	1627.55	0.56782	0.06057
259.533	1.29249	1.3625	0.58394	3702.52	825.501	0.14178	0.03161
353.043	3.50366	1.71468	0.14072	9879.38	1373.27	0.44418	0.06174
482.834	3.30167	1.72707	0.21668	7502.31	1099.94	0.31482	0.04616
438.947	3.95844	1.6367	0.16723	10739.2	1305.26	0.46746	0.05682
472.261	2.52895	1.38424	0.11495	11869.1	1557.87	0.49896	0.06549
385.5	2.63304	1.27801	0.14198	13127.5	1402.76	0.49011	0.05237
338.121	5.23889	2.03806	0.15876	14547.4	1493.06	0.5996	0.06154
384.859	4.05482	1.56514	0.11072	16266.8	1684.18	0.82771	0.0857
276.657	4.47489	1.34236	0.12501	14018.1	1473.34	0.64431	0.06772
329.565	3.85223	1.37336	0.10816	15224.6	1578.21	0.67441	0.06991
374.418	4.07219	1.43297	0.1313	9461.86	1235.2	0.4194	0.05475
371.526	3.56097	2.54706	0.12329	10880.5	1341.5	0.65673	0.08097
384.728	3.77487	2.85785	0.25982	13411.4	1534.5	0.75767	0.08669
371.029	4.43124	3.05135	0.16074	12724	1403.19	0.76547	0.08442
157.176	1.58009	1.20296	0.07397	10169	1241.37	0.89892	0.10973
380.562	4.1869	3.86718	0.21563	11777.5	1273.78	0.68735	0.07434
229.49	3.23067	1.7439	0.13323	14746.3	1571.92	0.52641	0.05611
241.506	2.86323	1.92066	0.07155	10123.9	1153.93	0.59449	0.06776
336.861	3.81184	2.59951	0.1699	12067.5	1302.57	0.5449	0.05882
143.158	2.22084	1.13127	0.07414	10549.3	1249.58	0.67635	0.08011
236.797	2.73251	1.72771	0.07389	5768.98	917.609	0.38028	0.06049
148.888	13.0708	4.73537	0.4688	5855.18	902.967	0.20776	0.03204
129.083	13.6971	4.25776	0.27568	5154.1	751.779	0.20296	0.0296
179.742	14.0891	3.34963	0.48064	7121.18	1010.34	0.27771	0.0394
103.018	7.91841	2.24485	0.22884	5142.08	776.31	0.19903	0.03005
141.87	8.99531	3.29623	0.46081	10321.5	1215.56	0.3709	0.04368
171.332	6.29852	4.21218	0.85413	13395.7	1308.41	0.31565	0.03083
167.994	5.99614	3.81444	0.68381	10618.8	1095.56	0.26415	0.02725
169.992	6.47356	4.21265	0.75095	10099.5	1091.4	0.23808	0.02573
154.63	5.85619	4.16783	0.77172	9756.83	1123.84	0.25625	0.02952
170.918	5.5901	4.03139	0.76447	7685.91	864.867	0.17738	0.01996
171.731	1.73549	1.49236	0.06115	8684.45	968.398	0.44297	0.0494
159.671	1.67446	1.28535	0.04529	5596.53	628.999	0.32352	0.03636
219.705	2.76148	1.5356	0.07018	10499.5	1035.39	0.56232	0.05545

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
182.061	2.67755	1.65851	0.11917	6238.38	833.992	0.2983	0.03988
180.379	2.66216	1.90075	0.15867	8843.44	1032.93	0.21049	0.02459
65.2459	1.80722	1.03223	0.05745	7011.61	910.789	0.34125	0.04433
90.6937	1.92507	0.92279	0.05171	8879.69	939.306	0.48829	0.05165
98.507	2.39147	1.11009	0.07329	7596.6	940.971	0.33669	0.0417
115.18	1.9479	1.07443	0.05457	7730.31	898.962	0.41619	0.0484
75.6207	1.97069	1.15404	0.08887	7692.58	1029.39	0.36196	0.04844
220.557	3.20916	0.79479	0.13972	6247.97	1025.77	0.36635	0.06015
258.775	3.45014	0.76851	0.20352	9688.89	1129.06	0.39714	0.04628
204.009	2.38636	0.65867	0.13358	7384.39	1077.05	0.36776	0.05364
227.015	2.87363	0.78033	0.15117	9524.84	1242.88	0.4822	0.06292
239.095	2.82617	0.61441	0.13037	15733.6	1386.75	0.88201	0.07774
163.263	3.86851	0.9384	0.11905	16239	1373.68	0.81499	0.06894
197.512	3.02129	0.87932	0.13198	14476.1	1351.52	0.56866	0.05309
124.428	3.52118	0.94562	0.07631	14669.1	1320.48	0.77103	0.06941
128.071	4.43033	0.93811	0.06215	15308.3	1435.54	0.77511	0.07269
161.418	5.13161	1.28498	0.11279	11986.7	1114	0.63516	0.05903
48.6791	4.72431	1.65374	0.0648	10404.5	937.829	0.52633	0.04744
67.3646	2.64525	1.405	0.07513	12542.7	1251.27	0.65997	0.06584
84.988	2.40854	0.94566	0.04907	9159.79	832.629	0.53414	0.04855
98.5125	2.83153	1.09011	0.06965	13866	1286.57	0.63512	0.05893
114.38	2.15632	0.87712	0.06779	19251.8	1724.28	0.96813	0.08671
63.4355	3.8525	1.62203	0.12599	14347.2	1155.05	0.68026	0.05477
85.3326	4.51263	1.99027	0.09915	16619.9	1521.24	0.69074	0.06322
70.3551	4.86631	2.00301	0.12345	17065.6	1677.93	0.6131	0.06028
95.0614	3.99023	1.67151	0.15058	16812.3	1670.16	0.8174	0.0812
87.0943	5.26408	1.90165	0.17721	14700.6	1255.76	0.53871	0.04602
127.953	1.99223	4.31065	1.51362	14949.8	1497.35	0.42853	0.04292
123.029	1.56281	4.07409	1.57773	12630.1	1290.12	0.45836	0.04682
127.958	1.75086	4.71325	1.61363	19253.3	1762.91	0.59935	0.05488
165.317	2.52069	4.82942	1.71667	20722.8	1954.13	0.53753	0.05069
126.068	1.92604	4.26623	1.47682	18270.8	1771.78	0.52186	0.05061
116.36	3.58677	4.98899	1.51053	19154.1	1842.28	0.48999	0.04713
126.612	3.02737	4.71221	1.80685	16011.8	1644.27	0.42293	0.04343
119.273	4.43996	5.14507	2.55278	12604.7	1334.11	0.30414	0.03219

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
105.047	2.80156	4.92488	1.37299	13208.3	1518.32	0.33688	0.03872
103.767	2.50376	4.71422	1.44984	14053.2	1588.62	0.36647	0.04143
90.1571	9.57964	1.99987	0.44624	9099.59	1644.9	0.49692	0.08983
87.2253	8.33065	1.74906	0.45083	10856.2	1626.76	0.4701	0.07044
102.559	10.6834	2.24343	0.48015	11973.5	1732.39	0.50025	0.07238
95.9159	14.8604	1.54954	0.33923	8730.41	1538.74	0.46095	0.08124
104.929	7.69087	1.98143	0.4501	8870.35	1659.47	0.45632	0.08537
81.8418	5.43837	1.84969	0.49886	6984.47	1669.08	0.4462	0.10663
95.9756	4.72808	1.61641	0.50463	7997.6	1716.39	0.47181	0.10126
101.464	6.11301	2.05404	0.65947	8043.58	1802.5	0.44593	0.09993
99.4296	6.60206	1.77692	0.52146	7076.45	1508.9	0.42763	0.09118
97.4613	5.14842	1.71784	0.50667	7231.52	1498.22	0.41455	0.08589
111.015	5.10056	2.31563	0.37211	14694.8	2182.88	0.48632	0.07224
118.93	6.25972	2.93723	0.34386	14471.1	1743.95	0.4763	0.0574
92.4719	4.62111	2.3666	0.31085	16167.4	1906.59	0.45369	0.0535
68.4652	2.928	1.72142	0.25864	12175.5	1884.7	0.45312	0.07014
78.6669	3.01993	1.73674	0.25934	14098.6	1673.46	0.5	0.05935
88.7654	3.22652	1.77909	0.34065	13265.4	1767.9	0.5005	0.0667
84.7635	2.71447	1.75333	0.22999	12861.7	1986.17	0.44762	0.06912
64.0018	2.12176	1.9084	0.27526	11814.9	2024.74	0.39257	0.06728
40.1903	1.56962	1.1438	0.21618	9853.53	1781.91	0.43447	0.07857
286.146	11.9956	0.94591	0.61001	10912	1809.87	0.50818	0.08429
60.4536	1.98294	1.4316	0.23971	12696.8	1960.99	0.46799	0.07228
286.672	15.3671	0.9141	0.79276	10768.1	1832.28	0.52522	0.08937
161.784	11.5503	0.97698	0.55828	9847.97	1751.75	0.52284	0.093
250.215	15.0824	1.0104	0.63539	10308.2	1933.19	0.52125	0.09775
252.286	9.38395	0.8728	0.59688	10878.6	1964.28	0.57926	0.10459
296.456	4.98513	0.94827	0.45075	6250.38	1752.22	0.42535	0.11924
190.473	4.91473	0.72572	0.57209	7919.28	1805.44	0.57736	0.13163
185.803	4.61931	0.85971	0.37639	6181.24	1688.23	0.42655	0.1165
182.521	3.29752	0.91811	0.30702	5847.13	1924	0.4742	0.15604
193.026	2.83596	0.78299	0.3966	6018.98	1743.22	0.42419	0.12286
154.759	8.32581	0.77708	0.39131	6321.4	1683.78	0.4259	0.11344
163.911	10.0921	0.57211	0.42373	8221.88	1828.91	0.44282	0.0985
182.154	15.7812	0.73432	0.51858	8825.48	1998.65	0.37787	0.08557

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
138.079	12.4834	0.78908	0.40306	10108.1	1990.81	0.50074	0.09862
230.062	11.0497	0.82216	0.52816	10282.4	1985.82	0.41007	0.0792
238.627	5.34469	0.88953	0.28898	5061.46	1936.6	0.37761	0.14448
134.949	4.30753	0.66697	0.3525	6104	1747.92	0.46272	0.1325
179.723	7.77794	0.75194	0.30875	5376.61	1781.04	0.41745	0.13828
125.439	4.02039	0.9887	0.3077	5338.18	1741.5	0.43997	0.14353
248.385	3.66937	0.91734	0.41331	6703.92	1825.92	0.47194	0.12854
164.183	4.71424	1.61625	0.37548	12589.7	1539.69	0.47604	0.05822
166.679	4.26987	1.56724	0.4366	12243.7	1545.96	0.3921	0.04951
148.285	3.02068	1.22457	0.28522	10508.9	1629.73	0.43872	0.06804
144.333	3.81262	1.5641	0.35007	14807.1	1631.58	0.56515	0.06227
134.81	3.10243	1.2782	0.26677	11125.3	1576.24	0.5038	0.07138
130.73	3.4707	2.06718	0.32409	8275.34	1674.82	0.47511	0.09616
166.449	2.85149	2.25153	0.32106	6710.74	1479.69	0.43738	0.09644
141.813	2.15716	1.58117	0.18412	5743.77	1391.33	0.39803	0.09642
160.329	3.02337	1.97403	0.28083	7613.87	1550.7	0.4625	0.0942
135.126	2.2002	1.59325	0.20485	5235.02	1371.9	0.44891	0.11764
115.062	3.87741	3.88399	0.75917	14457.1	1982.83	0.41689	0.05718
88.4515	3.85746	3.51695	0.65338	15471.4	1863.37	0.41662	0.05018
108.454	4.60699	3.6679	0.81703	16903.1	2111.94	0.42947	0.05366
80.19	4.34556	4.11498	0.74842	16301	2013.64	0.34986	0.04322
130.591	4.42189	3.53606	0.68428	17202.3	1818.88	0.42155	0.04457
64.372	3.04777	4.82309	0.74702	9112.38	1487.62	0.34911	0.05699
85.4564	3.45413	4.47451	0.72844	12540	1891.56	0.39445	0.0595
85.5856	3.81374	4.12033	0.65406	12314.7	1614.49	0.40601	0.05323
84.6741	4.37993	4.96733	0.88041	13868.6	2006.19	0.39574	0.05725
89.7569	4.12648	5.31328	0.84211	13180.5	1923.78	0.39014	0.05694
327.537	4.40412	1.36048	0.3912	9005.68	1481.55	0.441	0.07255
400.862	5.89404	1.76433	0.42654	9144.24	1714.77	0.39097	0.07332
288.529	3.66077	1.24572	0.28093	8559.68	1505.98	0.51321	0.09029
317.273	3.1591	1.11919	0.27404	9767.88	1665.28	0.45996	0.07842
315.055	3.53574	1.20205	0.32674	10231.2	1786.57	0.57706	0.10077
358.562	1.99955	1.33443	0.25881	6678.26	1682.99	0.46925	0.11826
417.54	4.38658	1.56684	0.36798	8020.87	1722.58	0.50743	0.10898
296.334	2.29443	1.27425	0.24752	7516.99	1544.18	0.48581	0.0998

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
290.664	2.5851	1.09597	0.19119	6609.2	1571.43	0.52858	0.12568
348.107	1.60421	1.17171	0.26572	6108.56	1653.92	0.46132	0.1249
364.132	6.60239	1.67379	0.46129	12368.7	1827.82	0.53167	0.07857
395.584	4.5396	1.29446	0.34031	9247.02	1661.31	0.42255	0.07592
543.449	3.8156	1.70268	0.35126	9002.89	1334.16	0.51509	0.07633
435.183	4.00666	1.52779	0.29342	6975.68	1515.23	0.41277	0.08966
392.79	3.69361	1.4015	0.37834	10055.9	1520.86	0.55377	0.08375
349.715	4.90315	1.51172	0.35741	9258.11	1504.43	0.34075	0.05537
458.991	3.93456	1.40908	0.2684	8013.82	1449.02	0.47221	0.08538
568.498	1.61464	1.25342	0.31098	5099.39	1272.63	0.43845	0.10942
427.084	5.72974	1.58542	0.26403	8802.15	1505.55	0.50926	0.08711
378.774	3.68004	1.28399	0.25513	7946.33	1504.48	0.38114	0.07216
129.83	3.98655	1.77765	0.52803	13064.1	1643.66	0.58668	0.07381
126.303	3.83888	1.36064	0.41001	11374.5	1518.71	0.40869	0.05457
125.014	2.93487	1.22753	0.40021	11724.7	1462.47	0.61879	0.07718
120.036	2.75022	1.39001	0.4542	12213.9	1497.06	0.52783	0.0647
115.02	3.31923	1.26045	0.44595	11395.3	1541.34	0.48279	0.0653
127.682	2.44864	1.97917	0.60497	11397.1	1567.92	0.48099	0.06617
118.458	3.69815	1.75485	0.50785	10267.2	1427.77	0.36802	0.05118
117.077	1.98748	1.68305	0.4121	7467.94	1306.99	0.53517	0.09366
116.516	2.18997	1.55583	0.51233	9357.81	1436.31	0.38312	0.0588
133.362	2.26796	1.59927	0.51105	9840.3	1316.56	0.60094	0.0804
153.128	2.9853	1.98401	0.34284	7396.75	1232.46	0.44537	0.07421
139.198	3.45491	2.23208	0.3425	8711.27	1409.69	0.46415	0.07511
102.511	5.7204	2.16213	0.4201	10012.3	1338.46	0.42201	0.05642
110.588	4.33946	2.29315	0.31147	8604.34	1228.9	0.38363	0.05479
130.54	4.8399	2.4816	0.3607	10542.6	1520.15	0.47588	0.06862
200.876	2.41301	2.14888	0.34775	7593.88	1374.4	0.3975	0.07194
129.944	3.09104	2.17513	0.31324	7869.46	1243.48	0.3541	0.05595
112.332	5.99718	2.31684	0.51028	11386.3	1570.84	0.35921	0.04956
127.802	3.75552	2.66109	0.36042	8522.05	1530.2	0.38079	0.06837
150.356	4.8853	2.86399	0.46863	10760.7	1484.09	0.40013	0.05519
169.247	13.7517	3.33398	0.49077	17164.7	1591.55	0.43819	0.04063
144.14	10.0029	2.30079	0.40352	13891.7	1602.48	0.46756	0.05394
165.911	9.53434	3.51757	0.52523	16984.5	1616.4	0.46223	0.04399

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
164.054	9.06155	3.35998	0.49692	17943	1852.21	0.43415	0.04482
154.795	11.7813	3.39845	0.5657	19984.9	1873.22	0.42281	0.03963
116.524	4.48623	2.89153	0.52087	14685.3	1762.38	0.44706	0.05365
118.219	2.14459	2.51143	0.46247	10499.4	1621.24	0.23415	0.03616
138.139	2.96861	3.58091	0.68049	13542.2	1672.55	0.42658	0.05269
145.85	2.15958	3.30563	0.65177	13737.2	1644.37	0.41369	0.04952
118.032	4.58093	3.71231	0.70464	16267.6	1923.65	0.45128	0.05336
180.089	8.40209	5.5294	0.88152	19777.7	1862.2	0.42437	0.03996
148.907	5.192	3.53358	0.80973	19005.9	1783.74	0.41854	0.03928
160.98	7.45382	5.79416	0.97824	20641.9	1768.49	0.44737	0.03833
153.678	4.79909	4.18705	0.93635	18787.1	1908.69	0.42805	0.04349
158.07	5.64939	4.63853	0.96509	17961.2	1803.18	0.41747	0.04191
128.061	6.46475	4.71078	0.89592	14025.7	1646.32	0.38421	0.0451
99.6266	4.29645	4.41155	1.03585	14544.6	1427.85	0.37726	0.03704
113.025	5.91519	4.89549	1.01971	15183.8	1868.05	0.37343	0.04594
112.226	2.76867	4.15535	0.97442	13075.3	1597.87	0.3591	0.04388
102.076	3.17277	4.11095	0.94057	12140	1566.52	0.32135	0.04147
61.0722	1.28202	0.86289	0.23876	13281.1	1516.84	0.4485	0.05122
90.2416	1.05534	1.03186	0.23109	13234.7	1671.73	0.49543	0.06258
95.517	1.60427	0.96635	0.3297	13068.2	1558.49	0.4438	0.05293
70.6079	1.81607	0.8685	0.27797	12392.9	1599.13	0.43361	0.05595
96.3841	0.99233	1.0243	0.26315	11545.3	1377.85	0.45601	0.05442
172.828	0.95148	0.85176	0.19944	11142.8	1595.35	0.46187	0.06613
151.353	1.08893	1.08077	0.22159	11102.2	1520.27	0.43102	0.05902
228.572	1.03467	1.1751	0.24935	11029.2	1531.56	0.44022	0.06113
87.9312	1.10808	0.79568	0.26013	11008	1444.74	0.44153	0.05795
139.063	1.3494	0.70214	0.31097	12034.5	1484.61	0.44775	0.05524
151.104	3.5477	0.856	0.27214	14065.1	1502.99	0.46021	0.04918
175.047	2.62807	1.03121	0.52375	11906.2	1402.62	0.46652	0.05496
152.229	2.34901	0.73551	0.62226	14922.7	1500.65	0.4698	0.04724
155.076	3.42606	1.03615	0.54223	14073.7	1501.61	0.46794	0.04993
173.699	2.79833	1.0127	0.49564	13934.5	1460.85	0.44569	0.04672
303.799	2.46335	1.3606	0.3525	11266.6	1238.86	1.27728	0.14045
370.116	1.584	1.08583	0.3341	8504.03	1449.59	0.36534	0.06228
216.326	1.76571	0.78999	0.49122	12409.9	1370.71	0.34033	0.03759

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
259.156	2.21512	1.19398	0.314	11176.1	1299.27	0.44236	0.05143
368.763	1.63683	1.15335	0.27523	9466.93	1493.08	0.38447	0.06064
71.8545	5.95116	1.33564	0.50809	10950.7	1382.32	0.41912	0.05291
58.6922	3.07707	1.21904	0.36571	11857.4	1335.33	0.44809	0.05046
55.1273	3.14446	1.7216	0.47799	12912.4	1373.76	0.47548	0.05059
73.5783	3.88365	1.72948	0.44285	11745.7	1354.41	0.4335	0.04999
40.1454	2.72	1.33602	0.419	10770.4	1256.28	0.50661	0.05909
61.5449	2.50584	1.64166	0.49279	9802.5	1364.2	0.43969	0.06119
45.0667	2.24966	1.32466	0.34034	9875.56	1483.65	0.47375	0.07117
52.4453	2.50625	1.9858	0.39896	9568.85	1487.34	0.36295	0.05642
68.1019	3.22104	2.46876	0.49345	11364.3	1439.1	0.50119	0.06347
35.4686	2.3351	1.50465	0.43011	9097.1	1331.84	0.47252	0.06918
140.011	2.8171	1.33239	0.39573	9010.33	1393.42	0.35707	0.05522
82.4276	3.05214	1.3809	0.29884	9943.31	1543.94	0.44849	0.06964
37.3686	2.79911	1.3198	0.35632	7139.89	1200.5	0.35495	0.05968
100.92	3.14746	1.33172	0.34516	10023.5	1425.13	0.49274	0.07006
60.9453	2.66312	1.43726	0.33626	9656.29	1362.93	0.46556	0.06571
180.865	2.83743	1.59497	0.51058	8712.99	1325.59	0.3755	0.05713
70.6701	2.67568	1.39653	0.31496	8661.25	1324.17	0.46073	0.07044
34.9009	2.18239	1.6875	0.33951	6156.19	1196.33	0.40977	0.07963
114.376	2.10942	1.41993	0.3031	7706.03	1183.9	0.38129	0.05858
81.6518	2.80161	1.78178	0.41522	9289.06	1268.27	0.45589	0.06224
79.6137	4.04459	2.35298	0.53568	10241.1	1157.12	0.41506	0.0469
64.9942	5.94953	2.27769	0.56942	10430.2	1210.5	0.44288	0.0514
44.4055	2.63721	1.63804	0.53487	8941.71	1232.4	0.45184	0.06228
43.368	3.02565	1.58837	0.46203	8076.05	1111.88	0.41972	0.05779
48.8723	3.22568	1.86082	0.47965	9306.32	1289.54	0.43063	0.05967
70.0408	3.6925	2.68772	0.63356	8077.24	1158.29	0.38264	0.05487
64.2442	4.56522	2.97778	0.66769	9632.95	1227.66	0.45739	0.05829
37.8431	2.52483	1.5069	0.53161	7685.45	1132.75	0.42781	0.06306
44.582	2.81981	1.9292	0.51319	7648.29	1268.25	0.43268	0.07175
43.8515	2.68274	1.6339	0.47978	8118.11	1140.68	0.4607	0.06473
83.6518	2.68772	2.50712	0.57191	92911.9	11637.8	4.22604	0.52934
43.4213	3.0221	1.56357	0.51676	10943.6	1297.27	0.39863	0.04725
61.4694	2.128	2.05475	0.52284	9924.55	1318.18	0.43354	0.05758

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
64.5114	2.31328	1.83664	0.73466	9365.67	1302.62	0.3975	0.05529
44.5528	2.05034	1.5931	0.61125	9885.56	1259.13	0.34597	0.04407
69.1626	2.36417	2.91017	0.55412	7996.33	1344.91	0.40432	0.068
42.2796	2.90781	2.38167	0.45518	6555.71	1142.99	0.38591	0.06728
52.8234	2.09401	2.46707	0.40737	7173.9	1356.75	0.43229	0.08176
41.22	1.5408	1.76112	0.24768	6345.82	1216.61	0.41234	0.07905
48.8442	2.05301	2.3571	0.44996	7989.75	1201.89	0.41126	0.06186
119.184	7.38268	3.43404	0.48585	12775.3	1357.69	0.45894	0.04877
123.996	5.1402	3.53246	0.53972	11853.8	1498.22	0.43951	0.05555
104.792	8.42172	3.64679	0.52338	14724.7	1428.96	0.47341	0.04594
91.456	6.83362	4.84904	0.74237	15610.4	1713.25	0.47495	0.05213
108.365	15.2397	5.27762	0.74184	18999.6	1569.5	0.487	0.04023
107.287	4.18865	3.76472	0.52957	9650.93	1256.48	0.44312	0.05769
119.619	2.48225	3.27757	0.73163	9078.41	1372.34	0.4135	0.06251
130.802	3.79439	3.63225	0.58656	10238.3	1294.51	0.44523	0.05629
88.1124	4.11782	4.51617	0.92022	10675.6	1409.4	0.42199	0.05571
117.228	4.84959	4.93238	0.90432	11541.2	1538.77	0.41526	0.05537
45.7761	2.24032	0.98102	0.09979	5725.81	1211.71	0.48981	0.10365
78.0578	4.43446	1.90772	0.32457	9511.57	1239.64	0.44826	0.05842
54.2908	3.62698	0.96274	0.14015	6059.95	1111.28	0.44048	0.08078
76.4934	3.2584	1.43225	0.18489	8339.84	1111.97	0.48424	0.06457
33.9996	2.39676	0.64672	0.16427	5141.48	1006.21	0.4038	0.07903
46.7151	1.49506	0.82132	0.06559	2811.12	975.13	0.41628	0.1444
75.4717	2.62176	1.87394	0.34762	6354.71	1125.24	0.45169	0.07998
50.4533	2.71665	1.15738	0.09089	3904.66	1039.17	0.38983	0.10375
96.8998	2.88978	1.75038	0.14111	5281.79	1169.14	0.06369	0.0141
33.6121	1.3993	0.69071	0.09356	3389.35	1035.22	0.45308	0.13839
300.606	2.66046	1.99445	0.18055	12781.9	1401.51	0.41577	0.04559
100.094	63.1616	3.51812	0.48406	14941.2	1339.58	0.51725	0.04638
159.449	4.71791	1.23367	0.29727	9858.93	1265.92	0.43709	0.05612
104.791	4.83188	1.64919	0.25353	10012	1215.17	0.46142	0.056
106.105	3.37188	1.49887	0.24441	9001.17	1114.51	0.41717	0.05165
94.3603	12.7396	1.70806	0.3096	11412.2	1313.77	0.43293	0.04984
83.7437	40.3337	2.65341	0.24219	10275.4	1346.23	0.53551	0.07016
214.199	3.94934	1.40256	0.1366	6418.66	1346.02	0.42035	0.08815

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
127.612	3.52881	1.76376	0.17094	6110.56	1220.01	0.36285	0.07245
112.636	2.21712	1.59111	0.15911	6172.91	1228.09	0.37312	0.07423
81.0715	9.28902	1.85147	0.22879	8087.42	1264.81	0.44374	0.0694
474.23	2.92626	2.05779	0.14113	15308.5	1440.67	0.43608	0.04104
388.96	2.59445	1.71146	0.10548	13343.2	1496.75	0.46047	0.05165
324.515	2.25931	1.43379	0.13517	13280.9	1534.33	0.47536	0.05492
275.905	2.64889	1.59123	0.11501	14232.9	1590.07	0.44647	0.04988
102.857	1.9613	1.97088	0.01232	6617.23	1478.55	0.32327	0.07223
377.193	2.79167	2.10463	0.02559	11451.9	1380.44	0.39711	0.04787
302.126	2.18034	1.95403	0.08535	8874.7	1089.87	0.37744	0.04635
315.298	1.8642	1.58074	0.05363	9722.75	1285.01	0.41375	0.05468
194.52	1.98726	1.89846	0.06593	9881.18	1502.15	0.38968	0.05924
174.906	2.55557	2.15583	0.40552	15341.5	1403.83	0.50507	0.04622
117.543	2.98859	2.19515	0.23343	13381	1426.76	0.48852	0.05209
68.7682	1.80382	1.85405	0.37735	13593.6	1487.23	0.50171	0.05489
48.1085	1.98641	1.59733	0.3715	14188.8	1310.21	0.50956	0.04705
91.151	2.36153	2.10226	0.29492	14078.8	1307.67	0.51357	0.0477
277.351	2.4413	2.38856	0.35665	13010.1	1320.34	0.41935	0.04256
116.301	3.57404	2.35896	0.16731	12002.5	1299.32	0.50971	0.05518
57.8392	1.74147	2.0863	0.3436	12375.9	1452.71	0.49867	0.05854
51.9596	1.73207	2.05192	0.3379	12640.5	1603.62	0.49982	0.06341
80.1585	2.37594	2.43305	0.33908	14376.5	1361.64	0.54072	0.05121
73.6348	2.33695	1.31148	0.6476	10547	1374.1	0.5609	0.07308
121.059	2.17858	1.52172	0.65443	13891.1	1521.14	0.60216	0.06594
126.102	2.56424	1.70277	0.56909	14037.2	1508.6	0.58066	0.0624
99.5528	2.13404	1.49383	0.84666	13711.1	1228.7	0.60417	0.05414
101.175	2.17376	1.45945	0.49751	12761.6	1257.59	0.60292	0.05941
142.688	1.80259	1.26936	0.71386	8811.07	1275.15	0.56277	0.08144
87.3662	2.14197	1.69907	0.67212	11957	1385.22	0.49414	0.05725
215.867	2.36972	1.74286	0.37329	9142.75	1248.52	0.51032	0.06969
112.312	2.39762	1.70275	0.7412	12587	1380.1	0.55815	0.0612
131.725	1.66712	1.70986	0.28213	6782.52	1133.97	0.50531	0.08448
150.283	3.67687	1.62526	0.04578	10980.5	1302.49	0.48326	0.05732
50.7778	3.38415	1.52435	0.01982	10396.5	1393.46	0.45745	0.06131
97.8289	4.17867	1.58863	0.06676	13027.4	1344.75	0.48173	0.04973

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
101.864	2.67059	1.23438	0.01098	8768.17	1381.28	0.47055	0.07413
203.343	3.97467	1.31833	0.02624	9322.21	1273.46	0.4658	0.06363
218.475	2.40408	1.27726	0.08443	7203.38	1386	0.46738	0.08993
61.2954	1.70044	1.28358	0.08247	6194.64	1408.22	0.46916	0.10665
92.9799	2.18805	1.43755	0.09105	7362.35	1317.23	0.46938	0.08398
170.77	1.13282	0.90538	0.09685	4616.44	1215.72	0.41456	0.10917
398.624	2.05918	1.20795	0.10105	6468.37	1437.3	0.43698	0.0971
164.456	3.59473	1.36669	0.09214	8646.02	1468.48	0.44014	0.07475
182.743	2.57441	1.35776	0.08785	8247.09	1279.21	0.4478	0.06946
170.57	4.63188	1.23277	0.08777	10763.6	1373.29	0.44864	0.05724
96.0435	2.94362	1.4051	0.08986	10299.5	1466.66	0.42403	0.06038
105.366	1.56653	1.14483	0.08921	7286.98	1337.54	0.45453	0.08343
376.365	1.65408	1.02627	0.09704	5993.17	1414.64	0.42842	0.10113
480.441	1.31369	0.88626	0.09864	5255.94	1424.95	0.41689	0.11302
292.228	1.86203	1.09522	0.02671	6615.71	1547.38	0.41594	0.09729
290.085	1.86278	1.24436	0.03002	7607.98	1552.08	0.43212	0.08816
285.635	0.9003	0.64804	0.00435	5191.39	1391.62	0.38664	0.10364
79.2949	6.63548	1.46354	0.22912	9502.37	1380.17	0.46061	0.0669
78.4498	8.10472	2.27156	0.26333	12127.4	1358.81	0.49493	0.05545
48.827	9.31346	2.27283	0.26554	11797.5	1410.36	0.50466	0.06033
83.5392	15.3067	1.62171	0.19906	10214.7	1478.38	0.46897	0.06787
56.7315	6.48953	2.99954	0.18241	10337	1282.83	0.42596	0.05286
198.98	2.36285	1.50882	0.11133	7084.01	1433.21	0.39813	0.08055
150.374	1.96774	2.30152	0.16619	9800.59	1435.36	0.44574	0.06528
179.694	2.42854	1.97214	0.14236	8549.6	1380.79	0.43306	0.06994
98.8891	2.18411	1.82057	0.15419	11554.4	1486.48	0.54509	0.07013
172.351	1.68581	1.8127	0.10876	7727.08	1271.99	0.45875	0.07552
64.1597	7.77377	1.25482	0.24885	11146.9	1259.18	0.50037	0.05652
93.8123	7.46429	1.33758	0.20219	10047.9	1452.21	0.42781	0.06183
69.4685	6.58238	1.74914	0.15961	9769.29	1277.3	0.52456	0.06858
100.584	6.64397	2.32448	0.1219	9845.86	1354.44	0.46865	0.06447
83.6301	7.31474	1.82406	0.17031	12633.7	1380.04	0.50011	0.05463
83.4765	1.19631	1.49858	0.05676	5977.33	1405.66	0.43154	0.10148
89.0932	1.42845	1.02551	0.05091	6563.19	1406.39	0.37619	0.08061
203.263	1.76798	1.34697	0.06994	7541.25	1392.93	0.45018	0.08315

Appendix A. (Cont.)

This appendix contains the spreadsheet of soil physical and chemical data that was inserted into the SAS program contained in Appendix C.

Mn (kg ha-1)	Zn (kg ha-1)	Cu (kg ha-1)	B (kg ha-1)	TC (kg ha-1)	TN (kg ha-1)	CfracSOM	NfracSOM
161.463	2.00827	2.03756	0.07392	9479.86	1613.45	0.46564	0.07925
219.73	3.08254	2.0555	0.11285	11198.6	1389.93	0.45418	0.05637

Appendix B.

This appendix contains the spreadsheet of soil microbiological data that was inserted into the SAS program contained in Appendix D.

Year	Region	Field	HY/AY	Rate	ShanD	ShanE	SimpD	SimpE
2014	7	1	HY	0.03716	2.88426	0.83992	13.6656	0.44083
2014	7	1	HY	0.04739	3.1459	0.91611	20.1387	0.64964
2014	7	1	HY	0.04617	2.97501	0.86634	16.0828	0.5188
2014	7	1	AY	0.03927	3.00117	0.87396	15.881	0.51229
2014	7	1	AY	0.02285	2.95667	0.861	11.5098	0.37128
2014	7	1	AY	0.03878	2.49371	0.72618	6.7865	0.21892
2014	1	1	HY	0.04034	2.36655	0.68915	6.66084	0.21487
2014	1	1	HY	0.05262	2.70423	0.78749	11.9815	0.3865
2014	1	1	HY	0.05104	2.91715	0.84949	15.2147	0.4908
2014	1	1	AY	0.03764	2.83352	0.82514	13.3074	0.42927
2014	1	1	AY	0.04604	2.82919	0.82388	14.1107	0.45518
2014	1	1	AY	0.03789	2.8457	0.82869	13.6291	0.43965
2014	1	2	HY	0.0445	2.86363	0.83391	14.6166	0.4715
2014	1	2	HY	0.04875	2.72069	0.79228	12.385	0.39952
2014	1	2	HY	0.03994	2.55224	0.74323	7.09936	0.22901
2014	1	2	AY	0.03871	2.76665	0.80567	12.1217	0.39102
2014	1	2	AY	0.04195	2.67341	0.77851	11.1743	0.36046
2014	1	2	AY	0.04397	2.81408	0.81948	13.3662	0.43117
2014	2	1	HY	0.04411	2.60088	0.75739	10.1454	0.32727
2014	2	1	HY	0.0464	2.71716	0.79126	12.289	0.39642
2014	2	1	HY	0.04982	2.80731	0.81751	13.2925	0.42879
2014	2	1	AY	0.05068	2.85149	0.83037	13.8585	0.44705
2014	2	1	AY	0.05876	2.82878	0.82376	13.8991	0.44836
2014	2	1	AY	0.04964	2.74181	0.79843	9.33772	0.30122
2014	7	2	HY	0.05228	2.9758	0.86657	16.2821	0.52523
2014	7	2	HY	0.06336	2.87661	0.83769	14.3295	0.46224
2014	7	2	HY	0.06154	2.99175	0.87122	16.852	0.54361
2014	7	2	AY	0.06059	3.00335	0.8746	16.4036	0.52915
2014	7	2	AY	0.04692	2.89072	0.8418	14.6128	0.47138
2014	7	2	AY	0.04095	3.00083	0.87386	16.536	0.53342
2014	3	1	HY	0.03964	2.74475	0.79929	11.9492	0.38546
2014	3	1	HY	0.04148	2.62779	0.76523	8.45062	0.2726
2014	3	1	HY	0.05083	2.64678	0.77076	11.0919	0.3578
2014	3	1	AY	0.05332	2.62589	0.76468	10.9538	0.35335
2014	3	1	AY	0.04979	2.82702	0.82325	13.8071	0.44539

Appendix B. (Cont.)

This appendix contains the spreadsheet of soil microbiological data that was inserted into the SAS program contained in Appendix D.

Year	Region	Field	HY/AY	Rate	ShanD	ShanE	SimpD	SimpE
2014	3	1	AY	0.05014	2.84265	0.8278	14.1773	0.45733
2014	3	2	HY	0.03894	2.72213	0.7927	10.5507	0.34034
2014	3	2	HY	0.0392	2.34673	0.68338	6.87531	0.22178
2014	3	2	HY	0.04628	2.5703	0.74849	9.74477	0.31435
2014	3	2	AY	0.05579	2.86424	0.83408	13.0634	0.4214
2014	3	2	AY	0.04331	2.70518	0.78777	10.2597	0.33096
2014	3	2	AY	0.04295	2.66055	0.77477	10.6581	0.34381
2014	2	2	HY	0.06126	2.67583	0.77922	12.0791	0.38965
2014	2	2	HY	0.05845	2.79011	0.8125	13.2578	0.42767
2014	2	2	HY	0.0475	2.78655	0.81146	13.4008	0.43228
2014	2	2	AY	0.04799	2.72502	0.79354	12.4447	0.40144
2014	2	2	AY	0.04712	2.73005	0.79501	12.7289	0.41061
2014	2	2	AY	0.05804	2.81742	0.82045	14.1131	0.45526
2014	5	1	HY	0.0455	2.73985	0.79786	12.455	0.40177
2014	5	1	HY	0.05127	2.76959	0.80652	13.0678	0.42154
2014	5	1	HY	0.05372	2.7181	0.79153	12.5061	0.40342
2014	5	1	AY	0.04797	2.59055	0.75439	9.61572	0.31018
2014	5	1	AY	0.04752	2.82777	0.82347	13.7916	0.44489
2014	5	1	AY	0.04859	2.67841	0.77997	11.8767	0.38312
2014	5	2	HY	0.04496	2.81035	0.81839	13.2042	0.42594
2014	5	2	HY	0.04469	2.66061	0.77479	11.042	0.35619
2014	5	2	HY	0.04371	2.85414	0.83114	14.1313	0.45585
2014	5	2	AY	0.04474	2.84005	0.82704	11.713	0.37784
2014	5	2	AY	0.0447	2.84981	0.82988	13.3591	0.43094
2014	5	2	AY	0.0406	2.84268	0.82781	12.5236	0.40399
2014	6	1	HY	0.04965	2.86499	0.8343	14.6382	0.4722
2014	6	1	HY	0.04342	2.86946	0.83561	14.5059	0.46793
2014	6	1	HY	0.04177	2.86121	0.8332	14.4063	0.46472
2014	6	1	AY	0.0519	2.86277	0.83366	14.8179	0.478
2014	6	1	AY	0.04472	2.7753	0.80819	12.95	0.41774
2014	6	1	AY	0.0495	2.83386	0.82524	14.2537	0.4598
2014	4	1	HY	0.04744	2.78661	0.81148	13.1855	0.42534
2014	4	1	HY	0.04714	2.83269	0.8249	13.3468	0.43054
2014	4	1	HY	0.05819	2.69266	0.78412	11.934	0.38497
2014	4	1	AY	0.05404	2.76496	0.80517	11.9738	0.38625

Appendix B. (Cont.)

This appendix contains the spreadsheet of soil microbiological data that was inserted into the SAS program contained in Appendix D.

Year	Region	Field	HY/AY	Rate	ShanD	ShanE	SimpD	SimpE
2014	4	1	AY	0.05438	2.78519	0.81107	12.6562	0.40826
2014	4	1	AY	0.04778	2.85983	0.8328	13.7472	0.44346
2014	4	2	HY	0.05225	2.74471	0.79928	12.6381	0.40768
2014	4	2	HY	0.04901	2.76912	0.80639	13.1334	0.42366
2014	4	2	HY	0.05014	2.75309	0.80172	12.7206	0.41034
2014	4	2	AY	0.05408	2.66564	0.77625	11.2426	0.36266
2014	4	2	AY	0.05315	2.78466	0.81091	13.3133	0.42946
2014	4	2	AY	0.06056	2.74639	0.79977	12.574	0.40561
2014	6	2	HY	0.05103	2.77436	0.80791	13.2189	0.42642
2014	6	2	HY	0.0535	2.81218	0.81893	14.1434	0.45624
2014	6	2	HY	0.05196	2.77887	0.80922	13.0827	0.42202
2014	6	2	AY	0.04747	2.8294	0.82394	12.8035	0.41302
2014	6	2	AY	0.04213	2.76321	0.80467	11.973	0.38622
2014	6	2	AY	0.05975	2.82008	0.82122	11.9433	0.38527
2015	6	2	HY	0.05711	2.84685	0.82902	14.0408	0.45293
2015	6	2	HY	0.05209	2.86352	0.83388	14.3262	0.46213
2015	6	2	HY	0.0485	2.87549	0.83736	14.6478	0.47251
2015	6	2	AY	0.04703	2.80246	0.81609	13.3703	0.4313
2015	6	2	AY	0.05617	2.77977	0.80949	13.1291	0.42352
2015	6	2	AY	0.0541	2.78038	0.80966	13.1991	0.42578
2015	5	1	HY	0.04039	3.00321	0.87456	16.9505	0.54679
2015	5	1	HY	0.04717	2.93662	0.85516	15.3204	0.49421
2015	5	1	HY	0.04452	3.03433	0.88362	17.5309	0.56551
2015	5	1	AY	0.0529	3.25381	0.94753	21.5403	0.69485
2015	5	1	AY	0.03693	2.21306	0.64446	7.51721	0.24249
2015	5	1	AY	0.03801	3.11665	0.90759	18.1707	0.58615
2015	3	1	HY	0.04886	2.82804	0.82355	13.913	0.44881
2015	3	1	HY	0.0508	2.81707	0.82035	14.2925	0.46105
2015	3	1	HY	0.04353	2.89829	0.844	14.6401	0.47226
2015	3	1	AY	0.04197	2.86961	0.83565	14.9347	0.48176
2015	3	1	AY	0.04708	2.93868	0.85576	16.0493	0.51772
2015	3	1	AY	0.04657	2.8567	0.83189	14.6519	0.47264
2015	1	1	HY	0.05131	2.85572	0.83161	14.4498	0.46612
2015	1	1	HY	0.05267	2.90407	0.84568	15.2328	0.49138
2015	1	1	HY	0.04721	2.89515	0.84309	14.9918	0.4836

Appendix B. (Cont.)

This appendix contains the spreadsheet of soil microbiological data that was inserted into the SAS program contained in Appendix D.

Year	Region	Field	HY/AY	Rate	ShanD	ShanE	SimpD	SimpE
2015	1	1	AY	0.05056	2.86481	0.83425	14.2466	0.45957
2015	1	1	AY	0.05343	2.99307	0.8716	17.1257	0.55244
2015	1	1	AY	0.05892	2.83221	0.82476	14.1295	0.45579
2015	1	2	HY	0.05899	2.80722	0.81748	13.3908	0.43196
2015	1	2	HY	0.06096	2.8776	0.83797	14.6018	0.47102
2015	1	2	HY	0.05031	2.91501	0.84887	15.2418	0.49167
2015	1	2	AY	0.05305	2.97982	0.86774	16.2178	0.52315
2015	1	2	AY	0.04721	2.89464	0.84294	14.9595	0.48256
2015	1	2	AY	0.04976	2.74396	0.79906	12.8578	0.41477
2015	6	1	HY	0.06239	2.92186	0.85087	15.6343	0.50433
2015	6	1	HY	0.05308	2.87193	0.83633	14.4102	0.46485
2015	6	1	HY	0.04781	2.8357	0.82577	13.529	0.43642
2015	6	1	AY	0.05648	2.7925	0.81319	13.8449	0.44661
2015	6	1	AY	0.04747	2.6543	0.77295	11.0882	0.35768
2015	6	1	AY	0.0565	2.85028	0.83002	14.133	0.4559
2015	4	1	HY	0.0325	2.88422	0.8399	13.6177	0.43928
2015	4	1	HY	0.05312	2.86453	0.83417	15.0386	0.48512
2015	4	1	HY	0.05264	2.96739	0.86412	16.3639	0.52787
2015	4	1	AY	0.03526	2.85247	0.83066	18.9551	0.61145
2015	4	1	AY	0.03883	2.46583	0.71807	6.28436	0.20272
2015	4	1	AY	0.04492	2.22363	0.64754	6.22066	0.20067
2015	2	1	HY	0.04624	2.46378	0.71747	6.43581	0.20761
2015	2	1	HY	0.06148	2.79974	0.8153	13.4403	0.43356
2015	2	1	HY	0.0556	2.65087	0.77195	11.6279	0.37509
2015	2	1	AY	0.04263	2.42721	0.70682	9.02456	0.29111
2015	2	1	AY	0.04188	2.41853	0.70429	7.34764	0.23702
2015	2	1	AY	0.0452	2.67651	0.77942	11.0305	0.35582
2015	7	1	HY	0.08251	2.83156	0.82457	14.7489	0.47577
2015	7	1	HY	0.07597	3.04167	0.88575	18.5076	0.59702
2015	7	1	HY	0.06412	3.03459	0.88369	18.2435	0.5885
2015	7	1	AY	0.05069	2.96538	0.86354	16.3129	0.52622
2015	7	1	AY	0.06141	2.95459	0.8604	16.1855	0.52211
2015	7	1	AY	0.06382	2.98156	0.86825	16.8217	0.54264
2015	2	2	HY	0.04414	2.96856	0.86446	16.1862	0.52214
2015	2	2	HY	0.04809	2.74516	0.79941	13.2092	0.4261

Appendix B. (Cont.)

This appendix contains the spreadsheet of soil microbiological data that was inserted into the SAS program contained in Appendix D.

Year	Region	Field	HY/AY	Rate	ShanD	ShanE	SimpD	SimpE
2015	2	2	HY	0.0457	2.79981	0.81532	13.8197	0.4458
2015	2	2	AY	0.05248	2.89938	0.84432	15.5158	0.50051
2015	2	2	AY	0.04599	2.80604	0.81714	14.0317	0.45264
2015	2	2	AY	0.05713	2.64909	0.77143	12.2697	0.3958
2015	3	2	HY	0.04805	2.77841	0.80909	13.9523	0.45007
2015	3	2	HY	0.04765	2.75339	0.8018	12.9646	0.41821
2015	3	2	HY	0.04868	2.8861	0.84045	15.3476	0.49508
2015	3	2	AY	0.06321	2.83972	0.82694	14.5398	0.46903
2015	3	2	AY	0.0575	2.82034	0.8213	14.0272	0.45249
2015	3	2	AY	0.05268	2.67292	0.77837	12.1801	0.39291
2015	4	2	HY	0.05703	3.01766	0.87876	16.9973	0.5483
2015	4	2	HY	0.06134	2.85091	0.8302	14.7322	0.47523
2015	4	2	HY	0.06413	3.0201	0.87947	17.5547	0.56628
2015	4	2	AY	0.06361	2.672	0.7781	12.2422	0.39491
2015	4	2	AY	0.04886	2.70859	0.78876	12.4117	0.40038
2015	4	2	AY	0.06989	2.90888	0.84708	16.115	0.51984
2015	5	2	HY	0.05611	2.92865	0.85284	15.4313	0.49778
2015	5	2	HY	0.06037	2.74315	0.79882	13.2224	0.42653
2015	5	2	HY	0.0652	2.82925	0.8239	14.4943	0.46756
2015	5	2	AY	0.04451	2.73325	0.79594	11.2792	0.36384
2015	5	2	AY	0.04263	2.70628	0.78809	11.4548	0.36951
2015	5	2	AY	0.04594	2.63817	0.76825	10.4766	0.33796
2015	7	2	HY	0.05614	2.92513	0.85182	16.0035	0.51624
2015	7	2	HY	0.06468	2.96879	0.86453	16.8146	0.54241
2015	7	2	HY	0.05101	2.95157	0.85952	16.2395	0.52385
2015	7	2	AY	0.05999	3.05128	0.88855	16.7249	0.53951
2015	7	2	AY	0.06047	2.83545	0.8257	14.1371	0.45604
2015	7	2	AY	0.06023	2.82781	0.82348	14.5434	0.46914

Appendix C.

This appendix contains the SAS program that was run on the soil physical and chemical data contained in Appendix A.

```
title 'Soil Property Data Analysis';
data a;
  infile 'Soil input file1.csv' firstobs = 2 delimiter = "," truncover LRECL = 600;
  input Id $ Year Region Field Hy_Ay $ Depth $ BD SA SI CY PH EC CN SOM_cnt P_cnt
K_cnt CA_cnt MG_cnt S_cnt NA_cnt FE_cnt MN_cnt ZN_cnt CU_cnt B_cnt TC_cnt TN_cnt
CfracSOM NfracSOM;
run;

proc sort data=a;
   by Year Region Field id Hy_Ay Depth;
run;
quit;

proc print data = a;
   by Year Region Field id Hy_Ay Depth;
   id Year Region Field id Hy_Ay Depth;
run cancel;
quit;

options mprint;


proc mixed data=a plots=all;
   class Region Field Hy_Ay Depth Year;
   model /* Variable */ = Year
          Region
          Year*Region
          Field(Region)
          Hy_Ay
          Region*Hy_Ay
          Hy_Ay*Year
                    Hy_Ay*Year*Region
                    Hy_Ay*Field(Region)
          Depth
          Region*Depth
          Hy_Ay*Depth
          Region*Hy_Ay*Depth
          Depth*Year
          Depth*Year*Region
          Depth*Field(Region)
          Depth*Hy_Ay*Year
```

Appendix C. (Cont.)

This appendix contains the SAS program that was run on the soil physical and chemical data contained in Appendix A.

```
  Depth*Hy_Ay*Year*Region;
   random Year
        Year*Region
        Field(Region)
        Hy_Ay*Year
                Hy_Ay*Year*Region
                Hy_Ay*Field(Region)
        Depth*Year
        Depth*Year*Region
        Depth*Field(Region)
        Depth*Hy_Ay*Year
                Depth*Hy_Ay*Year*Region ;
lsmeans Region Hy_Ay Depth Region*Hy_Ay Region*Depth Hy_Ay*Depth
Region*Depth*Hy_Ay / cl diff adjust=tukey;
run;
quit;
```

Appendix D.

This appendix contains the SAS program that was run on the soil microbiological data contained in Appendix B.

```
title 'Soil Microbial Data Analysis';
data a;
  infile 'Microbial input.csv' firstobs = 2 delimiter = "," truncover LRECL = 600;
  input Year Region Field Hy_Ay $ Rate ShanD ShanE SimpD SimpE;
run;

proc sort data=a;
   by Year Region Field Hy_Ay ;
run;
quit;

proc print data = a;
   by Year Region Field Hy_Ay ;
   id Year Region Field Hy_Ay ;
run cancel;
quit;

options mprint;


proc mixed data=a plots=all;
   class Region Hy_Ay;
   model /*Variable*/ = Year
          Region
          Year*Region
          Field(Region)
          Hy_Ay
          Region*Hy_Ay
          Hy_Ay*Year
                    Hy_Ay*Year*Region
                    Hy_Ay*Field(Region);
   random Year
        Year*Region
        Field(Region)
        Hy_Ay*Year
                  Hy_Ay*Year*Region
                  Hy_Ay*Field(Region);
lsmeans Region Hy_Ay Region*Hy_Ay / cl diff adjust=tukey;
run;
quit;
```