Nitrogen and Sulfur Fertilization Effects on Carbon Sequestration and Greenhouse Gas Emissions in S-deficient Soils

By

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Abstract

Depending on management practices, agricultural soils have the potential to be both a source and a sink of greenhouse gases (GHGs). Long-term fertilization and crop rotation management practices are considered to have an impact on carbon (C) sequestration and nitrous oxide (N_2O) emissions. Sulfur (S) deficient soils occupy a large area in agricultural production regions in Western Canada; however, much past research has focused mainly on the effect of long-term N fertilization on N_2O emissions, and there are only a few examples of the effects of long-term N and S fertilization on C sequestration. The research in this thesis, mainly aimed to investigate the effects of long-term combined N and S fertilization and crop rotation practices on soil C sequestration and N_2O emissions in S-deficient soils at the Breton Classical Plots, AB, Canada. This thesis reports the results of three studies. First, the influence of long-term N and S fertilization on the change in total soil organic C (SOC) over 28 years (1980-2008) was quantified. The results revealed that long-term S fertilization in combination with other macro nutrients (NPK) resulted in an increasing trend in SOC concentration over the years and increased accumulation of SOC at a rate of 0.11 Mg C ha^{-1} yr^{-1} over N fertilizer alone. In the second study, a 3-year growing season field study was carried out in order to quantify the growing season N_2O emissions from S-deficient soils from five soil fertility treatments with different fertilization history (Control (unfertilized), Manure, NPKS, NPK and PKS) under a 2-yr wheat-fallow (WF) and a 5- yr wheat-oat-barley-hay-hay (WOBHH) crop rotation. The results indicate that the 3-yr cumulative growing season N_2O-N emissions were higher in the WOBHH rotation than the WF rotation. On the other hand, WOBHH had a higher yield and reduced N_2O emission intensity (kg of N_2O-N per kg of grain, or kg of N_2O-N per kg crop N uptake) compared to the WF crop rotation system. In both crop rotation systems, N_2O emissions from the manure treatment were the highest of all soil fertility treatments. Soils with long-term combined N and S fertilization history had a highest yield and lowest N_2O emission intensity compared to the other soil fertility treatments, particularly in the WOBHH rotation. This implies that long-term balanced fertilization of S with other macro nutrients reduced the N_2O emission intensities without compromising the benefit of higher yield. Finally, a laboratory incubation experiment was conducted in order to examine whether different N and S fertilizer sources significantly interact with fertilization history with respect to N_2O emission potential, and whether N_2O emissions are influenced by the interaction of elemental S oxidation and nitrification. Results revealed that N_2O-N emissions from the contemporary applied N and S fertilizers were significantly influenced by fertilization history.

Furthermore, since elemental S (S^0) oxidation did not affect the nitrification process in soil, N_2O emissions from fertilizer treatments with S^0 or without S^0 were not significantly different. Investigating the interactions between S and N transformations in agricultural soils is vital in order to better understand the effects of long-term fertilizer management practices on N_2O emissions and C sequestration. The results presented in this thesis may have significant implication for sustainable agriculture, and can be considered in nutrient management strategies that can mitigate N_2O emissions, while also optimizing crop yield and increasing organic C storage in S-deficient soils.

Preface

Chapter 2 of this thesis has been published as Mekonnen Giweta, Miles F. Dyck, Sukhdev S. Malhi and Dick Puurveen, 2014, "Long-term S-fertilization increases carbon sequestration in a sulfur-deficient soil," Can. J. Soil Sci. 94: 295-301. I was responsible for data organization and analysis as well as the manuscript composition. Dick Puurveen and Dr. Robertson assisted with data collection and contribute to manuscript edits. Dr. Miles F. Dyck and Dr. Sukhdev S. Malhi were the supervisory authors, and were involved with concept formation and manuscript composition.

Chapter 3 of this thesis was submitted to the Canadian Journal of Soil Science in August 2016, as Mekonnen Giweta, Miles F. Dyck and Sukhdev S. Malhi, "Growing season N_2O-N emissions from a Gray Luvisol as a function of long-term fertilization history and crop rotation." I was responsible for data collection, organization and analysis as well as the manuscript composition. Dr Miles F. Dyck and Dr Sukhdev S. Malhi were the supervisory authors, and were involved with concept formation and manuscript composition.

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Dedication

I dedicate this work to all, who contributed to my academic journey, since my elementary school age.

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Chapter 1. General Introduction

1.1. Importance of Greenhouse Gases Emissions and Role of Agriculture

Anthropogenic activities such as agricultural activities, biomass burning, industrialization, fossil fuel combustion, urban expansion and land use change are mostly responsible for the increasing concentration of greenhouse gases (GHGs) in the atmosphere (IPCC, 2007). Greenhouse gases absorb infrared radiation from the earth's surface and affect the earth's climate through their influence on the global energy balance (Houghton, 2005). Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the three major GHGs that are associated with agriculture (Snyder et al., 2009).

The warming effect of the GHGs relative to CO_2 over a specific period of time is termed as global warming potential (GWP) (IPCC, 2013). The global warming potential of CH_4, and N_2O are ~ 23 and 298 times higher than CO_2, respectively (based on a time horizon of 100 years; IPCC, 2007). N_2O is also involved in the destruction of ozone layer (Ravishankara et al., 2009), which increases the amount of ultraviolet radiation reaching the earth (Pierzinski et al., 2005). Depending on management practices, agricultural soils have the potential to be both a source and sink of GHGs (Signor et al., 2013).

N_2O emissions from agriculture are primarily related to N inputs to soils (Snyder et al., 2009; IPCC, 2013). Because of continuous growth of human population and increased demand for food, feed, fiber and fuel, this trend is expected to continue in the coming decades (IPCC, 2013). The increased use of synthetic and organic fertilizers in agriculture in order to feed the rapidly increasing population of the world has increased food production, but also has a negative effect on the environment (Van Groenigen et al., 2010). In addition to soil N_2O emissions, leaching and runoff of nitrate (NO_3^-), ammonia (NH_3) volatilization and soil acidification are associated with agricultural N additions (Lagreid et al., 1999).

The need for reduction in N_2O emissions from soil to mitigate global warming and ozone depletion, and for removal of excess NO_3^- from soil for protection of ground and surface water is now urgent (Saggar et al., 2012). The N_2O emissions from agricultural soils, due to inappropriate fertilizer applications, are not just an environmental concern, but may also affect crop yields negatively and result in a financial loss to the farmers (Van Groenigen et al., 2010). Thus, in line with an effort to sustain global food production through the use of synthetic and organic fertilizers, and other farm management practices, considerable effort is needed in application of agricultural management practices, which can boost agricultural production, whilst simultaneously mitigating and protecting the environment (Lagreid et al., 1999).

1.2. Nitrous Oxide Production Processes and Pathways in Soil

Nitrification and denitrification are the main microbially mediated processes in soil affecting the production of N_2O – see Fig. 2-1 (Baggs, 2008). There are two known production pathways for N_2O during autotrophic nitrification (Groffman, 2006; Braker and Conrad, 2011). During the first reaction in the nitrification process, ammonium (NH_4^+) and/or ammonia (NH_3) are oxidized to hydroxylamine (NH_2OH) by chemolithoautotrophic bacteria. Hydroxylamine is then oxidized to nitrite and N_2O is a by-product of this reaction when the oxidation is not complete, which is commonly referred to as chemo-denitrification (Batjes and Bridges, 1992; Braker and Conrad, 2011). Nitrifier denitrification occurs during the oxidation of nitrate (NO_3^-) and nitrite (NO_2^-) (the second sequential reaction in the nitrification process) because nitrifying bacteria may use NO_2^- as an alternative electron acceptor when O_2 is limiting and this produces N_2O through subsequent reduction of NO to N_2O (Braker and Conrad, 2011).

Under anaerobic conditions, where oxygen is absent, and water, nitrate and decomposable organic compounds are present, anaerobic bacteria may use NO_3^- and NO_2^- as electron acceptors, and release N_2O and N_2 to the atmosphere through the process of denitrification (Batjes and Bridges, 1992; Braker and Conrad, 2011). Although dentrification has been commonly accepted to occur under anaerobic and anoxic conditions, there have been some reports of aerobic denitrification (Robert and Kuenen, 1984; Lampe and Zhang, 1996; Beller et al., 2006; Cardoso et al., 2006). Conversely, there is evidence that nitrification can occur under anaerobic conditions (Wlodarczyk et al., 2004), although it mainly occurs under aerobic conditions (Bremer, 1997; Braker and Conrad, 2011). Further, it is thought that all of the above mentioned processes can contribute simultaneously to N_2O production due to simultaneous existence of aerobic and anaerobic zones in a soil profile (Stevens and Laughlin, 1998; Braker and Conrad, 2011; Saggar et al., 2012). Before being reduced to N_2 by denitrification, N_2O produced by all processes are available for emission to the atmosphere or further reduction to N_2 by microorganisms producing the nitrous oxide reductase enzyme (Stevens and Laughlin, 1998; Siciliano, 2014). High recovery of genes coding for the nitrous oxide reductase enzyme in DNA extracted from agricultural soils were associated with reduced N_2O emissions from these soils (Siciliano, 2014). Bateman and Baggs (2005) have reported that it is very difficult to quantify the proportion of N_2O production from nitrification or denitrification processes in soil because both processes can occur simultaneously or separately.

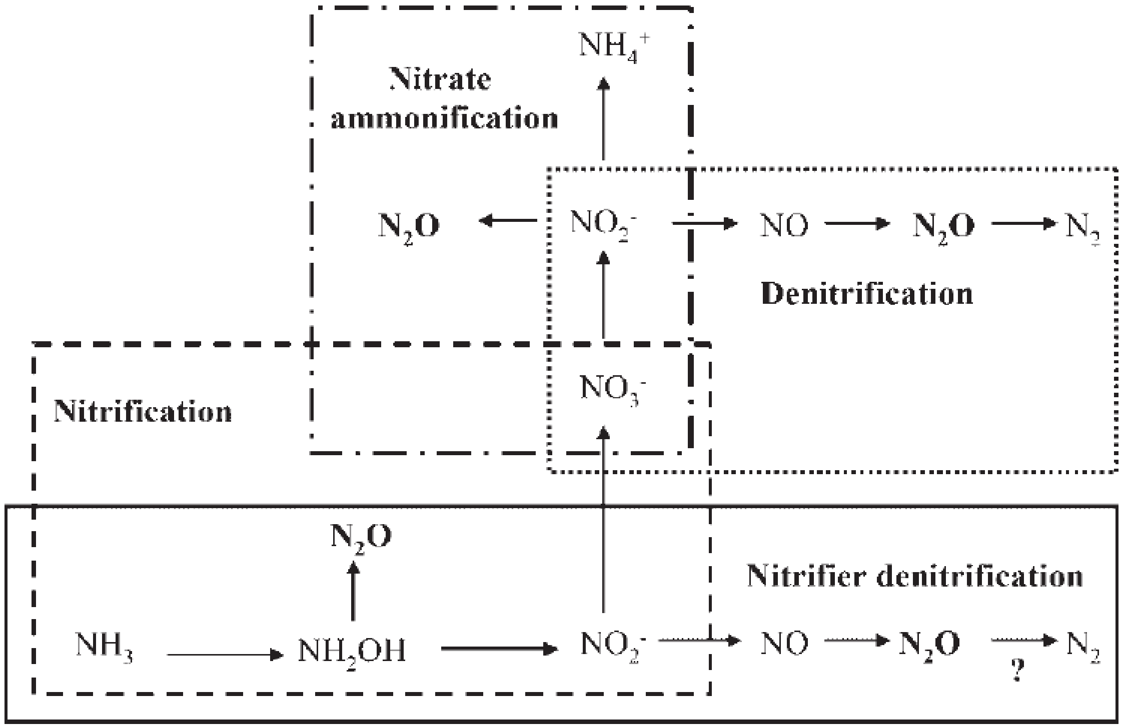

Figure 1-1. Microbial sources of nitrous oxide (N_2O) in soil from all microbial sources (Wrage et al., 2001; in Baggs, 2008).

Soil N_2O production is highly variable both spatially and temporally because N_2O production processes are highly influenced by soil conditions and management practices (Lilly et al., 2003). Due to spatial variability of land management practices (such as tillage, nutrient management, surface residues and cropping system) and slope aspect; soil temperature and soil moisture, accurate estimation of greenhouse gas emissions from agricultural soil is challenging (Signor et al., 2013).

The main factors that influence the nitrification process in soil are moisture status, aeration, temperature, pH and texture (Subbarao et al., 2006; Sahrawat, 2008). In addition to the above variables, Tisdale et al. (1999) and Signor et al. (2013) also noted that the amount of ammonium (NH_4^+) within the soil and population of nitrifying organisms influence the nitrification process in the soil. Since soil moisture and temperature determine the activity of microorganisms, they also influence the N_2O production processes (Signor et al., 2013). Because soil water-filled pore space (WFPS) influences oxygen (O_2) content and aeration of the soil, it is a controlling factor of N_2O production from agricultural soils (Signor et al., 2013). Castellano et al. (2010) observed that N_2O production is a positive linear or an exponential linear function of WFPS. Moreover, WFPS is one of the important variable, which determines the proportion of N_2O production from nitrification and denitrification processes (Signor et al., 2013).

Nitrification will continue only when the soil condition is favorable for the mineralization of ammonium (i.e., release of NH_4^+ from organic substrates through bacterial decomposition) (Tisdale et al., 1999). Therefore, a supply of ammonium is vital for nitrification (Signor et al., 2013). Further, a temperature range between 25-35 ^{0}C is optimal for nitrification (Subbarao et al., 2006; Tisdale et al., 1999). As the temperature increases from 0-50^0 C, N_2O production increases exponentially (Liu et al., 2010; in Signor et al., 2013).

Although nitrification can occur in a pH range of 4.5 to 10, the optimal range is 6.0 to 8.5 (Tisdale et al., 1999; Subbarao et al., 2006). In order to produce NO_3^-, aerobic nitrifying bacteria require the presence of oxygen (Tisdale et al., 1999). Soil conditions that allow the diffusion of gases into and out of the soil facilitate nitrification (Tisdale et al., 1999; Signor et al., 2013), and usually the highest nitrification occurs when the soil O_2 concentration is almost the same as the O_2 concentration in the atmosphere (Tisdale et al., 1999). Nitrification will occur when soil moisture is at field capacity (80% of total pore space) (Tisdale et al., 1999).

Similarly, the general requirements for denitrification are: the presence of bacteria, fungi or other denitrifying microbes, available organic C as electron donors, anaerobic conditions or restricted supply of O_2, and availability of N oxides (NO_3^-, NO_2^-, NO, or N_2O as terminal electron acceptor

(Saggar et al., 2012). In addition to the above factors, Tisdale et al. (1999) also noted that factors such as level and forms of inorganic nitrogen (N) such as NO_3^- vs. NH_4^+, soil moisture, soil pH, and soil temperature affect the denitrification process.

Providing other conditions are favorable, the amount and nature of the organic material (availability of readily decomposable organic matter or C) will influence denitrification (Bremner, 1997; Tisdale et al., 1999; Saggar et al., 2012). Organic C can stimulate the microbial growth and thereby increase O_2 consumption, which ultimately creates anaerobic conditions for denitrification (Signor et al., 2013). Soils with high amounts of available C can emit greater N_2O provided there is enough moisture and N (Russer et al., 2006, in Signor et al., 2013). Therefore, N_2O emissions from denitrification are significantly correlated with soil organic C levels (Ciampitti et al., 2008, in Signor et al., 2013). Due to lack of available O_2, saturated soils create a favorable environment for denitrification (Tisdale et al., 1999; Subbarao et al., 2006; Sahrawat, 2008; Saggar et al., 2012; Signor et al., 2013). Usually nitrification is dominant when the WFPS is less than 60%, whereas denitrification occurs when WFPS is higher than 70% (Signor et al., 2013).

Since the bacteria that are responsible for denitrification are sensitive to soil pH, denitrification is usually high in soils with a high pH and is rarely found in soil with a pH below 5.0. (Tisdale et al., 1999; Signor et al., 2013). Soil temperatures stimulate soil respiration and increase anaerobic sites which many eventually increase the occurrence of denitrification (Signor et al., 2013). Since denitrification is very sensitive to soil temperature, it will be inhibited when the temperature exceeds 60 ^{0}C. However, denitrification can occur in the soil at temperatures ranging between 2-60 ^{0}C (Tisdale et al., 1999) and has even been observed at sub-freezing temperatures (Nemeth et al., 2014).

Although a wide range of heterotrophic bacteria and fungi are responsible for denitrification, not all can reduce N_2O to N_2. Because of this, the amount of N_2O produced can vary from almost 0 to over 90% of the total N-gases produced by denitrification (Saggar et al., 2012). Moreover, the relative ratio of N_2O to N_2 depends on the interaction between soil microorganisms, climate (temperature), soil properties (availability of mineral N (both NH_4^+ and NO_3^-), labile C, pH, O_2 availability, soil water content and texture) and management practices (Morley and Baggs., 2010; Saggar et al., 2012).

Excessive use of N fertilizers increases soil acidification and thereby enhances N_2O emissions, and adjustment of soil pH by liming is essential in order to reduce N_2O emission (Thomson et al., 2012). Soil C/N ratios of crop residue also affect the two important biological N transformation processes (mineralization and immobilization) in the soil (Signor et al., 2013). When soil and residues have a small C/N ratio (lower than 30/1), mineralization will be dominant over immobilization (Signor et al., 2013). However, immobilization will increase in the case of a high C/N ratio (higher than 30/1) (Baggs et al., 2003).

1.3. Management Practices and Options for Reduction of N_2O Emission and Carbon Sequestration

Onema (1999) suggested that agricultural management practices which increase nitrogen use efficiency (NUE), and decrease the release of N_2O per unit of applied N from denitrification and nitrification, are the two important strategies in order to reduce the direct and indirect N_2O emissions from agricultural soils. On-farm management options that may reduce N_2O production include: minimizing N inputs from animal excreta and chemical fertilizers, improving soil aeration and decreasing soil NO_3^- concentrations (Saggar et al., 2012).

Fertilizer best management practices, using the 4-Rs (the right source, at the right rate, at the right time, and with the right placement), will increase farmers' profit through increasing yields, while contributing to the reduction of greenhouse gases (particularly N_2O emissions) by minimizing risks of N loss via all pathways (Snyder et al., 2009). For example, when the N rate exceeds the crop demand, Nitrate-N can accumulate in soil and eventually will be prone to environmental losses (Snyder et al., 2009).

Several studies found that N_2O emissions from agricultural soils significantly correlate with fertilizer N rate (Bouwman et al., 2002a; Drury et al., 2008; Halvorson et al., 2008). Hultgreen and Leduc (2003) observed lower N_2O emissions when fertilizer N was side-banded rather than mid-row banded, and when urea was banded rather than broadcast. Hao et al. (2001), in wheat and canola plots in Alberta, found that spring fertilizer N application resulted in significantly lower N_2O emissions than autumn fertilizer N application. Tenuta and Beauchamp (2003) observed lower emissions of N_2O from ammonium sulfate than from urea. However, in contrast to these findings, Lemke et al. (2003), in their two-year N fertilizer study, at four locations, in Saskatchewan, did not observe any differences in N_2O emission (between spring vs. fall application, side-banded vs mid-row banded, and anhydrous ammonia vs. urea). The main reason for this is likely there was little snow cover at each location during their study (Lemke et al., 2003).

N fertilizer applications in agricultural soils without sufficient application of other nutrients to meet crop demand, either in the form of inorganic or organic fertilizers, could result in a surplus of NH_3 and NO_3^- , and this surplus N will be prone to losses through N_2O emissions (Inselbacher et al., 2011). In this context, in a Dark Gray Chernozem loam soil, which is deficient in plant available S and N, at Canwood in north-central Saskatchewan, Canada, Malhi et al. (2010)

observed that long-term N, S and/or K fertilization of grass forage increased yield, nutrient uptake and root biomass, and increased C sequestration and N storage in soil, and minimized accumulation and downward movement of NO_3^--N in the soil profile.

Although there are different research reports regarding the influence of tillage on N_2O production, since soil tillage affects rates of residue decomposition, soil structure, soil moisture and temperature, soil aeration and microbial activity, it has a direct influence on N_2O production (Liu et al., 2006; in Signor et al., 2013). Citing several authors, Signor et al. (2013) reported that, compared to conventional tillage (CT), no tillage increases N_2O emissions. Wagner-Riddle et al. (2010), in their five-year study at Elora Research Station, Ontario, have shown that crop rotation system that was managed with Beneficial Management Practices (BMP) such as reduced N fertilization and no-tillage (NT) decreased N_2O emissions compared to a conventional management system. Rochette et al. (2008) compiled approximately 45 site-years of data and compared the N_2O emissions from tilled and no-till soils, and reported that no-till operation did not increase N_2O emissions in soils with good and medium aeration, but it increased N_2O emissions in poorly aerated soils. Thus, further to the application of N (mineral or organic), recycling N from crop residues and soil tillage may affect N_2O production (Signor et al., 2013).

Long-term manure applications to soil may generate much higher rates of N_2O emissions than soils receiving manure application for short time (Chang et al., 1988). For example, Rochette et al. (2008) reported that fertilization of silage maize with synthetic fertilizer resulted in lower emissions when compared with dairy cattle manure. Thus, avoiding excessive application rates and optimized timing of manure application are important for the reduction of N_2O emission from agricultural soils. Amendments such as nitrification inhibitors also contribute to the reduction of the N_2O emissions, improve the NUE, and ultimately increase yield (Di and Cameron, 2002).

Sulfur-driven autotrophic denitrification, as a widely distributed microbial process, can occur in different habitats such as soil, sediments, aquifers, and engineered bioreactors and are believed to influence the N and sulfur (S) cycles (Shao, 2010). Without exceptions, *Thiobacillus denitrificans* and *Thiomicrospira denitrificans* are the dominant bacterial species in these processes, which oxidize reduced inorganic sulfur compounds such as sulfide (S^{2-}), elemental sulfur (S^0), thiosulfate ($S_2O_3^{2-}$), sulfate (SO_4^{2-}), or sulfite (SO_3^{2-}) by using nitrate/nitrite as an electron acceptor resulting in the production of N_2 gas (Beller et al., 2006; Cardoso et al., 2006; Shao, 2010; Zhou et al., 2011). Moreover, these bacteria have the unusual ability to oxidize S under both aerobic and anoxic conditions (Shao, 2010). In line with this, Cardoso et al. (2006) and Zhou et al. (2011) observed that during S-driven autotrophic denitrification (the chemolithotrophic process coupling denitrification with the oxidation of reduced inorganic S compounds), NO_3^- was reduced to NO_2^- , and subsequently to N_2, using S as an electron donor. Therefore, all these studies demonstrate that N_2 can be produced during S-driven autotrophic denitrification and N-S interaction, but this process has mostly been observed in wastewater systems, with only a few examples in soils. Oxidation of S in soil decreased soil pH (Modaihsh et al., 1989; Heydarnezhad et al., 2012) and, this decrease in soil pH has a direct influence on N_2O production processes (Signor et al., 2013).

Beneficial fertilizer management practices also enhance the sequestration of atmospheric CO_2 into the soil by alleviating nutrient deficiency, increasing plant growth and yield and, as a result, returning more C into the soil (Snyder et al., 2009; Banger et al., 2010; Huang et al., 2010; Malhi et al., 2010). Optimized fertilizer management is important to increase fertilizer use efficiency and reduce fertilizer losses to the environment (Snyder et al., 2009). Balanced fertilization considers crop requirements of all macronutrients (N, P, K, Ca, Mg and S) and their interactions (Havlin et al., 1999). Balanced crop nutrition contributes to an increase in dry matter yield and root mass, which may result in an increase in soil C (Snyder et al., 2009). Furthermore, balanced fertilization at rates compatible with crop demands has the potential to improve soil quality and nutrient and water use efficiency (Havlin et al., 1999; Snyder et al., 2009). In addition to mitigating C emissions, with proper management, soils have the potential to sequester C (Al-Kaisi., 2008; Kane., 2015). The benefits of increasing soil carbon include improved water-holding capacity, improved water infiltration and water use efficiency, improved soil structure, and increased soil nutrient stocks (Al-Kaisi., 2008; Lal., 2008).

Soil contains a smaller pool of actively cycling organic matter derived from recent organic residues (plant and animal) besides a large pool of stable organic matter (Curtin and Wen., 1999). A large proportion of enzyme activity and microbial population in soil is associated with the light fraction of organic matter which is more active than the stable pool (Janzen et al., 1992). Physically uncomplexed organic matter is composed of particles of organic matter that are not bound to mineral particles (Gregorich et al., 2006). Two common forms of physically uncomplexed organic matter are light fraction and particulate organic matter (Gregorich et al., 2006). Light fraction organic matter is considered a transitory and intermediate form of organic matter between plant litter and stable organic matter with respect to amino acid composition and C/N ratio (Janzen et al., 1992; Gregorich and Janzen, 1996). Because light fraction organic matter decomposes faster than the bulk soil organic matter, it is a substrate for soil micro-organisms and nutrients (N and other nutrients) for plants, and improves soil quality (Janzen et al., 1992; Gregorich et al., 1994; Gregorich., 2008).

Previous research has shown that since light fraction organic matter has a higher rate of turnover; it can play a main role in N and C cycling (Janzen et al., 1992; Gregorich et al., 2006). Because of the lack of protection by the soil colloids and labile nature of its constituents, the light fraction is mineralized rapidly (Janzen et al., 1992). Since light fraction organic carbon (LFOC) and light fraction organic N (LFON) are responsive to cropping system and soil management practices (Malhi et al., 2010), they may provide an earlier indication of management effects than the total amount of organic matter in soils (Janzen et al., 1992; Gregorich et al., 1994).

Moreover, light fraction soil organic matter could be a major predictor of soil nutrient losses through greenhouse gas emissions and soil nutrient mineralization. For example, Grogan and Jonasson (2005) have observed that recently fixed C such as fresh litters were the main source of soil CO_2 emissions. Because the rate of whole respiration in the soil has been strongly correlated with light fraction organic carbon, it is likely an important C and energy source for soil microorganisms (Jansen et al., 1992; Gregorich., 2008). Velthof et al. (2003) reported that since easily available organic matter fractions provide substrates for nitrification and denitrification, and promote the anoxic microsites in soils, they can trigger N_2O emissions. It is generally agreed that C availability decreases the ratio of N_2O/ N_2. On the other hand, a high N_2O/ N_2 was also observed when there was a high NO_3^- concentration following fertilizer application (Saggar et al., 2012). Moreover, addition of low C/N ratio crop residues to soil can enhance net N_2O loss, whereas addition of high C/N ratio residue lowers the denitrifier N_2O to N_2 (Morley and Baggs, 2010).

Agricultural soil management practices such as maintaining continuous living plant cover on soils year-round, improving soil microbial diversity and abundance, increasing the mass and quality of plant and animal inputs to soils and decreasing the level of soil disturbance (i.e., tillage) to enhance the physical protection of soil carbon aggregates can lead to increased soil C levels (Lal., 2008; Kane, 2015).

Balanced fertilization, which is application of other essential nutrients such as N, P, and K and S, can increase crop apparent recovery of applied N, increase crop growth and maximize crop capture of CO_2 (Snyder et al., 2009). In S-deficient soils, the use of high yielding S-demanding cultivars such as canola, with too much application of N and with an insufficient amount of S, will worsen the S deficiency problem due to more rapid depletion of S from the soil, which in turn leads to poor crop yield and greater residual N in soil (Malhi et al., 2004). Malhi et al. (2004) have shown in their research, which was conducted on four S-deficient Gray Luvisols, in northern Saskatchewan, that S is a greater limitation on canola seed yield than N when neither N nor S fertilizers were applied. Moreover, to achieve any response to N fertilization, adequate supply of S and other macronutrients is critical.

Nyborg et al. (1999) and Malhi et al. (2010) have shown that N plus S fertilization increased soil organic C (SOC) in two S-deficient soils in Saskatchewan under forage and annual crops, respectively. Snyder et al. (2009) reported that N fertilization plays a significant role in SOC levels, both by augmenting crop dry matter production and by chemically stabilizing C in the soil. Malhi et al. (2012) also observed that compared to N alone, combined application of N and S fertilizers for nine growing seasons increased the LFOC and LFON in the 0-15 cm layer of the wheat-canola rotation soil by 1,018 kg C ha^{-1} (36.9%) and by 42 kg N ha^{-1} (27.5%), respectively.

1.4. Objectives of the Study

Given the above background, the overall objective of the thesis is:

- To investigate the interaction of N and S fertilization on soil C sequestration and N_2O emission in S-deficient soils.

The specific objectives of the study are:

- To estimate the effect of S fertilization on temporal changes in total SOC stocks in a S-deficient soils.
- To quantify the N_2O-N emissions over three growing seasons from S-deficient soils under two crop rotation systems, wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH), five long fertility treatments, and long-term limed and non-limed plots of Breton Classical Plots, AB, Canada.
- To quantify the effect of different N and S fertilizer sources with respect to long-term N and S fertilization history in S-deficient soils in wheat-oat-barley-hay-hay (WOBHH) rotation system.

1.5. Significance of the Study

Many soils in the Parkland region of the Canadian prairies are potentially S-deficient or have already been identified as deficient for optimum crop yields (Malhi et al., 2004; Solberg et al., 2007). Furthermore, in these regions, S is the most limiting plant nutrient in crops next to N and P (Malhi et al., 2004). S-deficiency became a widespread problem in these regions due increased crop removal of S by higher-yielding and S demanding cultivars (for example, canola), reduction in summer fallow, and an increase in cropping intensity which in turn increases the rate of S depletion from soil (Malhi et al., 2004; Malhi and Gill., 2006).

However, there is currently limited information on the interactive effect of N and S fertilizers on TOC and N_2O emissions with respect to the long-term management history (fertilization and rotation), in the S-deficient Canadian prairie soils, particularly in the Parkland region where many Gray and Dark Gray soils are deficient in available S for optimum yield (Malhi et al., 2012). Therefore, this study will improve understanding of how N and S interact in soil and affect the TOC and N_2O emissions, with respect to long-term management history (fertilization and crop rotation system). It will also contribute to the existing knowledge on best management practices (for example, fertilization and crop rotation systems), which mitigate N_2O emissions and sequester C in S-deficient soils.

1.6. Thesis Outline

The thesis is organized into five chapters and the details of each chapter are described as follows: Chapter 1 introduces the general background of this study through reviewing of the literatures, which are relevant to the objectives of the study. It mainly covers the importance of greenhouse emissions, the major microbial processes (nitrification and denitrification) of N_2O production in the soil, the major factors that affects N_2O production processes, and the agricultural management options to sequester C in soils and mitigate N_2O emissions from agricultural soils. The chapter also outlines the objectives, hypotheses and significance of the study.

Chapter 2 focuses on the findings from the field study at Breton Plots, which quantified and compared the change in total SOC over 28 years from long-term NPK and NPKS fertilized soils in a wheat-oat-barley-hay-hay cropping system at the University of Alberta Breton Classical plots.

Chapter 3 focuses on the findings from the field study for three crop growing seasons at Breton plots, which quantify the N_2O emissions from soils with different rotation and fertilization histories.

Chapter 4 focuses on the findings from a laboratory incubation experiment. It is an effort towards a better understanding of how long-term N and S fertilization history and the contemporary application of various forms of N and S fertilizers interact and influence the N_2O emissions from S-deficient soils.

Chapter 5 is a general synthesis and conclusion of the findings from the field research as well as laboratory incubation experiments. Conclusions and summary of the entire research project were drawn based on findings from each experiment. Finally, recommendations are made on the possible future direction of the research work.

Chapter 2. Long-term S-fertilization Increases Carbon Sequestration in a Sulfur-deficient Soil

2.1. Introduction

Agricultural soils may be net sources or net sinks of atmospheric carbon dioxide (CO_2) depending how they are managed (Al-Kaisi, 2008; Snyder et al., 2009; Banger et al., 2010; Huang et al., 2010). Carbon sequestration in soil has a significant impact on increasing productivity, mitigating climate change and reducing greenhouse gas emissions (Halvorson and Reule, 1999; Al-Kaisi, 2008). Carbon sequestered in the soil can be traded as a marketable product (Banger et al., 2010). Moreover, C credits can be sold in order to comply with C offset protocols (Banger et al., 2010). Soil C has a strong correlation with soil quality (Al-Kaisi, 2008; Snyder et al., 2009).

Increasing C storage in the soil has many benefits: it improves soil water holding capacity, improves soil aggregate stability to resist erosion, provides the major natural source of nutrients and microbial energy, promotes soil aggregation and root development, improves water infiltration and water use efficiency and favors the development of antagonistic organisms that serve to combat certain plant diseases (Al-Kaisi, 2008). Soil management practices that optimize plant yield through fertilization and minimize soil disturbance can reduce C losses in the soil due to oxidation and erosion (Al-Kaisi, 2008).

Good fertilizer management enhances the sequestration of atmospheric CO_2 into the soil by alleviating nutrient deficiency, increasing plant growth and yield and, as a result, returning more C into the soil (Snyder et al., 2009; Banger et al., 2010; Huang et al., 2010; Malhi et al., 2010). Optimized fertilizer management is important to increase fertilizer use efficiency and reduce fertilizer losses to the environment (Snyder et al., 2009). Balanced fertilization considers crop requirements of all macronutrients (N, P, K, Ca, Mg and S) and their interactions (Havlin et al., 1999). Balanced crop nutrition contributes to an increase in dry matter yield and root mass, which may increase in soil C (Snyder et al., 2009). Furthermore, balanced fertilization at rates compatible with crop demands has the potential to improve soil quality and nutrient and water use efficiency (Havlin et al., 1999; Snyder et al., 2009).

Sulfur (S) deficiency is becoming more frequent in many agricultural areas of the world (Solberg et al., 2007; Scherer, 2009; Jamal, 2010). For example, naturally occurring S-deficient soils occupy an area of about 4 million ha in the cultivated areas of the Canadian Prairie Provinces (Solberg et al., 2007). The major reasons for S deficiency in the soil are: low S in soil parent material, lack of S fertilizer application (or imbalanced fertilization), greater export of soil S through the harvest of high-yielding crops, decreased sulfur dioxide (SO_2) emissions from industrial sources (Solberg et al., 2007; Scherer, 2009; Jamal, 2010), lack of S as a contaminant in fertilizers and the decreasing use of S-containing fungicides and pesticides.

Unbalanced fertilization (inadequate amounts of the macronutrients N, P, K and S added in fertilizers) has been reported in many long-term experiments (Malhi et al., 2010). Both N and S are required for crop growth and microbial activity, so S deficiencies will restrict crop utilization of N fertilizer as well as nutrient cycling from organic matter mineralization (Jamal, 2010). Nyborg et al. (1999) and Malhi et al. (2010) have shown that N plus S fertilization increased soil organic carbon (SOC) in two S-deficient soils in Saskatchewan under forage and annual crops, respectively. Snyder et al. (2009) reported that N fertilization plays a significant role in SOC levels, both by augmenting crop dry matter production and by chemically stabilizing C in the soil. However, there is currently limited information on the interactive effect of N and S fertilizers on SOC in the S-deficient soils of the Parkland and Boreal Transition Ecoregions (Malhi, 2012). Available information on the effect of long-term NPKS fertilization on SOC stocks compared with NPK alone in S-deficient soils is limited. We hypothesized that long-term S-fertilization in a S-deficient soil would increase total soil organic carbon (SOC) over the long-term. Our study provides the unique opportunity to quantify the effect of combined application of NPK and S on the change in soil organic carbon. Understanding the effect of S fertilization on SOC sequestration will contribute to the adoption of appropriate fertilizer management practices for SOC storage in the soil. Therefore, the objective of this study was to estimate the effect of S fertilization on temporal changes in total SOC stocks in a S-deficient soil in the Boreal Transition Ecoregion of Alberta.

2.2. Material and Methods

The Breton Classical Plots were established at Breton, AB, in 1930 to address production challenges on Gray Luvisolic soils in west-central Alberta. These soils are difficult to manage because they are low in organic matter, moderately acidic and low in several plant nutrients such as sulfur. Details of the experimental design and treatments of the Classical Plots can be found in Dyck et al. (2012). Briefly, the Classical Plots have eight fertility treatments (referred to as plots) super-imposed on two cropping rotations. The two rotations are a 2-yr wheat-fallow and a 5-yr Wheat-oat-barley-hay-hay. The forage crops were varied over the years; initially the forage crops were clover (red or sweet)-alfalfa or clover (red or sweet)-grass mixes, but since 1967 the hay phases of the rotation have been an alfalfa-brome mixture. All fertilizers were applied every other year until 1964, afterwards fertilizers were applied annually with seed-applied phosphorus and broadcast N, K and S incorporated with pre-seeding tillage for grains and broadcast for hay. Prior to 2000, all above-ground biomass (grain and straw) was removed from plots at harvest.

However, since 2000, straw has been returned to the plots with the use of a straw-spreader on a combine harvester. Prior to 1964, tillage was used to control wild oats and broadleaf weeds, but subsequently herbicides have been used on the plots for weed control. In the wheat and oat phases of the rotation, plots were tilled once each spring before planting and once each fall after harvest. The tillage depths varied over the years between 10 and 15 cm. (Grant et al., 2001; Dyck et al., 2012).

The samples analyzed in this paper were taken from the NPKS and NPK treatments of the 5-yr rotation. Grain and hay yields were measured on an annual basis with four 1-m^2 subsamples from each grain plot, and two 6-m x 1-m strips for each forage plot. This paper compares SOC concentrations in soil samples from plots 3 and 7 of the classical plots representing NPKS and NPK fertility treatments. The fertility treatments have been consistent since 1980 (Table 2-1). Prior to 1980, however, both plots received NPKS fertilizers at the rates listed in Table 2-1 since 1964. Prior to 1964, only P fertilizer [triple super phosphate (TSP)] was applied to plot 7. From 1972 to the present, lime was applied to the eastern half of both plots whenever soil pH was lower than 6, to raise soil pH to 6.5, but prior to 1972, lime was only applied to plot 7 (6.6 Mg ha^{-1} between 1930 and 1948). In 1980, S was no longer applied to plot 7 to better test the crop responses to individual nutrients and the fertilizer rates were updated to reflect higher nutrient application rates commonly used for modern cereal varieties (Table 2-1). The dataset for this work is based on SOC measurements of soil samples taken from limed and unlimed halves of plots 3 and 7 (Table 2-1). Soil samples were collected in the fall of 1979, the spring of 1980 and the fall of 1990, 1998, 2003 and 2008. Because of the small number of samples taken in 1979 and because the 1979 and 1980 sampling times were only separated by the winter season (not a growing season), we feel it is justified to consider the 1979 and 1980 samples as one sampling period and we will refer to them as the samples collected from 1980.

Table 2-1. Treatment descriptions in the Breton Classical Plots study, where the soil samples were taken.

Treatments 1930-1979 inclusive						Treatments, 1980 onward				
		kg ha^{-1}					kg ha^{-1}			
Plot	Treatment	N	P	K	S	Treatment	N	P	K	S
3	NPKS	10	6	16	10	NPKS	-[z]	22	46	5.5
7	NPKSL[y]	11	6	16	9	NPK	-[z]	22	46	0

[z] N amount depends on the crop and its place on rotation: wheat on fallow (90 kg N ha^{-1}), wheat after forage (50 kg N ha^{-1}), oat or barley after wheat (75 kg N ha^{-1}), barley under seeded to hay: 50 kg N ha^{-1} and legume-grass forages: 0 kg N ha^{-1}.

[y] This treatment received an additional 6.6 Mg ha^{-1} of lime prior to 1972 and only P fertilizer (TSP) prior to 1963.

Because of the age of the Classical Plots, the fertility treatments are not randomized and the rotations are not fully phased, so the number of plots sampled at each collection time is 5 (one for each crop in the rotation). For all years from 1980, two to four samples were taken from each plot (limed and unlimed halves of each plot equally represented, labeled and stored separately) resulting in a total of 10-20 samples for each plot. Given that the area of each experimental plot is large, the samples were separated by at least 1 or 2 m and we assume that all samples from a given fertility treatment within and between the five plots are statistically independent.

Following collection, the soil samples were dried at room temperature and ground to pass through a 2-mm sieve and stored in glass jars in an un-insulated storage building in an air-dry condition at the University of Alberta Ellerslie Research Farm. Bulk density was calculated at the time of sampling. The bulk density of the soil was determined using a truck-mounted soil core tube (2.5 cm diameter), by weighing the wet core and drying a subsample of the soil at 105 ^{0}C to correct for water content (McKeague, 1978). In 2011, sub-samples from the archived samples were sent to the University of Alberta Natural Resources Analytical Laboratory (NRAL) and Exova Laboratories in Edmonton, AB, and analyzed for SOC and total nitrogen (N). Soil organic carbon (SOC) in the soil was determined by the loss on ignition method, which gave quantitative oxidation of organic matter (Lim and Jackson, 1982) and the Leco combustion method (Nelson and Sommers, 1996). Total N was determined by the Leco combustion method (Bremner, 1996). The present paper mainly focuses on the treatments effect on SOC.

2.3. Data Analysis

Bulk density did not change with time and did not differ between treatments. The mean bulk density of the samples was 1.4 g cm^3. Therefore, the concentration of SOC in the samples was used for treatment comparisons. Standard errors in SOC (%) were calculated using bootstrap methods (Hesterberg et al., 2010). Since the experimental design violates the assumptions of parametric tests such as ANOVA, non-parametric permutation tests (Hesterberg et al., 2010) were used to execute statistical hypothesis testing. For this dataset, we are interested in the effect of S-fertilization on the change in SOC over time. Therefore, we used a permutation method to test the null hypothesis that the difference between the changes in SOC versus time for the NPKS and NPK treatment is zero:

$$H_0: \frac{dTOC_{NPKS}}{dt} - \frac{dTOC_{NPK}}{dt} = 0 \quad [1]$$

A permutation test involves the non-parametric construction of a test statistic distribution using the measured data under the assumption that there is no treatment effect. In this case, the following algorithm was followed:

1. An equal number (N/2) of samples from each treatment were randomly sampled without replacement for each sampling time and the slope of SOC versus time for the sampled data was calculated.

2. Step (1) was repeated to estimate another slope and the difference between the two slopes was Calculated.

3. Steps (1) and (2) were repeated 10,000 times to construct a sampling distribution of the difference between the slope of SOC versus time assuming there is no treatment effect (i.e., the mean of this sampling distribution is zero and the variance depends on the variability of the data).

The P value is estimated by determining the percentile of the value of the actual (observed) difference in slope between the two treatments $\frac{dTOC_{NPKS}}{dt} - \frac{dTOC_{NPK(-S)}}{dt}$ from the sampling distribution:

$$P = 1 - F\left(\frac{dTOC_{NPKS}}{dt} - \frac{dTOC_{NPK(-S)}}{dt}\right) \quad [2]$$

Where P is the P-value and F is the cumulative distribution function of the difference in the slope of TOC versus time. This is a one-tailed test which makes the alternative hypothesis:

$$H_A: \frac{dTOC_{NPKS}}{dt} - \frac{dTOC_{NPK(-S)}}{dt} > 0 \quad [3]$$

All calculations were executed in MathCad version 15 (Parametric Technology Corporation).

2.4. Result and Discussion

Previous studies have reported an increase in SOC due to NPK fertilization alone (Purakayastha et al., 2008; Banger et al., 2010; Bhattacharyya et al., 2010; Huang et al., 2010; Nie et al., 2012). Purakayastha et al. (2008), in a long-term fertilization experiment, in Delhi, India, cultivated intensively with maize, wheat, cowpea rotation, observed a 4.5 Mg C ha^{-1} yr^{-1} increase in SOC over 10 yr. The NPK fertility program helps to increase the soil organic matter by increasing plant growth, and subsequently returning organic C into the soil (Purakayastha et al., 2008). In contrast to this, Su et al. (2006) reported that application of inorganic fertilizer (NPK), in a long-term fertilization experiment in the arid region of northwest China, resulted in a decrease in SOC by 18%, on average, compared with the initial value at the beginning of the experiment, and had no significant influence on SOC compared with an un fertilized treatment. Regardless of all these contradictory reports concerning NPK influences on SOC, our results show that NPK fertilizer increased SOC. However, application of NPK in combination with S in a S-deficient soils resulted a higher concentration of SOC compared with NPK fertilization alone.

Mean grain and forage yields from the NPK and NPKS treatments averaged over time periods between soil sampling are presented in Table 2-2. The effects of removing S from plot 7 in 1980 (when it became NPK) on grain and hay yields were not apparent until the 1991-1998 period. This is likely a result of residual S remaining from ammonium sulfate applied from 1964 to 1980. From 1991 onward, the NPK treatment had lower average yields than the NPKS treatment.

The mean estimated bulk densities of the NPKS and NPK plots were 1.41 g cm^3 and 1.40 g cm^3 with standard deviations of 0.2 and 0.1 g cm^3, respectively. Figure 2-1 shows the change in SOC concentration in the soil under NPKS and NPK fertilization as a function of time. Both treatments show an increase in SOC concentration with time, but closer inspection of the data shows very little change in the NPK treatment until after 2003. In 1998, the SOC concentrations of the two treatments were very similar, which may be explained by lower yields and growing season precipitation in the years prior to this sampling (1991-1998; Table 2-2).

However, there was a noticeable increase in SOC with both treatments between 2003 and 2008 sampling dates. The main reason for this could be that prior to 2000 the straw was removed from the plots. However, since 2000 straw has been returned for both treatments and this account for the rise of the SOC in those years. The increases in SOC in both treatments with time suggest that long-term crop rotation has increased the C storage of this soil. This may be attributable to the increased organic matter inputs from the roots and litter of the grain and forage crops following conversion to agriculture. The soil at this site was originally under a boreal forest ecosystem where the majority of organic C resided on top of the mineral soil in the LFH layer. This carbon-rich LFH layer was likely removed with the forest when the land was converted to agriculture, leaving a mineral soil low in organic C, but not without the capacity to store more C.

Table 2-2. Summary of average growing season precipitation, grain and hay yield for the NPK and NPKS fertility treatments of the 5-year rotation (WOBHH) of the Breton Classical Plots.

Time period	[x]Average growing season precipitation (mm)[z]	Average wheat grain yield (kg ha^{-1})		Average barley grain yield (kg ha^{-1})		Average oat grain yield (kg ha^{-1})		Hay yield (sum of 2 cuts kg ha^{-1})[y]	
		NPK	NPKS	NPK	NPKS	NPK	NPKS	NPK	NPKS
1980-1990	454	3079	2889	2745	2887	4044	4202	3274	3490
1991-1998	377	2011	2672	2581	2674	3461	3597	2426	3650
1999-2003	360	2111	2991	2603	3378	2746	3264	2864	4280
2004-2008	402	1950	2452	3490	3759	4713	5933	2521	4262

[z] Average of April – September precipitation.

[y] Two cuts of hay were not possible in every year.

[x]Averages are over periods of time corresponding to the period prior to soil samples taken in 1990, 1998, 2003 and 2008.

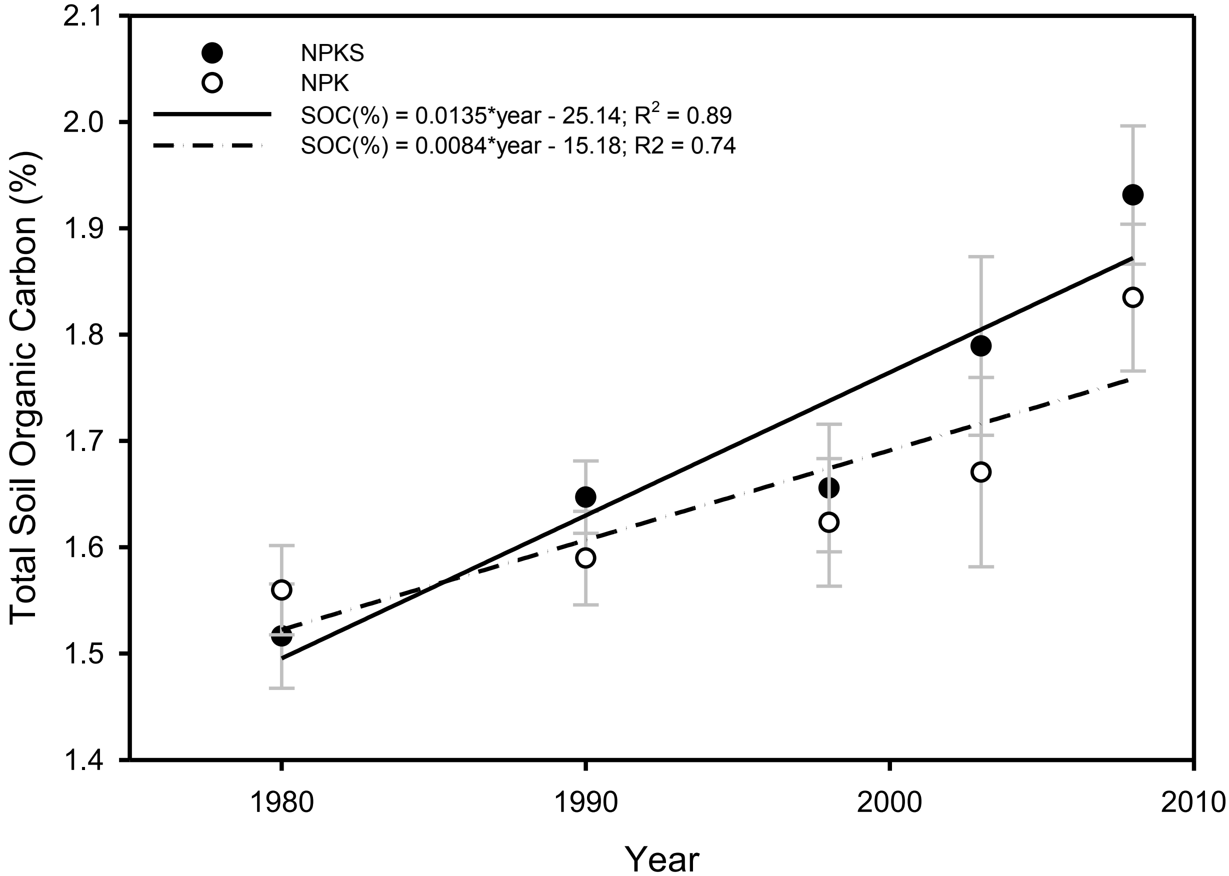

Figure 2-1. Changes in SOC concentration with time and linear trends. The circles represent the mean and error bars represent the bootstrap-calculated standard error.

The permutation analysis indicated that the difference between the slopes of the two lines was significantly different from zero using the Exova data and the combined data from both laboratories (Table 2-3; $P < 0.05$). It appears that S fertilization (in addition to NPK) significantly influenced the rate of change of total SOC stocks in this S-deficient soil. The estimated difference between the two slopes is 0.005% yr^{-1} (combined data; Table 2-3) or 0.11 Mg C ha^{-1} yr^{-1}.

Table 2-3. Summary of statistical comparisons and estimates of mean changes in SOC over time from treatments 3 (NPKS) and 7 (NPK) from the Breton Classical Plots.

Laboratory	Characteristics of sampling distribution of $\frac{dTOC_{NPKS}}{dt} - \frac{dTOC_{NPK(-S)}}{dt}$			Observed statistic	P value
	1st quartile	median	3rd quartile		
Commercial	-0.0021	-0.000013	0.0021	0.0057	0.041*
University of Alberta	-0.0020	-0.000027	0.0019	0.0043	0.064
Combined	-0.0019	0.000017	0.0020	0.0050	0.039*

* Significant at the P < 0.05 level.

In line with the findings of this experiment, in a Dark Grey Chernozemic soil under a perennial forage rotation in Saskatchewan, Malhi et al. (2010) and Nyborg et al. (1999) observed increases of 6.3 to 7.0 Mg C ha^{-1} in the top 0.05 m in N+S fertilizer treatments over and above N only fertilizer treatments in a span of 10 and 26 yr, respectively (0.63 Mg C ha^{-1} yr^{-1}; 0.26 Mg C ha^{-1} yr^{-1}). Further, Malhi (2012) in a Gray Luvisol under a wheat-canola rotation in Saskatchewan observed a 2.9 Mg C ha^{-1} increase in SOC over 9 yr (0.24 Mg C ha^{-1} yr^{-1}) in the top 0.15 m soil layer when comparing N+S fertilizer treatments to N-only fertilizer treatments.

The relatively low rate of C sequestration in the Breton soil in the current study as compared with the Saskatchewan soils reported by Malhi (2012) and Malhi et al. (2010) may be partially explained by the management history. As indicated in Table 2-1, both plot 3 (NPKS since 1930) and plot 7 (currently NPK) received S fertilization from 1964 to 1979, but S fertilization was continued only in plot 3 after 1980. Since plot 7 received S fertilization for 15 yr of application prior to a change in treatment, it is likely that residual S from the previous 15 yr was available to crops for a period of time after application ceased in 1980.

The results obtained are also in agreement with the earlier findings of Nie et al. (2012), who reported that S fertilization in combination with NPK increased the SOC of the soil. Although an increase in SOC in the soil due to NPKS fertilization could be explained by the increase in the dry matter yield or root mass resulting from balanced fertilization (Malhi and Gill, 2002; Malhi et al., 2010; Malhi, 2012), in our case, yield differences between the two treatments for the cereals did not become apparent until 1999, and forage yield differences did not appear until about 1991. Regardless of yield differences, changes in SOC were apparent within the first 10 yr of treatment implementation.

Our results are also corroborated by earlier work of Nyborg et al. (1993), who reported that annual application of 112 kg of N and 11 kg of S ha^{-1} for 11 yr to native grasses on a Dark Gray Chernozemic soil, in north-central Saskatchewan, increased light fraction C in soil by 8 Mg C ha^{-1} in the 0-to 37.5-cm depth. In this context, Janzen et al. (1998) reported that although the magnitude of benefit depends on the indigenous fertility of the soil, alleviation of nutrient deficiencies by applying inorganic fertilizer can increase SOC by several Mg C ha^{-1}. Findings from this study demonstrate that application of S in combination with NPK has a potential for augmentation of C sequestration in prairie soils and thereby contribute to sustainable agriculture.

2.5. Conclusion

Annual combined application of NPK with S (i.e., NPKS) at the Breton Classical Plots has resulted in greater average grain and hay yields and, as a result, an average net SOC increase of 0.11 Mg C ha^{-1} yr^{-1} over and above NPK fertilization alone between 1980 and 2008. Our result is a good indicator of the potential of long-term S fertilization in the accumulation of soil C in the S-deficient soils. Although the net C sequestration on S-deficient soils is enhanced with S fertilization, it is dependent on crop rotation (i.e., perennials versus annuals), current management practices (tillage frequency) and management history (i.e., previous fertilization, straw return to soil). For example, because straw was returned to the soil since 2000, the pattern of the C sequestration was changed. i.e., the difference between two treatments in terms of C sequestration was noticeable since 2003. Increased C sequestration caused by S fertilization on S-deficient soils could be considered for augmented C credits in Alberta, in addition to those associated with optimum tillage and N fertilizer management.

Our results have significant implications for soil C sequestration potential in S-deficient soils of Canada. S-fertilization in combination with NPK will help to enhance the capacity of C sequestration and improve the soil quality in prairie soils. Therefore, combining S fertilization with NPK fertilizer improves soil quality and could have a positive impact on crop productivity in the long-term. While our study has demonstrated an increase in soil SOC content resulting from long-term S fertilization in a S-deficient soil at Breton Plots, Alberta, we strongly recommend that more observations at other sites are required for a more accurate estimate of the mean S fertilization- induced soil C sequestration.

Chapter 3. Growing Season N_2O-N Emissions from a Gray Luvisol as a Function of Long-term Fertilization History and Crop Rotation

3.1. Introduction

As a result of soil biological processes involved in N cycling - nitrification and denitrification - agricultural soils emit approximately 10.3-12.8 Tg N_2O-N year^{-1}, and research efforts have been focused on possible mitigation of agricultural nitrous oxide (N_2O) emissions through reduction of soil emissions (Butterbach-Bahl et al., 2013). However, due to greater variability in environmental conditions (soil and air temperature, precipitation, soil moisture, oxygen concentration, amount of available carbon and nitrogen and soil C/N ratio), research results of N_2O emissions are inconsistent (Drury et al., 2006; Koga 2013; Signor et al., 2013). Moreover, N_2O and carbon dioxide (CO_2) emissions from soils are also influenced differently by the forms and amount of N fertilizers and the type of manure applied (Snyder et al., 2009; Koga, 2013).

Long-term manure application is believed to increase C sequestration and fertility; however, the presence of easily available C contained in manure may stimulate denitrification (Velthof et al., 2003). In addition, long-term soil management practices such as crop rotation practices, liming, crop residue management, soil tillage, and the interaction among these factors affect N_2O emissions (Drury et al., 2006; Snyder et al., 2009). For example, Barton et al. (2013) reported that the cumulative N_2O emissions from a wheat-wheat rotation decreased following liming which reduced N_2O emissions following summer-autumn rainfall events.

Nutrient use efficiency (NUE) and soil greenhouse gas emissions have a strong linkage to soil and fertilizer management - often, higher crop yields and N uptake are associated with higher N_2O emissions (Van Groeningen et al., 2010). Thus, in order to compare the impact of different fertilizer management practices, expressing N_2O emission per unit of yield or per unit of crop N uptake can be useful (Snyder et al., 2009; Van Groeningen et al., 2010). Although it is challenging to achieve simultaneously higher yield and effective NUE (Cassman et al., 2003), best fertilizer management practices (BMP) such as 4R Nutrient Stewardship (application of the right nutrient source, at the right rate, in the right place and at the right time) improve crop yield, increase NUE, and potentially reduce N_2O emissions (Snyder et al., 2009). In this context, van Groeningen et al. (2010) suggest that instead of focusing on reducing N application rate, fertilizer management practices should focus on maximizing the N uptake and increasing the NUE. They also concluded that N_2O emissions should be assessed as a function of crop yield and N uptake (i.e., N_2O emission intensity) rather that expressing it as a function of land area or N application rate.

Many soils in the Parkland region of the Canadian prairies are potentially sulfur (S)-deficient or have already been identified as S-deficient for optimum crop yields (Malhi et al., 2005; Solberg et al., 2007). S-deficient soils in this region potentially constitute 12 million ha, and these soils are widely used for agricultural production (Solberg et al., 2007). Furthermore, in these regions, S is the most limiting plant nutrient in crops next to N and phosphorus (P) (Malhi et al., 2005). S-deficiency became a wide spread problem in these regions due increased crop removal of S by higher-yielding and S demanding cultivars (for example, canola), reduction in summer fallow, and an increase in cropping intensity which in turn increases the rate of S depletion from soil (Malhi et al., 2005; Malhi and Gill., 2006).

Nyborg et al. (1999) and Malhi et al. (2010) have shown that N plus S fertilization increased soil organic carbon (SOC) in two S-deficient soils in Saskatchewan under forage and annual crops, respectively. Giweta et al. (2014) showed that N plus S fertilization increased SOC at the Breton Plots in west-central Alberta. Snyder et al. (2009) reported that N fertilization plays a significant role in SOC levels, both by augmenting crop dry matter production and by chemically stabilizing C in the soil. Malhi (2012) also observed that compared to N alone, combined application of N and S fertilizers for nine growing seasons increased the light fraction of carbon (LFOC) and light fraction of nitrogen (LFON) in the 0-15 cm layer of the wheat-canola rotation soil by 1,018 kg C ha^{-1} (36.9%) and by 42 kg N ha^{-1} (27.5%), respectively.

However, there is currently limited information on the effect of the long-term inorganic fertilizer and manure fertilization and crop rotation practices on N_2O-N emission in the S-deficient Canadian prairie soils, particularly in the Parkland region where many Gray and Dark Gray soils are deficient in available S for optimum yield (Malhi et al., 2010). The effects of long-term soil management practices (fertilization, crop rotation and liming) on N_2O-N emissions from S-deficient agricultural soils in Western Canada have not been widely investigated and warrant further attention.

Therefore, the main objective of this study aimed to quantify N_2O-N emission over three growing seasons from S-deficient soils under two crop rotation systems, wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH), five long-term fertility treatments, and long-term limed and non-limed plots at Breton, Alberta, Canada. Studies on the long-term managed plots are necessary to investigate the tangible response of N_2O emissions. Long-term cropping system (crop rotation) and fertilization (fertility) experiments such as "Breton Plots" provide unique opportunities to elucidate the effect of the long-term fertilization history on the nutrient uptake, NUE and N_2O emissions.

The overall hypothesis underlying the research presented here is that long-term rotation and fertilizer treatments are factors that would significantly influence growing season total N_2O-N emissions and intensity of emissions, and also fertilizer N_2O-N emission factors. Specifically: 1) N_2O-N emissions would be higher in the long-term manure fertility treatment than the other fertility treatments (2) Cumulative N_2O emission would be higher in the five-year rotation (wheat-oat-barley-hay-hay - WOBHH) than the two years (Wheat-fallow - WF) crop rotation; and (3) N_2O-N emission intensity (kg of N_2O-N per kg of crop N uptake) would be lower in soils with a long-term history of combined N and elemental S fertilization). The outcome of this research would provide suggestion on fertilizer management practice for annual crops production in S-deficient soils of Western Canada that can improve NUE, N uptake and yield, while decreasing nitrous oxide emissions.

3.2. Material and Methods

3.2.1. Study Site Description and Field Management

The research was carried out on a long-term experimental field at the University of Alberta, "Breton Classical Plots", which was established in 1930 near Breton, AB, Canada (53^0 07' N, 114^0 28' W). The soils at the plots are classified as a Gray Luvisols with moderate to poor drainage, slightly acidic pH and S-deficient (Dyck et al., 2012). The mean annual air temperature and precipitation at the site are 2.1 ^{0}C and 547 mm, respectively (Grant et al., 2001). The potential evapo-transpiration is 732 mm (Izaurralde et al., 1995A).

The "Breton Classical Plots" were established in 1930 for two main reasons: a) to test which nutrients were deficient in local soils; and b) to get a better understanding which crop rotations performed best (Dyck et al., 2012). Details on the experimental site and the layout of the Breton plots have been reported by Dyck et al. (2012). There are 8 fertility treatments that have been constant since 1980 (Table 3-1). Since 1941, two rotation systems were practiced: a 2-yr wheat-fallow (WF) and a 5-year wheat-oat-barley-hay-hay (WOBHH). Table 3-1 shows the fertilizer treatments from 1930-till present. For this research, soil N_2O emissions were measured on plots 2, 3, 5, 7 and 8 of the WF and WOBHH rotations.

Table 3-1. Treatment descriptions in the Breton Classical Plots study, where the gas (N_2O) samples were taken.

Treatments 1930-1979 inclusive						Treatments, 1980 onward				
kg ha^{-1}						kg ha^{-1}				
Plot	Treatment	N	P	K	S	Treatment	N	P^x	K^x	S
2	Manure	76	42	91	20	Manure	#			
3	NPKS	10	6	16	10	NPKS	z_	22	46	Y
5	Control	0	0	0	0	Control	0	0	0	0
7	NPKSL	11	6	16	9	NPK	z_	22	46	0
8	P	0	9	0	0	PKS	0	22	46	Y
11	Control	0	0	0	0	Control	0	0	0	0

[z]N (applied as urea) rate depends on the crop and its place on rotation: wheat after forage (50 kg N ha^{-1}), oat or barley after wheat (75 kg N ha^{-1}), barley under seeded to hay: 50 kg N ha^{-1} and legume-grass forages: 0 kg N ha^{-1}.

[y]S is applied as elemental S at a rate of 5.5 kg S ha^{-1} from 1980 – 2007 and 20 kg S ha^{-1} from 2007 – present.

[x]Rates represent rates of the nutrient element rather than P_2O_5 and K_2O convention. P is applied as triple super phosphate (TSP) (0-46-0) and Potassium (K) is applied as muriate of potash (0-0-62).

[#]N application via manure depends on crop rotation. i.e., wheat-fallow: 90 kg N ha^{-1} during cropped years, and cereal crops in WOBHH rotation: 175 kg N ha^{-1} every 5 years applied in two equal applications.

Prior to 1964, all fertilizers were applied with the broadcast method and fertilizer applications were done every other year. However, after 1964, the fertilizer application method changed. N, K and S were broadcast and incorporated with pre-seeding tillage, but fertilizers were only broadcast and not incorporated for hay. Phosphorus was seed-placed for all crops (Dyck et al., 2012; Giweta et al., 2014). Lime was applied to the east half of the 5-year rotation plots and to both east and west halves of the W-F rotation plots whenever soil pH fall below 6.0 – soil pH was measured every 5 years. Lime was applied to both halves of the W-F plots because the wheat and fallow phases alternate between the two halves.

For the 5-year rotation, manure was applied twice at equal rates every five-year cycle in the fall, following the 2nd growing season of hay, incorporated with hay plough down and following oats. For the WF rotation, manure is incorporated every fall at the end of the fallow phase. Further to the fertilizer application, since 1972 periodic liming (every five years) of the east half of the plots in the WOBHH rotation and to both halves of the plots in the WF rotation enabled the soil pH to be maintained near 6.5.

The forage crops that were included in the crop rotation varied over the years. However, since 1967, alfalfa-brome mixtures have been used in the hay phase of the crop rotation. Prior to 2000, a binder was used for crop harvest, and straw was removed from the all plots. Subsequently, a combine harvester was used for crop harvest and straw has been retained in plots. Similarly, weed control and tillage have varied over the years, i.e., since 1964 herbicides were used to control weeds, but prior to 1964 tillage was used to control broadleaf weeds and wild oats. The depth of tillage was within the range of 10-15 cm (Grant et al., 2001; Dyck et al., 2012).

3.2.2. Gas Fluxes (N_2O and CO_2) Measurement

Measurements of gas (N_2O and CO_2) fluxes were conducted in growing seasons of 2013 (14 measurements, 8 June to 29 August), 2014 (14 measurements, 22 May to 21 August) and 2015 (15 measurements, 15 May to 20 August) twice per week always between 10:00 am to 16:00 pm (Mountain Standard Time). Therefore, over the three growing seasons, gas sampling was conducted for a total of 43 weeks.

The nonsteady-state chamber method (Rochette and Bertrand, 2008) and a 1312 Photoacoustic Multi-gas Monitor (Innova Air Tech Instruments, Ballerup, Denmark) was used to measure the gas fluxes from both wheat and fallow phases of the WF rotation and in the wheat phase of the WOBHH rotation, (limed and unlimed subplots): treatments: (1) Control – plots 5 and 11, (2) Manure – plot 2, (3) NPKS – plot 3, (4) NPK(-S) – plot 7 and (5) PKS(-N) – plot 8. Due to the annual crop rotation cycle of the plots, wheat was in series D in 2013, series F in 2014, and series A in 2015, while wheat-fallow was in series E consistently throughout the gas sampling period.

In 2013, 2 chamber collars were installed in each plot - one in the east half and one in the west half (6 plots x 2 rotations x 2 chambers; N = 24). For 2014 and 2015, 4 chamber collars were installed in each plot - 2 per half following fertilizer incorporation and seeding (N=48). Gas chambers consisted of the chamber body and a detachable, vented lid. Lids were used only during gas flux measurements. The chamber bodies were inserted 5 cm into the soil such that 10-cm remained above the surface and any loose soil near the walls at the soil surface was pressed against the walls in order to make sure the chamber had no gas leakage. The chambers were rectangular plastic (65 cm x 16 cm x 15 cm), and with detachable lids and collars.

The chamber bodies were positioned perpendicular to the crop rows in order to cover emissions from crop rows and inter-row areas. The above-ground portion of the chamber bodies and chamber lids were covered with adhesive, reflective aluminum insulation in order to reduce light penetration and heating during gas flux measurement. The chamber bodies remained installed in each of the plots until crop harvest and the end of gas measurement. However, prior to gas sampling, whenever necessary, the plants were cut to a height of 7 cm within the chamber area. Furthermore, at each measurement time, weeds/unwanted plants were removed from the chambers in order to impede the interference of the measurement of N_2O from the main crop (wheat) in the plots and the soil.

During gas flux measurements, the lids were fastened to the chamber bodies using rubber bands. Gas measurements, from the head space of the chamber, were done in sets of 3 with sampling at 0, 9, 18, 27 minutes, after placing the lid on the collar. Gas concentrations were measured with a Innova 1312 photoacoustic gas monitor connected to ports on the chamber lid with plastic tube (the gas monitor required 1.2 minutes to measure the gas concentrations). The gas in the head space of the chambers was mixed between gas measurements, using small fans under the lids/cover of the chambers. After completion of gas sampling from each set of three chambers, the lids of the chambers were removed and chambers remained open until the next measurement period. Therefore, the gas fluxes were calculated from the concentration change in the chamber headspace over the 27-min sampling period (slope).

Since it was difficult to complete the gas measurements from the whole sets of 48 chambers in a one day in 2014 and 2015, the measurements were made on one set (24 chambers) at a time or in the same day, and the rest (24 chambers) were measured the following day within the week.

Gas (N_2O) fluxes were calculated by the following equation (Rochette and Hutchinson, 2005)

$$F = \frac{dc}{dt} \times \frac{V}{A} \qquad [1]$$

Where dc/dt is the rate of change of gas concentration in the chamber head space (mg m^{-3} min^{-1}), V= Volume of chambers (m^3), and A=area covered by chambers (m^2).

3.2.3. Soil Sample Analysis

In fall 2013, after crop harvest, soil samples were taken from Control, Manure, NPKS, NPK and PKS treatments of limed and unlimed plots of both crop rotation (wheat-fallow and wheat-oat-barley-hay-hay), at a depth of 0-7.5 and 7.5-15 cm (four locations per plot, using a shovel). After removing the course roots, plant residues and stones, the soil samples were air dried, at room temperature, and stored until further use. A portion of each sample was sent to the University of Alberta Natural Resources Analytical Laboratory (NRAL) in Edmonton, AB for analysis of total organic carbon (TOC), total nitrogen (TN), total sulfur (TS), plant available N (NH_4^+-N and NO_3^--N), sulfate-S (SO_4^--S).

To determine the TOC, TN and TS, soil samples were finely pulverised by Brinkmann ball grinder (Retsch, type MM200), dried over 24 h and analysed by the Dumas Combustion method using a Costech 4010 Elemental Analyser System (Costech Analytical Technologies Inc., Valencia, CA, USA). Then, the samples were combusted, in the presence of oxygen, under helium and the resulting gases were separated, using gas chromatography, and finally detected quantitatively by thermal conductivity detector (TCD) (AOAC, 2000). Sulfate in the soil was determined by the method of water extraction (1:5 soil: water solution) and concentrations in extracts were measured with ion chromatography (Small et al., 1975). Plant available nitrogen (NH_4^--N and NO_3^--N) were measured colorimetrically on a SmartChem Discrete Wet Chemistry

Analyser (Maynard and Kalra, 1993). Soil pH was determined using 1:2 soil: water suspension (with a pH meter), following the method by Kalra (1995).

3.2.4. Yield and N Uptake

At crop maturity, on annual basis over three years (2013-2015), four 1-m^2 quadrant subsamples of each wheat plot half were harvested for determination of grain and straw yield. The samples were dried at 60^0 C for 7 days and threshed so as to determine seed: straw ratios (Barton et al., 2013). Seed yields plus seed: straw ratios were calculated in order to determine straw yields, and a CNS combustion analyzer was used to determine total N from representative samples of both straw and seed (Malhi et al., 2010). Furthermore, seed (or straw) yield in kg ha^{-1} x total N concentration (g N kg^{-1}) in seed (or straw) x 0.001) was used to calculate total N uptake (kg N ha^{-1}) (Malhi et al., 2010).

3.2.5. Soil Environment and Climate

The amount of N_2O produced from agricultural soils is affected by climatic and environmental factors such as soil moisture, soil temperature, soil aeration etc. and management practices, which could alter these properties (Li-mei et al., 2011). Therefore, climatic data such as daily air temperature, precipitation, soil temperature, and soil moisture were collected from Alberta Agriculture and Forestry weather data website, which is linked to the meteorological station at the Breton Classical Plots.

3.3. Statistical Analysis

General linear model (GLM) procedures in the Minitab statistical software package (v. 17) were used to identify factors having a significant influence on cumulative growing season N_2O-N and CO_2-C fluxes, wheat yield, wheat N uptake at harvest (grain + straw), N_2O-N emissions intensities - kg N_2O-N per kg grain yield or kg N_2O-N per wheat N uptake and selected soil properties. Because of the inherited experimental design, east and west plot halves were not directly comparable between the two rotations – in the WF rotation, east and west halves alternated between wheat and fallow phases with regular lime additions and in the 5-year rotation, east halves received lime regularly and west halves did not. Therefore, in order to test if WF rotation phase and liming were factors that significantly affect N_2O emissions, a nested model was fit to the data from each rotation separately:

Response = Plot Half (Fertility Treatment) + Fertility Treatment [2]

Here, the model assumes that the fertility treatments are nested in the rotation phases for WF and nested in the liming treatment (5-year rotation).

For cumulative growing season N_2O-N, the Plot Half (Fertility Treatment) factor was not significant. Therefore, for response variables measured for more than one year (all but the soil properties), the following model with year as a random effect and fertility treatments nested within rotation as fixed effects was used:

Response = Year + Fertility Treatment + Year*Fertility Treatment + Rotation (Fertility Treatment) [3]

Because the soil properties included in this analysis were measured in only one year, the statistical model for soil properties was:

Soil Property = Fertility treatment + Rotation (Fertility Treatment) [4]

Fertility treatments were nested within rotation because measurements from both rotation phases were included for WF (represented as different plot halves) and data from limed and un-limed halves were included in the WOBHH rotation. Because of this, a rotation* fertility treatment interaction term was not included in the model.

Pairwise comparison of means using the Tukey test was carried when possible for significant model factors.

3.4. Result and Discussion

3.4.1. Effects of Long-term Rotation and Fertility Treatment on Soil Properties

The long-term rotation and fertility treatments have resulted in significantly different levels of soil SOC, total N, pH, and to a lesser extent, total S (Table 3-2). All fertility treatments in the 5-year rotation have accumulated more SOC and total N than their counterparts in the 2-year rotation. The greater levels in the 5-year rotation are likely a result of greater crop residue additions to soil because of more diverse and intense rotation. There is much more variability in soil total S, resulting in no apparent statistical differences, but the magnitude of the relative differences in mean total S between the fertility treatments in the two rotations is similar to the relative differences between SOC and total N.

Within each rotation, the long-term fertility treatments have also resulted in some significant differences in SOC and total N and S levels. The manure treatment consistently had the highest levels of SOC, total N and total S with the remaining treatments not being statistically different. Long-term application of manure in soil has been observed to increase soil N and organic C content in other studies (Meng et al., 2005) likely because of the high manure application rates – much greater than rates of crop residues that are returned to the soil – required to achieve a nutrient rate target result in a large addition of organic matter to the soil. For fertilized treatments, the NPKS treatment had the highest levels of SOC, total N and total S which are likely a reflection of greater crop yields and higher levels of crop residue returned to the soil over the long-term.

Table 3-2. Mean soil properties of soil at surface soils (0-15 cm) of treatments of series A, B, C, D and E and two crop rotations (wheat-oat-barley-hay-hay - WOBHH and wheat-fallow - WF) at the Breton Classical Plots (samples taken in 2013).

Crop rotation	Soil fertility treatment	SOC (Mg C ha^{-1})	Total N (Mg N ha^{-1})	C:N ratio	Total S (Mg S ha^{-1})	pH
WF	Control	19.0 d	1.8 d	10.6	0.34 b	6.4 a
	Manure	38.0 ab	3.6 ab	10.6	0.61 ab	6.6 a
	NPKS	22.0 cd	2.2 bcd	10.0	0.44 ab	5.9 abc
	NPK(-S)	19.0 d	2.0 d	9.5	0.37 ab	6.3 abc
	PKS(-N)	18.0 d	1.7 cd	10.6	0.37 ab	6.4 ab
WOBHH	Control	31.0 bc	2.9 bc	10.7	0.48 ab	6.0 ab
	Manure	47.0 a	4.4 a	10.7	0.60 a	6.2 a
	NPKS	35.0 b	3.3 b	10.6	0.52 ab	5.5 c
	NPK(-S)	33.0 b	3.1 bc	10.6	0.47 ab	6.0 ab
	PKS(-N)	34.0 b	3.2 bc	10.6	0.53 ab	5.6 bc

3.4.2. Growing Season Conditions and Crop Yields

Table 3-3 summarizes the growing season conditions for the 2013, 2014 and 2015 growing seasons. Mean growing season temperature, growing degree days (GDDs) and reference ET were very consistent between years, but growing season precipitation was significantly lower in 2015. Long-term averages for growing season precipitation, air temperature, and GDDs are 340 mm, 13.6 ^{o}C and 1066, respectively. Thus, all three years were drier and warmer than the long-term average, but 2015 was especially dry, resulting in poor growing conditions and dry soil conditions for most of June and July, 2015. The first precipitation event greater than 10 mm during the 2015 growing season occurred in the second week of July. Because the variability in growing season precipitation between the three growing seasons, year was a significant factor affecting the variability of the growing season N_2O and CO_2 emissions, wheat grain yields and N_2O-N emission intensities (Table 3-4).

Table 3-3. Summary of precipitation, air temperature, growing degree days and reference evapotranspiration (ET) during the growing season (2013-2015, May to August) at Breton Classical Plots.

Year	Growing season* precipitation (mm)	Average growing season air temperature (°C)	Growing season* growing degree days	Growing season reference ET (mm)
2013	258	14.0	1123	442
2014	249	13.8	1085	437
2015	160	14.3	1137	491

The drought in 2015 reduced wheat yields compared to the previous two growing seasons, but the relative differences in yields between the rotations and fertility treatments within and between rotations was consistent over the three growing seasons, and wheat N uptake did not appear to decrease because of the drier conditions (Table 3-4). Despite similar total growing season precipitation in 2013 and 2014, yields were higher in 2014 because of more favorable seeding conditions in the spring of 2014. Soil moisture was near saturation for the majority of June, 2013 (the month following seeding), and this likely inhibited root development in early growth stages which impacted yields.

Overall, higher yields and N uptake were observed in the 5-year rotation compared to the 2-year rotation, which is likely a reflection of the rotation effects on soil nutrient reservoirs discussed in the previous section. Reynolds et al. (2014) also observed higher yields and improved soil quality in a corn-oat-alfalfa-alfalfa rotation compared to a continuous corn rotation, in which more diverse, intense rotations appear to have larger organic matter pools and consistently have higher yields.

Table 3-4. Summary of the P value of the statistical analysis model comparing the effect of year, fertility treatments, year*fertility treatments and fertility treatment nested in rotation on cumulative growing season N_2O-N emissions, CO_2-C emissions, wheat grain yield, wheat N uptake (grain + straw), N_2O-N emissions per grain yield, N_2O-N emissions per wheat N uptake, total soil N, total soil C and soil pH.

Model Term	Growing season N_2O-N	Growing season CO_2-C	Wheat grain yield	Wheat N uptake (grain + straw)	N_2O-N per grain yield	N_2O-N per wheat N uptake	Total soil N (0-15 cm)	Total soil C (0-15 cm)	Total soil S (0-15 cm)	pH
Year	< 0.001	< 0.001	0.006	0.154	0.010	0.090				
Fertility Trt	< 0.001	0.033	0.001	< 0.001	0.014	0.101	< 0.001	< 0.001	0.015	0.002
Year * Fertility Trt	0.981	0.525	0.081	0.232	0.405	0.056				
Rotation (Fertility Trt)	< 0.001	< 0.001	< 0.001	< 0.001	0.010	0.005	< 0.001	< 0.001	0.112	0.008
Model R^2	0.71	0.81	0.87	0.84	0.62	0.68	0.71	0.78	0.27	0.47

There are also rotation effects with respect to wheat yield and N uptake response to applied nutrients. Yield and N uptake response to fertilizer N was much greater in the WF rotation compared to the 5-year rotation as observed by comparing the NPKS and PKS (-N) treatments (Table 3-5). Despite no fertilizer N applications in the PKS (-N) treatment of the 5-year rotation, significant N is added to the soil through biological fixation and residue incorporation of the alfalfa-brome hay phases. Comparing the NPKS and NPK (-S) treatments, wheat yield and N uptake are much more sensitive to applied S in the 5-year rotation compared to the 2-year rotation, because of high S removals in the alfalfa-brome phases of the 5-year rotation causing S deficiency for the following wheat phase in the absence of long-term S fertilization. In fact, wheat yields were more sensitive to S than N in the 5-year rotation as is apparent when the PKS (-N) and NPK (-S) treatments are compared (Table 3-5). Wheat yields and N uptake in the manure treatment of the WF rotation were consistently lower than the NPKS treatment (but not statistically different), but were equal in the 5-year rotation. The reason for this difference is not clear.

Table 3-5. Effect of soil fertilization history x crop rotation interaction on growing season grain yield and wheat N uptake.

Rotation	Fertility treatment	Grain yield (kg ha^{-1})			
		2013	2014	2015	3-year average*
WF	Control	522	698	823	681 d
	Manure	1572	1314	1672	1520 bcd
	NPKS	2574	3052	1975	2534 ab
	NPK(-S)	1824	2377	2038	2079 abc
	PKS(-N)	516	622	786	641 d
WOBHH	Control	1244	1499	533	1092 cd
	Manure	2245	4152	2689	3029 a
	NPKS	2475	4349	2378	3067 a
	NPK(-S)	1761	3021	802	1861 c
	PKS(-N)	2364	2531	2060	2318 ab
		Wheat N uptake – grain + straw (kg N/ ha)			
WF	Control	27	19	29	25 d
	Manure	71	37	58	56 bcd
	NPKS	116	88	79	95 ab
	NPK(-S)	89	73	87	83 abc
	PKS(-N)	24	16	30	23 d
WOBHH	Control	58	55	34	50 cd
	Manure	94	147	104	115 a
	NPKS	97	153	96	115 a
	NPK(-S)	68	93	53	72 bc
	PKS(-N)	81	69	86	79 bc

*Values in the same column by the same letters are not significantly different at ($P < 0.05$) probability level. The letters are comparing means for both rotations.

Our results indicated that, in both crop rotations, soil treatments that received N fertilizer or manure in combination with other macro nutrients for long-term, provided a higher yield. In line with our result, Malhi and Gill (2006) observed that application of fertilizer N improved seed, straw and chaff yields and root mass in barley, wheat and canola grown in rotation, However, the PKS soil under WOBHH crop rotation recorded a comparable yield with NPK soil, but not in WF and this could be explained by the fact that the PKS soil received N input from straw and crop residues (roots and stubble) in the in the 5-year rotation, and biologically fixed N from the alfalfa-brome phase of the rotation. In agreement with our result, Meng et al. (2005) observe higher yield from manure-amended plots and this may be attributed mainly to the increase in SOC and soil fertility. Furthermore, Paustian et al. (1997) reported that long-term application of mineral fertilizers such as N in combination with other macro nutrients increased the input of crop residues (roots and stubbles), and this ultimately contributed to an increase in crop yield. However, in contrast to our result, Zhang et al. (2009) reported that long-term fertilization of NPK resulted in a decline in wheat yield in red soil (Ferralic Cambisol) in China due to soil acidification and NO_3^--N leaching caused by N fertilization.

3.4.3. Growing Season N_2O-N and CO_2-C Emissions

Year was a significant factor affecting cumulative growing season N_2O and CO_2 emissions, but the 5-year rotation had consistently higher emissions and the ranking of fertility treatment mean N_2O and CO_2 emissions within each rotation was fairly consistent across years (Table 3-6).

The differences in cumulative emissions between years can be explained by the unique environmental conditions in each year. Growing season daily average air temperature, cumulative precipitation, daily volumetric water content at 5 ^{0}C, and weekly N_2O-N and CO_2-C emissions are presented in Figs. 3-1, 3-2 and 3-3. N_2O-N and CO_2-C emissions were infulenced by the preciptation amount and soil moisture content in each growing season. For example, in 2013, spring soil moisture was high (near saturation) resulting in relative high early growing season N_2O-N emissions, possibly from denitrification, and a lag in CO_2-C emissions (i.e., soil respiration) until soil aeration improved following decreased soil moisture in late June/ early July (Fig. 3-1). N_2O-N emissions increase again following a significant precipitation event of 35 mm in the second week of July and weekly emissions were relatively constant for the remainder of the growing season.

In 2014, spring moisture conditions were not as wet as 2013 so there was no lag in CO_2 emissions (soil respiration). Weekly N_2O emissions were fairly consistent and similar between the two rotations until a significant precipitation event of ~35 mm in the third week of July. N_2O emissions from the 5-year rotation responded much more than the WF rotation and emissions in both rotations decreased after the soil moisture content decreased to about 20% at the end of the growing season.

In the 2015 growing season, precipitation was below the 3-yr (2013, 2014 and 2015) average (222 mm). As a result of low rainfall, soil moisture decreased more or less continuously from mid- May until mid-July, however, rainfall increased over the last half of the growing season. Because of this, early growing season N_2O-N and CO_2-C emissions from both rotations were low and of similar magnitude. Following a number of small precipitation events in the second and third weeks of June (cumulative amount ~20 mm), soil moisture increased slightly and was followed by a large increase in air and soil temperature. Thus, starting in the last week of June, N_2O and CO_2 emissions from the 5-year rotation increased to a much greater extent than the WF rotation, though both rotations' emissions increased and were sustained by more regular rainfall.

Table 3-6. Effect of soil fertilization history x crop rotation interaction on growing season N_2O-N and CO_2-C emissions.

		Cumulative growing season N_2O-N emissions (kg N ha^{-1})			
Rotation	Fertility treatment	2013	2014	2015	3-year average
WF	Control	0.38	0.33	0.28	0.33 d
	Manure	0.78	1.18	0.42	0.79 bcd
	NPKS	0.48	1.11	0.42	0.61 cd
	NPK(-S)	0.70	0.64	0.72	0.74 bcd
	PKS(-N)	0.48	0.50	0.31	0.43 d
WOBHH	Control	1.14	1.44	0.61	1.06 bc
	Manure	1.77	1.49	1.61	1.62 a
	NPKS	1.75	1.19	0.94	1.36 ab
	NPK(-S)	1.67	1.37	0.96	1.23 ab
	PKS(-N)	1.44	1.40	0.70	1.18 abc
		Cumulative growing season CO_2-C (kg C / ha)			
WF	Control	1521	1072	714	1102 d
	Manure	3186	2194	1361	2247 abc
	NPKS	1801	1600	1036	1479 cd
	NPK(-S)	2195	2024	1144	1788 bcd
	PKS(-N)	1922	1306	781	1336 cd
WOBHH	Control	3221	3320	1710	2750 ab
	Manure	4365	3496	1697	3186 a
	NPKS	4065	2983	1800	2949 a
	NPK(-S)	4115	3127	1630	2957 a
	PKS(-N)	3830	3504	737	2690 ab

*Values in the same column by the same letters are not significantly different at ($P < 0.05$) probability level. The letters are comparing means for both rotations.

Rainfall, soil moisture content and soil temperature appears to be the main drivers for the difference in pattern of cumulative N_2O-N and CO_2-C emissions from WOBHH and WF crop rotations within the growing season in each year. In line with this, Bremner and Blackmer (1981) stated that rainfall amount and soil temperature clearly influence the microbial processes associated with N_2O and CO_2 emissions. Furthermore, Parkin and Kaspar (2004) reported that rainfall events and timing could influence the GHGs flux patterns from soil surfaces. Soil N cycling processes that produce N_2O – nitrification and denitrification – are sensitive to soil moisture and temperature. In the spring of 2013, there was a long period of near-saturated soil conditions and the high N_2O-N emission and a low CO_2-C emission during this period is consistent with anaerobic denitrification. For the rest of the measurement record, although soil moisture reaches near-saturated conditions following significant precipitation events, it was very short-lived and soil aeration conditions favored aerobic nitrification. The significant relationship between soil average cumulative N_2O-N and CO_2-C emissions (i.e., aerobic respiration) reinforces the hypothesis that aerobic nitrification is responsible for the majority of the growing season N_2O emissions (Fig. 3-4). Therefore, growing seasons with sustained soil conditions favorable for denitrification or nitrification had higher cumulative N_2O-N emissions. The distribution of rainfall and air temperature in 2014 created soil conditions favorable for sustained nitrification resulting in higher cumulative N_2O emissions than 2013 and 2015. In 2013, conditions were favorable for denitrification in the spring, but this was interrupted by a dry period where conditions were less favorable for denitrification. In 2015, soil conditions in the first half of the growing season were not favorable for denitrification or nitrification.

Despite annual variations in soil and growing conditions, average, cumulative N_2O-N and CO_2-C emissions over the three growing seasons were consistently higher in the 5-year compared to the

2-year rotation. The possible explanation for this is higher net mineralization and nitrification of previous forage residues in the 5-year rotation. In line with this, Chen et al. (2008) cited results from researchers and reported that previous crops in the rotation can contribute to an increase in easily mineralizable soil C and N, and this ultimately induce N_2O emission. Further, Farrell et al. (2015) observed that crop residues accounted for a greater fraction of N_2O emissions than chemical fertilizers.

Differences between N_2O and CO_2 emissions of the fertility treatments within each rotation were much smaller than between rotations. For N_2O, the Manure treatment of the 5-year rotation produced the highest cumulative emissions, significantly higher than the 5-year rotation control, but not significantly higher than the remaining soil treatments (Table 3-6). Similarly, in WF, cumulative N_2O-N emissions were highest in the manure treatment, significantly higher than the PKS and Control, but were not significantly different from NPKS and NPK soils. Beauchamp et al. (1989) and Wagner-Riddle (1997) observed that compared to inorganic N fertilizers addition, addition of equivalent rates of N in the form of manure had a much higher effect on N_2O emissions. Wakasawa and Kosugi (2001) and Li et al. (2002) also confirmed this and reported higher N_2O emissions from plots fertilized with cattle manure than plots fertilized with chemical fertilizers. In addition, Meng et al. (2005) reported that since long-term application of animal manure increase organic C in agricultural soil, it could feed the main microbial processes in N_2O production (nitrification and denitrification). However, since emissions from manure are dependent on application rate (VanderZaag et al., 2011), emission factors (EF) should be applied in order to compare emissions from chemical fertilizers and manure (Koga, 2013).

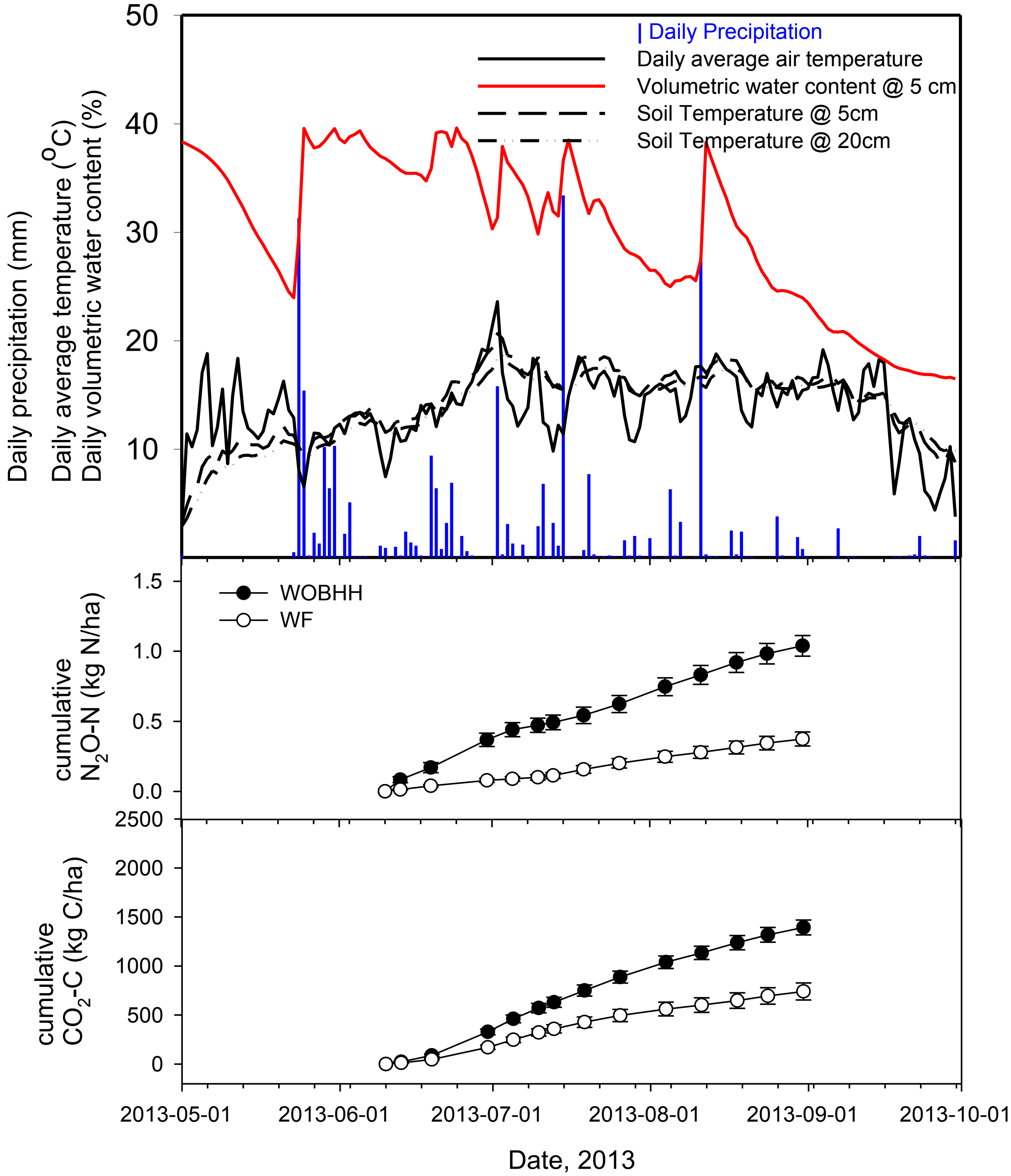

Figure 3-1. Daily precipitation, daily average air temperature, daily volumetric water content at 5 cm, daily soil temperature at 5 and 20 cm, and gas fluxes (N_2O-N and CO_2-C) over the 2013 growing season.

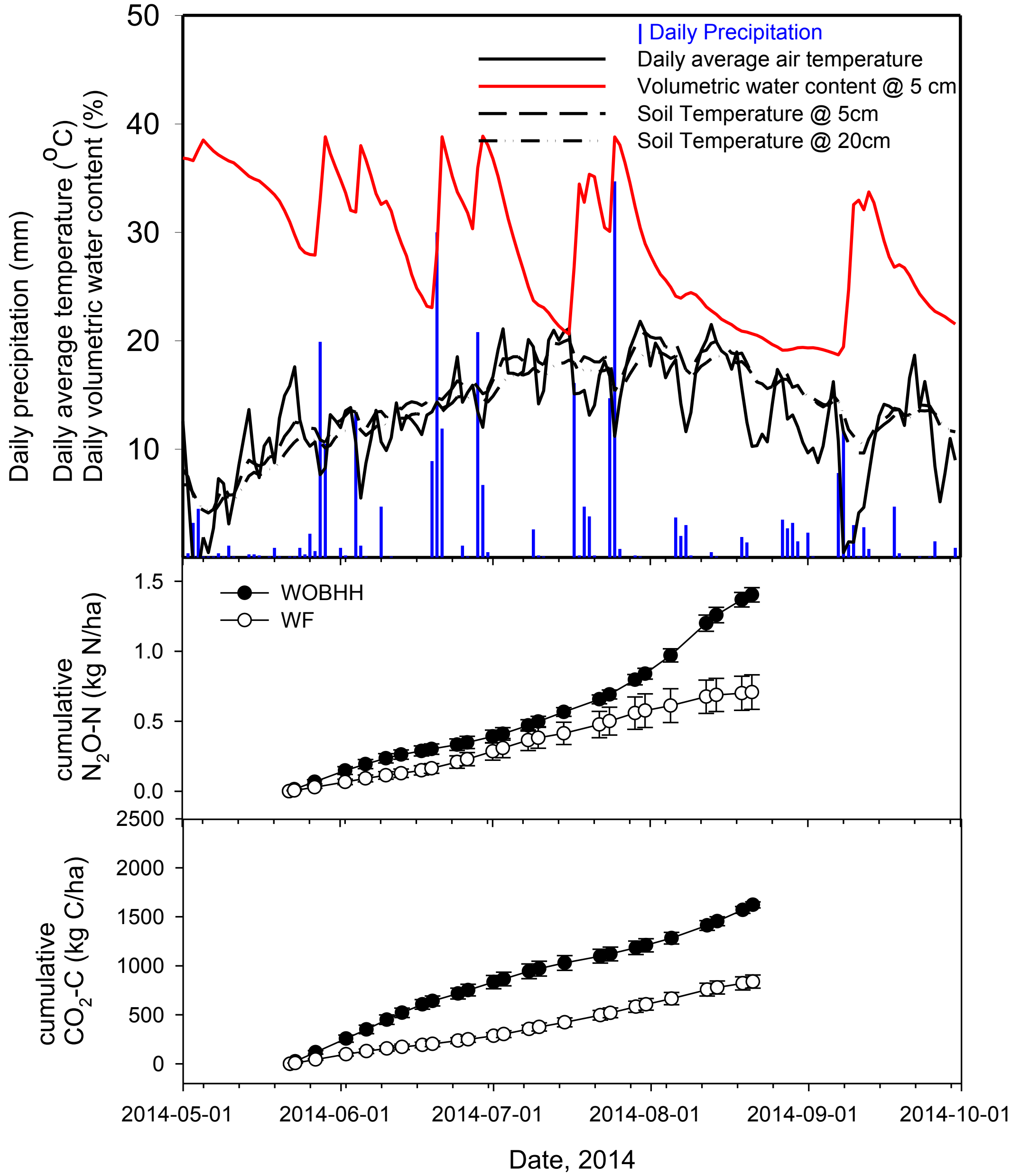

Figure 3-2. Daily precipitation, daily average air temperature, daily volumetric water content at 5 cm, daily soil temperature at 5 and 20 cm, and gas fluxes (N_2O-N and CO_2-C) over the 2014 growing season.

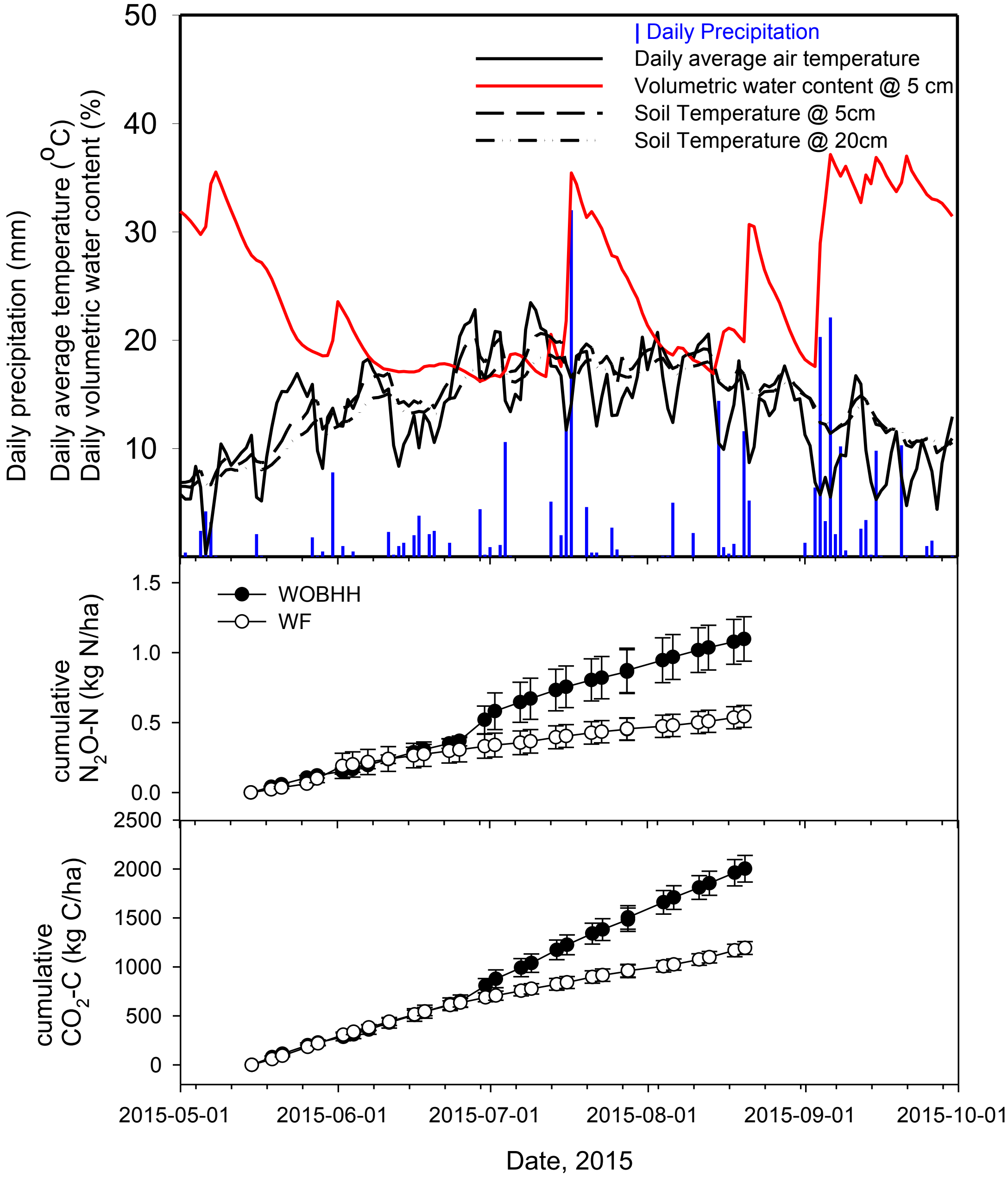

Figure 3-3. Daily precipitation, daily average air temperature, daily volumetric water content at 5 cm, daily soil temperature at 5 and 20 cm, and gas fluxes (N_2O-N and CO_2-C) over the 2015 growing season.

Therefore, 3-year average emission factors were estimated for the fertility treatments in each rotation using the 3-year average cumulative N_2O-N data. The emission factors were calculated to estimate the contribution of manure or fertilizer N to the cumulative growing season N_2O-N in each treatment and are estimated as follows:

$$F_{N2O,x} = \frac{N2O_x - N2O_0}{N_x} \cdot 100\% \qquad [5]$$

Where $F_{N2O,x}$ is the % of cumulative growing season N_2O-N attributed to applied fertilizer or manure N for treatment x; $N2O_x$ and $N2O_0$ are the cumulative growing season N_2O-N emissions from treatments x, and a control or reference treatment without added fertilizer or manure N, respectively (kg N/ha); and N_x is the rate of applied fertilizer or manure N (kg N/ha) in treatment x.

Using Eq. [5], two sets of emission factors for the NPKS, NPK (-S) and Manure treatments of both rotations were calculated. The first and second sets of emission factors were calculated using the Control and PKS (-N) as the reference treatments, respectively (Table 3-7). First, it should be noted that all estimated emission factors are less than the 1.25% recommended by the IPCC (Lemke et al., 2010). For both rotations, the emission factor for manure is about 40% greater than for fertilizer N in the NPKS treatment and the emission factors for 5-year rotation are twice that of the WF rotation.

In the WF rotation manure and fertilizer emission factors are much closer when comparing the manure and NPK (-S) treatments, but emission factors for the NPK (-S) treatment in the 5-year rotation are much lower than NPKS or manure treatments. In the 5-year rotation, S significantly influences the productivity of the alfalfa-brome and wheat phases of the rotation. Further, reduced wheat N uptake was observed in the NPK (-S) treatment of the 5-year rotation. Thus, there appears to be a synergy between fertilizer N application, N from previous crop residues and S deficiency with respect to N_2O emissions in the wheat phase of the five-year rotation.

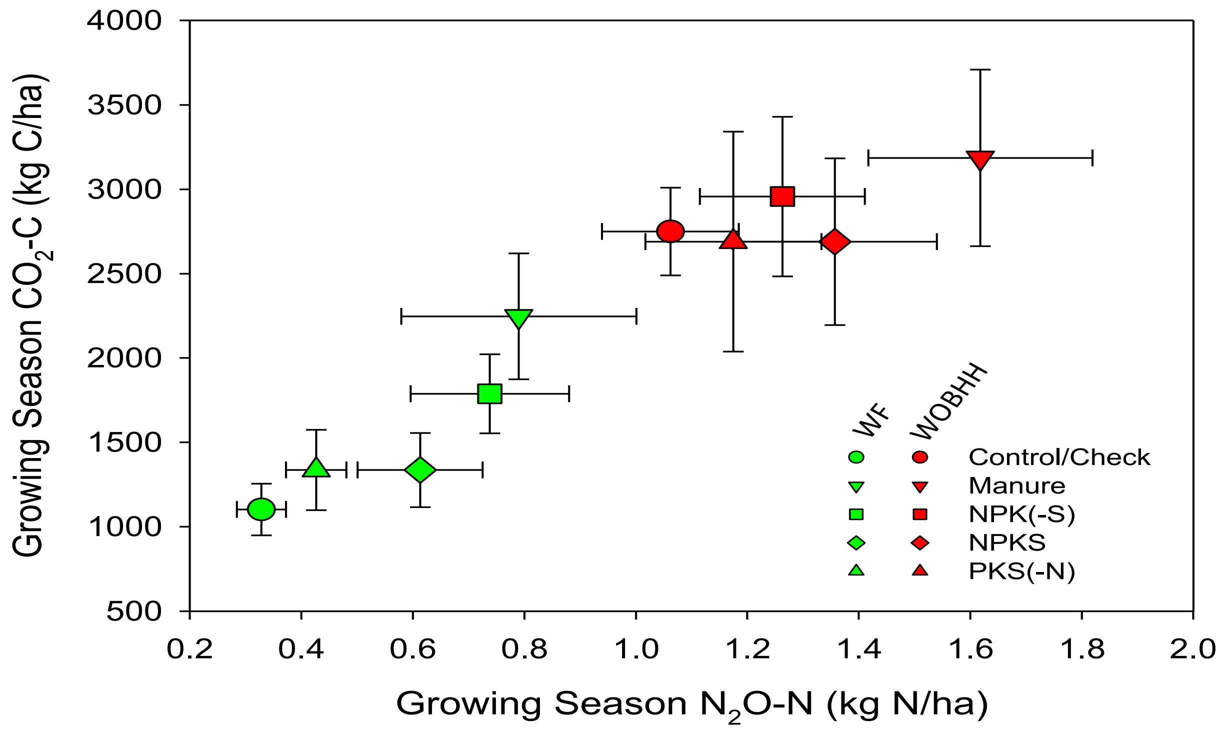

Figure 3-4. Relationship between cumulative growing season N_2O-N emissions and cumulative growing season CO_2-C emissions averaged over the 2013, 2014 and 2015 growing seasons from soils with different fertilization history under wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH) crop rotations at Breton Classical Plots, Western Canada. Symbols represent mean values and error bars represent 1 standard error. The line represents the orthogonal regression relationship: $y = 1858*x + 507$. The slope and intercept are both highly significant ($P < 0.001$).

Table 3-7. Summary of the average growing season (2013-2015) N_2O-N emission factors (%) for the Manure, NPKS and NPK fertility treatments of the 2-yr rotation wheat-fallow (WF) and the 5-yr rotation wheat-oat-barley-hay-hay (WOBHH) of Breton Classical Plots.

Rotation	WF		WOBHH	
Fertility treatment	Control reference	PKS(-N) reference	Control reference	PKS(-N) reference
Manure	0.51	0.40	1.12	0.88
NPKS	0.31	0.18	0.60	0.36
NPK(-S)	0.45	0.34	0.34	0.10

3.4.4. N_2O-N Emission Intensity

Ensuring food security by increasing yield, while reducing environmental costs of gaseous N emissions, is a big challenge (Zhao et al., 2015). Since larger N losses to the environment are often associated with highly productive agriculture, simultaneous achievements of high NUE and larger yield is difficult (Cassman et al., 2003). Taking these facts into account, we calculated N_2O-N emission intensity - that is N_2O emission per kg of wheat grain and N_2O emissions per kg of wheat N uptake from the soil fertility treatment plots, in both crop rotations. A yield-specific N_2O emission is a partial measure of N use efficiency (Drury et al., 2014). In order to evaluate the overall GHGs impacts properly, expression of N_2O emission on a yield-scaled basis is essential (Venterea et al., 2011). Table 3-8 illustrates a significant interaction effect of crop rotation and long-term soil fertility treatments on N_2O-N emission intensity, and demonstrates the relationship between soil fertility treatments, crop rotation, N_2O-N emission and yield. Under a 5-year crop rotation (WOBHH), N_2O-N emissions intensities from the soils varied slightly, range from 5x 10^{-4} to 2x 10^{-3} kg N_2O-N per kg grain. However, under a 2-year crop rotation (WF), N_2O-N emission intensities from the soil fertility treatments were in the range of 10 x 10^{-4} to 12 x 10^{-4} kg N_2O-N per kg grain. The data revealed that both crop rotations showed comparable N_2O-N emissions intensity, indicating similar N_2O emissions from the production of 1kg grain of wheat when using either of the two rotations, although the cumulative N_2O-N emission per ha was higher in 5-year rotation.

The higher cumulative growing season N_2O-N emissions from WOBHH were compensated by greater yield. Despite a higher cumulative N_2O-N emission in WOBHH, the N_2O-N emission intensity (emission per kg of wheat grain) of WOBHH was similar to that of WF, indicating a similar amount of N loss per kg of wheat gain produced and a more efficient use of N. Therefore, even though the N_2O-N emission intensity of WOBHH was similar to that of WF, WOBHH provided higher yield, and had an agronomic and economic advantage compared to WF. In line with this, van Greoenigen et al. (2010) suggested that in order to achieve cropping systems that are both environmentally sustainable and highly productive, yield-scaled N_2O emissions should be minimized.

The 34% higher yield in WOBHH compared to WF with similar N_2O-N emission intensities in both crop rotation systems is remarkable. A significant decrease in N_2O-N emission intensity, relative to the growing season cumulative N_2O-N emissions, in WOBHH, combined with a significant increase in overall yield is applicable to crop and fertilizer management practices, particularly over the long-term could have an agronomic benefit while reducing the negative environmental impacts. In line with this, Cui et al. (2013) suggested that in order to achieve sustainable agricultural production, a substantial increase in grain yield with efficient management of N fertilizer is crucial. Zhao et al. (2015) also confirmed that N_2O-N emission intensity is an appropriate agronomic practice, which could accommodate grain yield benefit, while mitigating gaseous N emissions.

Taking into account the effects of long-term crop rotation on N_2O-N emissions intensity and yield response of wheat, the WOBHH rotation can be taken as a superior crop rotation practice than WF because it can mitigate N_2O-N emission intensity while increasing yield. However, it should be considered that the N_2O-N measurements in this experiment were executed only during the growing season and the results might be different if the measurements had been carried out over the entire year. Therefore, in order to examine the overall benefit of the WOBHH crop rotation in the various growing seasons, further investigation might be needed in the spring snowmelt and late fall seasons. Furthermore, even though it is not statistically different from the other fertility treatments, NPKS soil fertility treatment in the WOBHH crop rotation, had the lowest N_2O-N emission intensity (N_2O-N emissions per unit of grain yield and N_2O-N emissions per unit of N uptake), and this suggests that long-term balanced fertilization (combined application of S with other macro nutrients) has a great potential in reducing N_2O-N emissions intensity in S-deficient soils, while simultaneously boosting crop yields. The decrease in N_2O-N emission intensity in the NPKS soil is hypothesized to be the result of the interaction of N and S in the soil. Therefore, the implication of our results for nutrient management, in terms of reducing the greenhouse gases emissions, is similar to those promoting balanced fertilization. In particular, combined application of N, P, K and S fertilizers in a S-deficient soil likely helps to reduce N_2O-N emissions from soils. However, more field measurements are required in the long-term to verify whether NPKS fertility treatment is significantly different from the other fertility treatments.

Table 3-8. Effect of soil fertilization history x crop rotation interaction on growing season on N_2O-N emission intensities (N_2O-N emissions per unit of grain yield and N_2O-N emissions per unit of N uptake).

Rotation	Fertility treatment	N_2O-N per unit of grain yield (kg N_2O-N/ kg grain) x 10^{-3}			
		2013	2014	2015	3-year average*
WF	Control	1.04	0.39	0.39	0.61 ab
	Manure	0.59	0.44	0.24	0.42 ab
	NPKS	0.28	0.25	0.21	0.25 b
	NPK(-S)	0.52	0.47	0.22	0.40 ab
	PKS(-N)	1.14	0.95	0.36	0.82 ab
WOBHH	Control	0.96	0.95	1.17	1.03 a
	Manure	0.86	0.35	0.59	0.60 ab
	NPKS	0.70	0.31	0.42	0.48 b
	NPK(-S)	0.95	0.39	1.34	0.90 ab
	PKS(-N)	0.61	0.55	0.33	0.50 b
		N_2O-N per unit of N uptake (kg N_2O-N/ kg N wheat) X 10^{-2}			
WF	Control	1.86	1.48	1.14	1.49 abc
	Manure	1.30	1.58	0.68	1.19 abc
	NPKS	0.61	0.88	0.53	0.67 c
	NPK(-S)	1.05	1.51	0.52	1.03 bc
	PKS(-N)	2.51	3.76	0.92	2.40 ab
WOBHH	Control	1.96	2.64	1.82	2.14 a
	Manure	2.46	1.00	1.54	1.50 abc
	NPKS	1.83	0.89	1.09	1.27 bc
	NPK(-S)	2.46	1.27	1.80	1.85 abc
	PKS(-N)	1.78	2.05	0.81	1.54 abc

*Values in the same column by the same letters are not significantly different at ($P < 0.05$) probability level. The letters are comparing means for both rotations.

3.4.5. Relationship among Total Soil N, N Uptake and Cumulative N_2O-N Emissions

Fig. 3-5 shows the relationship between total soil N and wheat N uptake. Despite some variability, all soil fertility treatments in both rotations showed a linear increase in wheat N uptake with increasing total soil N and the relationship between total soil N and cumulative growing season N_2O-N emissions is shown in Fig. 3-6.

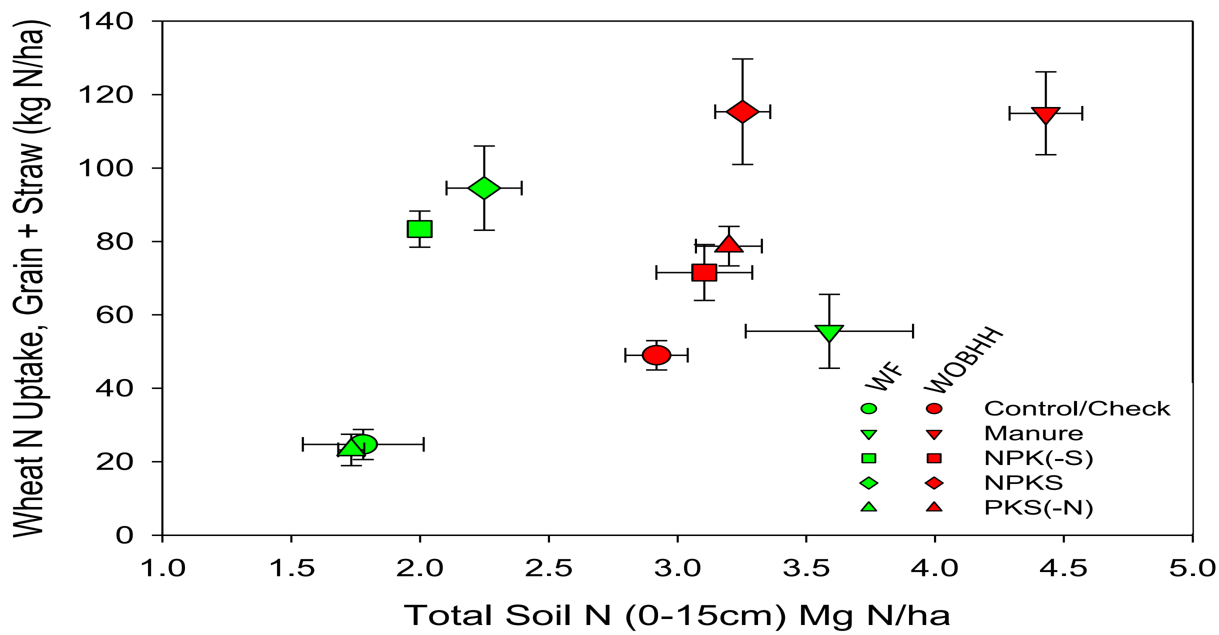

Figure 3-5. Relationship between wheat N uptake (grain + straw) and the total soil N stock (0-15 cm) of soils with different fertilization history under wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH) crop rotations at Breton Classical Plots, Western Canada. Symbols represent

mean values and error bars represent 1 standard error. The line represents the orthogonal regression relationship: y = 34.17*x – 25.45. The slope is significantly different from zero ($P < 0.05$), but intercept is not ($P = 0.59$).

All soil fertility treatments under both rotations showed a linear increase in cumulative growing season N_2O-N emissions and wheat N uptake with increasing total soil N. Despite the annual variability making it difficult to observed differences in N_2O emissions between difference fertility treatments within rotations, the significant slope of the regression line in Fig. 3-6 confirms the long-term effect of crop rotation and fertilizer or manure applications on soil total N , N_2O emissions and crop N uptake and this is corroborated by a similar observation made by Gomes et al. (2009). Moreover, some mechanisms may contribute to this effect; for example, if there is a surplus total soil N in the soil, it might serve (following mineralization) as a substrate for both microbial N_2O production processes (nitrification and denitrification) (Van Greoenigen et al., 2010) and provide plant-available N. In this context, treatments with larger total soil N stocks had higher N_2O-N emissions. Greater N stocks can increase N mineralization and thereby contribute to an increase in N_2O-N emissions and, simultaneously, crop N uptake (Gomes et al., 2009).

The synchrony between crop N demand and the quantities of N supplied by the soil and by the fertilizer determines fertilizer use efficiency, which could provide higher yield while preventing environmental pollution, but this mainly depends on crop and fertilizer management practices (Sturm et al., 2010). It is reasonable to hypothesize that N_2O emissions will decrease as crop N uptake increases because there may be less mineral N available to be converted to N_2O, but, in the present study, growing season cumulative N_2O-N emission showed a significant positive linear relationship with wheat N uptake (Fig. 3-7). Although the wheat N uptake in soil treatments in WOBHH were greater than the wheat N uptake in WF, WOBHH exhibited greater cumulative growing season N_2O-N emissions compared to WF.

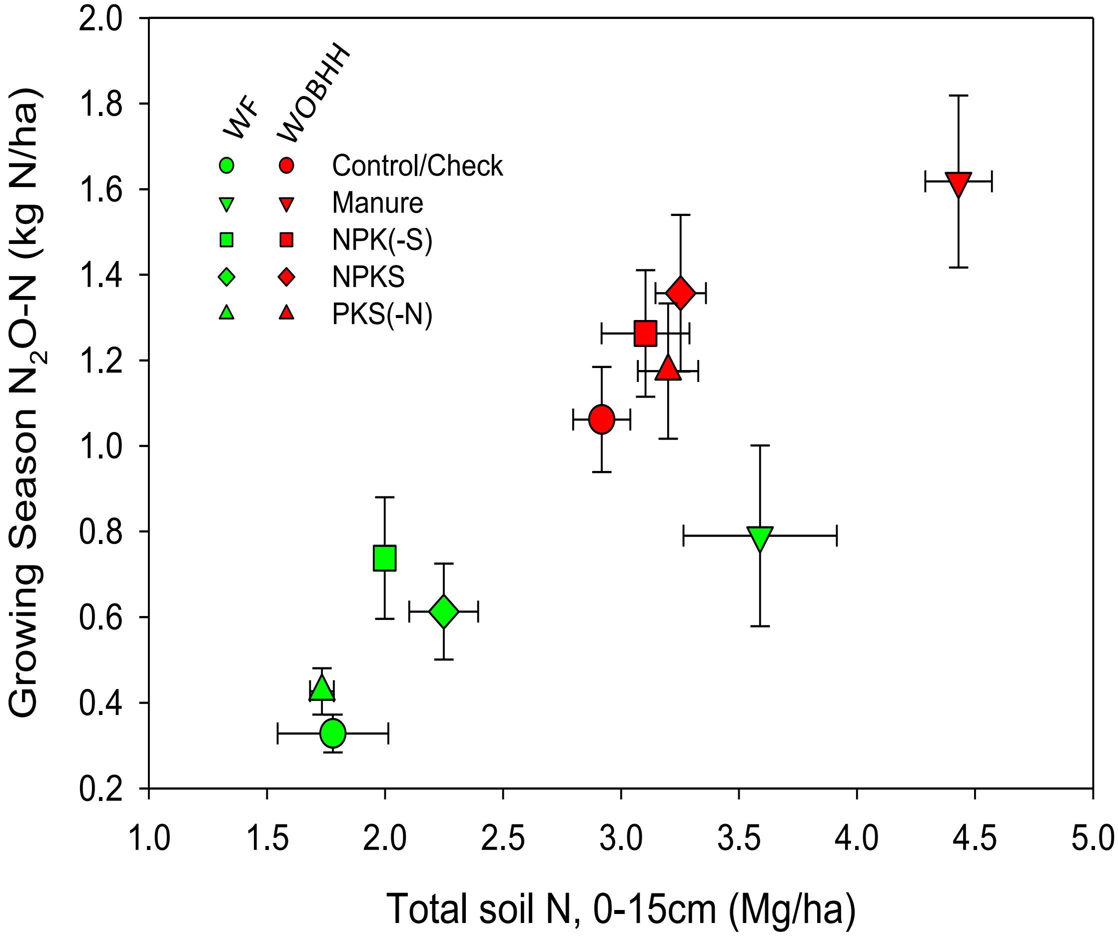

Figure 3-6. Relationship between cumulative growing season N_2O-N emissions and the total soil N stock (0-15 cm) of soils with different fertilization history under wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH) crop rotations at Breton Classical Plots, Western Canada. Symbols represent mean values and error bars represent 1 standard error. The line represents the orthogonal regression relationship: $y = 0.45*x - 0.33$. The slope is significantly different from zero ($P < 0.001$), but intercept is not ($P = 0.21$)

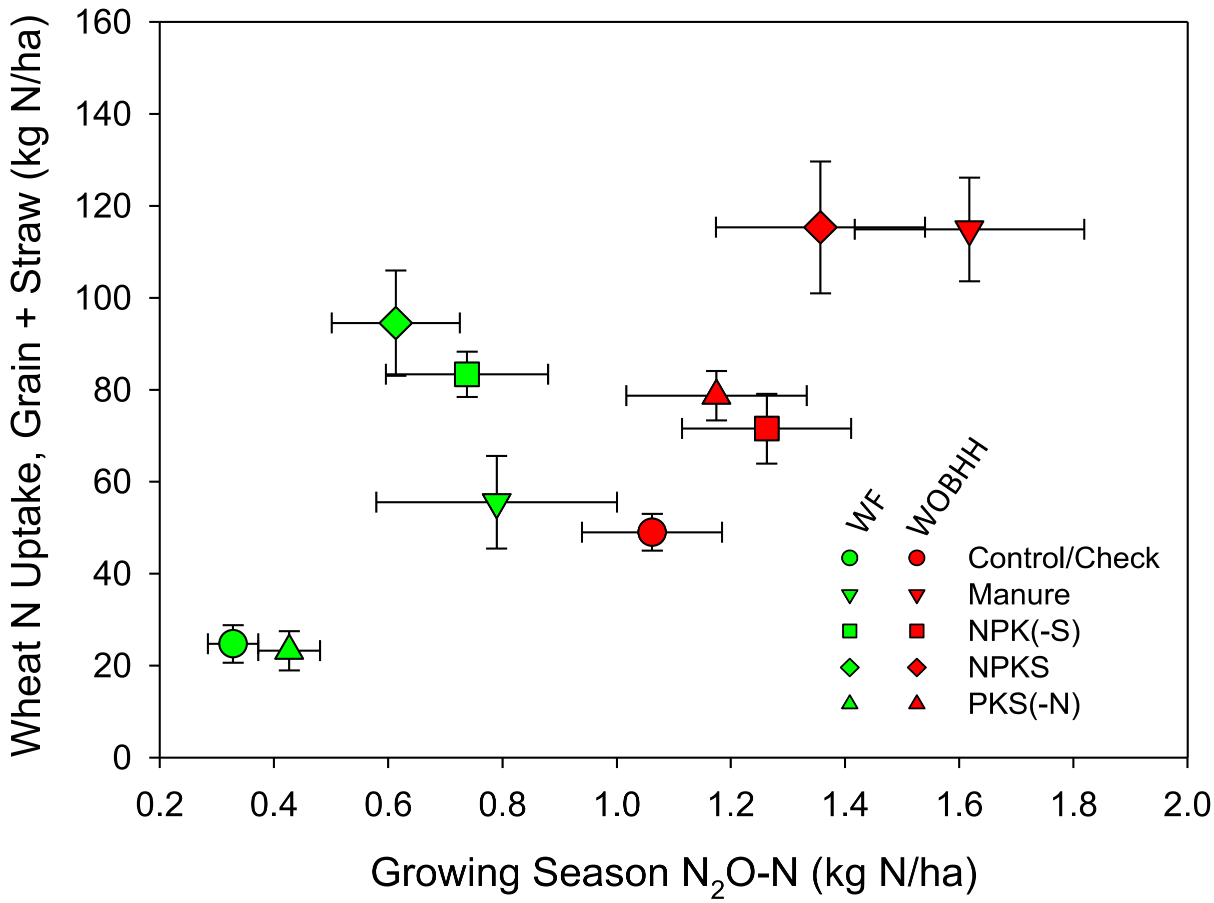

Figure 3-7. Relationship between cumulative growing season N_2O-N emissions and the wheat N uptake (grain + straw) from soils with different fertilization history under wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH) crop rotations at Breton Classical Plots, Western Canada. Symbols represent mean values and error bars represent 1 standard error. The line represents the orthogonal regression relationship: $y = 81.9*x - 5.7$. The slope is significantly different from zero ($P < 0.01$), but intercept is not ($P = 0.83$)

The relationships presented in Figs. 3-5, 3-6 and 3-7 show the influence of long-term rotation and fertilizer applications on soil N stocks and cycling, crop N uptake and N_2O emissions. In both rotations, treatments with long-term applications of nutrients through fertilizer or manure that were able to consistently meet crop nutrient requirements have accumulated soil N and C. These treatments have consistently higher yields and crop uptake of N. The higher yields and crop N uptake are apparently a function of the soil's ability to supply plant available N through nitrification and other nutrients like S as the crop demands. These observations are consistent with the hypothesis that the majority of N_2O emissions were a result of nitrification as suggested by the positive relationship between N_2O and crop N uptake in Fig. 3-7. Only by nitrification could plant available N and N_2O emissions simultaneously increase. Therefore, our results suggest that an increase in crop uptake of plant available N (NO_3^--N) will most likely will not result in decreased cumulative growing season N loss through N_2O emissions. However, it appears that crop N uptake increases as a function of soil total N at a greater rate than N_2O-N increases as a function of total soil N as indicated by the negative relationship between total soil N and the N_2O-N per wheat N uptake emission intensity parameter (Fig. 3-8). In the non-manure treatments, there is a negative relationship between total soil N and N_2O-N per crop N uptake emission intensity. Counter-intuitively, this implies a positive correlation between nitrogen use efficiency and cumulative N_2O-N emissions under well-aerated soil conditions where nitrification simultaneously produced N_2O-N and plant available NO_3^--N. Thus, under well aerated soil conditions an increase NUE may not decrease cumulative growing season N_2O-N emissions if a significant amount of crop N uptake is in the form of NO_3^--N, but may decrease N_2O-N emission intensities. On the other hand, our results suggest that, further to an increase crop N uptake, the use of nitrification inhibitors may decrease total growing season N_2O through increased uptake of NH_4^--N.

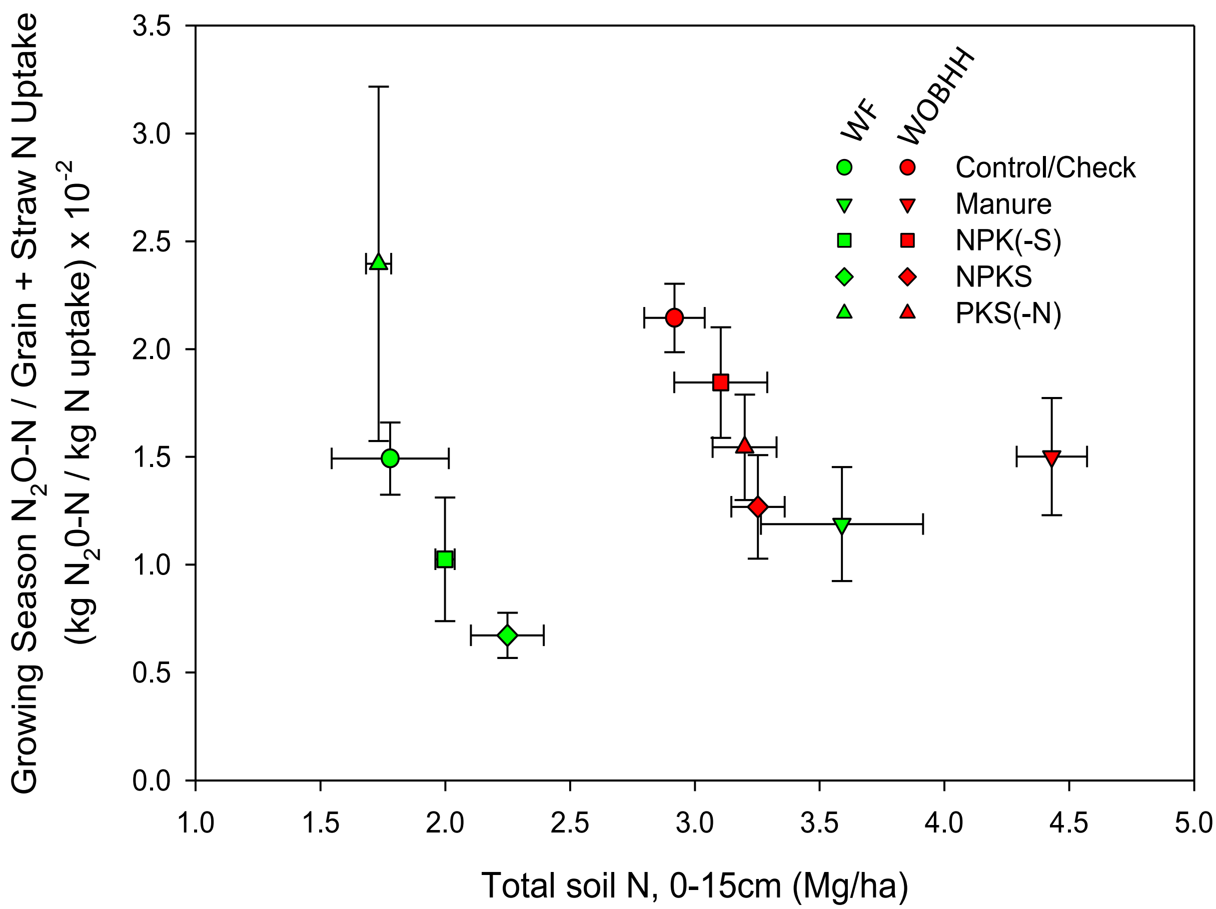

Figure 3-8. Relationship between total soil N (0-15 cm) and N_2O-emission intensity from soils with different fertilization history under wheat-fallow (WF) and wheat-oat-barley-hay-hay (WOBHH) crop rotations at Breton Classical Plots, Western Canada. Symbols represent mean values and error bars represent 1 standard error.

3.5. Conclusions

In the present study, although the cumulative growing season N_2O-N emissions were affected by long-term crop rotation as well as fertilization history, long-term crop rotation explains most the variability of N_2O-N emissions from soil treatments. Overall, soil treatments and crop rotations with a higher N input increased the total soil N. In both rotations, long-term Manure fertilized soils produced the highest N_2O-N emissions. Although the five-year rotation had higher wheat yield and N uptake, the cumulative growing season N_2O-N emissions were greater than the WF rotation. Consistent with our hypotheses, soil treatments with long-term combined S and N fertilization had higher yield, N uptake, and cumulative growing season N_2O-N emissions; however, they had similar N_2O emission intensities, although not statistically different from the remaining fertility treatments except the Control.

Even though higher cumulative growing season N_2O-N emissions are observed in the five-year rotation, a different picture emerged when N_2O-N emission intensity was considered. In this case, fertilizer and crop rotation management practices that increase NUE decreased N_2O-N intensity rather than cumulative growing season N_2O-N emissions. Aerobic soil conditions during the growing season and all other evidences showed suggesting that nitrification is potentially significant contributor to N_2O-N emissions.when N_2O-N is mainly produced via nitrification process, higher crop N uptake in the form of NO_3^--N does not necessarily decrease the cumulative growing season N_2O-N emissions. Therefore, the use of nitrification inhibitors might be the good choice to reduce growing season N_2O-N emissions because it might increase the uptake of NH_4^- -N.

The findings of this study provide insights into the effect of long-term fertilization history and crop rotation management practices on wheat yield and growing season N_2O-N emissions in S-deficient soils of western Canada. Our results suggest that long-term crop rotation and soil fertility treatments, which increase yield and crop N uptake reduce the N_2O-N emission intensity are the best management practices, and have significant implication for sustainable agriculture. Since it is a win-win solution for N_2O-N emission reduction and yield increase, adoption of long-term S fertilization in combination with other macro nutrients and long-term crop rotation practices should be considered in N_2O-N reduction strategy. However, since the N_2O-N measurements in this study were done in summer, it would be prudent to compare the annual emissions from a wide range of rotations over many years.

Chapter 4. Effect of Long-term Fertilization History and Contemporary N and S Fertilizer Application on N_2O Emission in S-deficient Soils in a Laboratory Incubation

4.1. Introduction

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the three major greenhouse gases that are associated with agriculture (Snyder et al., 2009). N_2O has a warming potential 298 times greater than CO_2 over 100 years (IPCC, 2007), and it is the main gas involved in ozone layer degradation (Crutzen., 1981; Jeuffroy et al., 2013). Moreover, because of the release of large quantities of N_2O from the soil to the atmosphere, N_2O emissions from soil have received considerable attention in recent years (Smith et al., 2007).

At a global scale, 80% of N_2O emissions are derived from agricultural systems (Liang et al., 2015). In Canada, in 2013, N_2O contributed 6% of Canada's total GHGs emissions, which is largely attributed to agricultural soil management and transportation (CGGI, 2014). Moreover, in Canada, 40-70% of the N_2O emissions occur during the spring, in the period of snow melting and soil thawing (Nyborg et al., 1997; Lemke et al., 1999). However, during the growing season, fertilizer and manure applications, soil moisture, microbial activity and other meteorological factors, are the main drivers of N_2O production (Tenuta and Beauchamp, 2003).

Nitrification (the step-wise oxidation of ammonia to hydroxylamine to nitrite to nitrate) and denitrification (the anaerobic reduction of nitrate (NO_3^-) to gaseous forms of nitrogen [N]), are the two microbial processes, which are responsible for the production of N_2O in soil (Jeuffroy et al., 2013). Results from long-term experiments have shown that the contribution of these two processes for N_2O production in cultivated soils can be influenced by soil management practices such as fertilization, liming, crop rotation, tillage, etc. (Skiba and Smith, 2000; Drury et al., 2008; Li-mei et al., 2011), environmental conditions, concentration of inorganic N (NH_4^+, NO_3^-) and organic carbon (C) in the soil. Moreover, N_2O production can be influenced by the type of fertilizer used and the type of N applied (urea, ammonium [NH_4^+], NO_3^- or organic N) (Velthof et al., 1997; Tenuta and Beauchamp, 2003).

Approximately 80% of arable land in Canada is located on the Western Canadian Prairies (Campbell et al., 2002). Around 4 million ha of these soils are sulfur (S)-deficient and an additional 8 million ha of these soils are also identified to be potentially S-deficient (Solberg, 2007). In Canada, several studies have been conducted and reported on the influence of long-term or current N fertilizers applications on N_2O emission in various agricultural soils, including Gray Luvisols (Lemke et al., 1999; Bergstrom et al., 2001; Bouwman et al., 2002; Tenuta and Beauchamp, 2003; Malhi and Lemke, 2007; Hangs et al., 2013). For example, Bergstrom et al. (2001) compared N_2O emission from some granular N sources, under non-saturated conditions, on a silty loam soil near Guelph and found that N_2O emissions were in the following order: Urea > $(NH_4)_2$ SO_4 > Ca $(NO_3)_2$ = Control. However, to our knowledge, although the potential interaction between the N and S transformation processes in the soil may influence N_2O emissions, past studies have generally not evaluated the impact of the long-term combined application of N and S fertilization on N_2O-N emission in S-deficient soils with respect to other associated soil management history (crop rotation and liming).

Therefore, there is a lack of information on the influence of soil management history on N_2O-N production in S-deficient soils, particularly in the western Canada. The “Breton Classical Plots”, an experimental site located in western Canada, Alberta, is a long-term experimental site initiated in 1929, and is representative of Gray Luvisolic soils in western Canada, which are S-deficient soils (Dyck et al., 2012). Long-term experimental plots such as "Breton Classical Plots" would give the best opportunities to investigate the effects of the long-term soil management history such as (combined N and S fertilization), liming and cropping system (crop rotation) on N_2O production within the scope of a long-term trial.

Therefore, the questions motivating this research are: (1) Do fertilizer N and S sources significantly interact with soil fertilization history with respect to N_2O-N emission potential? (2) Are emissions of N_2O-N influenced by the interaction of elemental S oxidation and nitrification? We hypothesized N_2O-N production potential would be significantly influenced by long-term fertilization history (combined application N and elemental S fertilization with other macro nutrients). In addition, we hypothesized contemporary N and S fertilizer effects on N_2O-N are greater in soils with a long-term history of N plus S fertilization compared to soils with long-term N or S fertilization alone. In order to address these questions and hypotheses, a soil incubation experiment was designed in order to: (a) quantify the effect of different N and S fertilizer sources on N_2O-N emissions with respect to long-term N and S fertilization history in S-deficient soils from a wheat-oat-barley-hay-hay rotation; and (b) to quantify the N_2O-N emissions from the soils with long-term combined N and S fertilization history.

The results from this study would improve understanding of how N_2O-N emissions are influenced by long-term fertilization history, and demonstrate the potential interaction between contemporary N and S application with long-term fertilization history, which in turn helps to adopt good fertilizer management practices to mitigate N_2O-N emissions.

4.2. Material and Methods

4.2.1. Soil

The soils used in this study were collected from agricultural experimental field located at the University of Alberta, Breton, Alberta, Canada (53^0 07' N, 114^0 28' W). Details of the experimental site and design are given in in Dyck et al. (2012) and in the previous chapter. The long-term average annual air temperature is 2.1 ^{0}C, and mean annual precipitation is 547 mm, which mostly occurs between July and August, and the potential evapotranspiration of the site is close to the annual precipitation (Izaurralde et al., 1995b). The soil is classified as a Gray Luvisol with a bulk density of 1.4 g/cm^3.

In 2014, following harvest of the wheat phase (series F), wheat-oat-barley-hay-hay (WOBHH) rotation soil samples were collected at four random locations, using a shovel, from the surface layer of (0-10 cm) limed (east) halves of plots: (1) Control (2) NPKS (3) NPK (-S) and (4) PKS (-N). Then, after removing the easily detectable crop residues and coarse roots, the samples were air-dried, homogenized, sieved < 2 mm and stored in tin buckets in insulated storage until use. The fertilizer treatment description of the Breton Classical Plots is explained in Table 4-1 (Giweta et al., 2014). In addition to fertilizers, since 1980, lime has been applied to restore soil pH to 6.5 whenever soil pH falls below 6.0 (approximately every 5 years). Further details on the management of the Breton Classical Plots can be found in Dyck et al. (2012).

Table 4-1. Treatment descriptions in the Breton Classical Plots study, where the soil samples were taken (Giweta et al., 2014)

Treatments, 1930-1979 inclusive						Treatments, 1980 onward				
kg ha^{-1}						kg ha^{-1}				
Plot	Treatment	N	P	K	S	Treatment	N	P^x	K^x	S
5	Control	0	0	0	0	Control	0	0	0	0
3	NPKS	10	6	16	10	NPKS	z_	22	46	y_
7	NPKSL	11	6	16	9	NPK	z_	22	46	0
8	P	0	9	0	0	PKS	0	22	46	y_

[z]N (applied as urea) rate depends on the crop and its place in the rotation: wheat after forage (50 kg N ha^{-1}), oat or barley after wheat (75 kg N ha^{-1}), barley under seeded to hay: 50 kg N ha^{-1} and legume-grass forages: 0 kg N ha^{-1}.

[y] S was applied as elemental S at a rate of 5.5 kg S ha^{-1} from 1980 – 2007 and 20 kg S ha^{-1} from 2007 – present.

[x] Rates represent rates of the nutrient element (P or K) rather than P_2O_5 and K_2O convention. P was applied as triple super phosphate (0-46-0) and K is applied as muriate of potash (0-0-62).

Prior to the incubation experiment, three 90-g sub-samples from each treatment were sent to the University of Alberta Natural Resources Analytical Laboratory (NARL) in Edmonton, Alberta, for analysis of total organic C (TOC), total N (TN), light fraction of C (LFC), light fraction of N (LFN), ammonium-N (NH_4^--N), nitrate-N (NO_3^--N), total S (Total S), sulfate-S (SO_4^{-2} -S) and pH and these properties are summarized in Table 4-2.

Soil pH was determined using (1:2 soil: $CaCl_2$ suspension, with a pH meter) as described by Karla (1995). Water extraction (1:5 soil: water solution) was used to determine SO_4^{-2} -S content in the soil. Total S was determined by HNO_3^- digestion of the soil samples and measuring sulfate by ion chromatography (Tabatabai and Frankenberger, 1996). After separating the light fraction of organic matter by physical fraction method, on the basis of density using a Sodium Iodide (NaI) solution of 1.7 mg m^{-3} (Gregorich and Beare, 2008, Malhi., 2012), the resulting light fractions of organic matter were analysed for LFC and LFN After soil samples were pulverised by Brinkmann ball grinder (Retsch, type MM200) and dried over 24 hrs, TOC and TN were determined by the Dumas Combustion method using a Costech 4010 Elemental analyser System (Costech Analytical Technologies Inc., Valencia, CA, USA). NH_4^--N and NO_3^--N were measured colorimetrically on a SmartChem Discrete Wet Chemistry Analyser (Maynard and Kalra, 1993).

4.2.2. Experimental Setup

4.2.2.1. Incubation

A seven-week laboratory incubation experiment (15 October to 12 November, 2015) was conducted to investigate N_2O emissions in response to the long-term fertilization history and contemporary application of N and S fertilizers. A split-plot experimental design with three replicates was used, which resulted in a complete set of 84 incubation vessels. Main plot treatments (soils) consisted of fertilization history of the soils and were named in accordance to the Breton Classical Plots treatment name: 1) Check (no fertilizer) 2) NPKS 3) NPK 4) PKS.Sub plot treatments (fertilizers) were: (1) nil (no fertilizers), (2) Urea (UR), (3) Ammonium chloride (AC) (NH_4Cl), (4) Calcium nitrate (CN) (Ca $(NO_3)_2$), (5) Urea (UR) + S^0, (6) Ammonium chloride (AC) + S^0 ,and (7) Calcium nitrate (CN) + S^0. Target rates of N and S were 100 kg N/ha and 20 kg S/ha.

For all treatments, 30 g of soil was weighed and 7.5 mL deionized water for the control, and 7.5 mL of fertilizer solution for the other fertilizer treatments was applied using a plastic syringe and repacked to a bulk density of 1 g/cm^3 into an ABS cylinder with a sealed bottom and placed inside a 1 Litre mason jar using forceps. The density of the aggregate was not changed and was similar to the field condition. A separate reservoir consisting of 10 mL of tap water was also placed in the jar to help maintain the soil moisture content at 25% v/v throughout the incubation period by means of humidity.

For the fertilizer solutions, 100 g of each fertilizer was ground with a mortar and pestle and mixed thoroughly. At total of 6 fertilizer solutions (total volume 2 litres) were made according to the fertilizer treatments above at concentrations such that addition of 7.5 mL of solution to 30 g of soil would achieve the target N and S (if added) rates of 100 kg N/ha and 20 kg S/ha. Fertilizer solutions were stirred thoroughly and kept for one day at room temperature. Furthermore, before application, all fertilizer solutions were mixed thoroughly by hand shaking. Following the incubation experiment, the soil in each jar was dried at 60 ^oC for three days and sent to the NRAL for NO_3^--N, NH_4^--N, and SO_4-S analysis according to the methods mentioned previously.

Table 4-2. **S**elected soil properties for the 0 to 10 cm depth for each soil treatments of the sampling site (Breton Classical Plots) in the current study.

Soil	TOC (kg C ha^{-1})	TN (kg N ha^{-1})	C/N ratio	LFC (kg C ha^{-1})	LFN (kg N ha^{-1})	NH_4^+-N (kg N ha^{-1})	NO_3^--N (kg N ha^{-1})	TS (kg S ha^{-1})	SO_4^--S (kg S ha^{-1})	pH
Control	2032	201	10.1	98	5.9	0.93	0.58	26.0	0.77	6.3
NPKS	2493	242	10.3	160	10.2	1.64	4.26	37.8	2.53	5.5
NPK	2299	227	10.1	123	7.1	0.84	0.62	27.5	0.72	6.0
PKS	2527	243	10.4	163	9.9	0.67	0.58	37.0	2.31	5.5

TOC: total C, TN: total N, LFC: light fraction of C, LFN: light fraction of N, TS: total S.

4.2.2.2. Gas Sampling

Because we were interested in the cumulative gas emission, gas concentrations in the jar head space were measured only once per sampling period by attaching the tubes from the gas analyzer to the ports on the lid and the jars remained sealed between sampling times. Following gas sampling, the lids were removed for 2 minutes in order to re-aerate the atmosphere in the jars. Following aeration, the mason jars were re-sealed and, in order to avoid light penetration between sampling periods, the jars were covered with a large dome made of cardboard. N_2O measurements were carried out twice per week for the first 3 weeks, and once per week in the remaining four weeks, using a 1312 Photoacoustic Multi-Gas Monitor (Innova Air Tech Instruments, Ballerup, Denmark).

Gas concentrations measured at each sampling time represented a cumulative N_2O-N emission over the time elapsed since the last sampling period and were converted to kg N_2O-N/ha, based on the actual packing density of the soil (1 g/cm^3). Total cumulative N_2O emissions were calculated by adding up the N_2O emissions from each sampling period.

4.3. Statistical Analysis

Statistical analyses were performed using the Proc MIXED procedure of SAS software (version 9.2, Cary, NC., USA) (Littell et al., 1998). The effect of fertilizer source, soil type and their interaction on cumulative N_2O and CO_2 fluxes and other measured soil properties for the entire period of incubation were assessed by analysis of variance using a split plot design.

Prior to the statistical analysis, all the data were tested with respect to the assumptions of normality, independence and heteroscedasticity of residuals. Whenever necessary, log transformation is used in order to attain uniformity for statistical analysis. The relationship among measured variables was identified, using Pearson correlations. Comparisons of least squares means were done using Tukey's procedure and statistical significance was declared at ($P < 0.05$).

4.4. Results and Discussion

The results of the ANOVA for cumulative N_2O-N and CO_2-C emissions, and post-incubation, NH_4-N, NO_3-N and SO_4^--S are presented in Table 4-3. Both N_2O-N and CO_2-C fluxes differed significantly ($P < 0.05$) among the soil and fertilizer treatments. In addition, the soil and fertilizer treatments interaction was significant ($P < 0.05$). NH_4^--N was significantly ($P < 0.05$) affected by soil and fertilizer treatments, but not by soil x fertilizer interaction. NO_3^--N was significantly ($P < 0.05$) affected by fertilizer treatments, but not by the soil treatments and soil x fertilizer treatments interaction. Similarly, SO_4^--S was significantly ($P < 0.05$) affected by fertilizer treatments, but not by the soil and soil x fertilizer treatments interaction.

Table 4-3. Summary of the P value of the analysis of variance (ANOVA) comparing the effect of soil, fertilizer, and soil x fertilizer interaction on cumulative NH_4^--N, NO_3^- -N, SO_4^- -S content, and N_2O-N and CO_2-C emission during the seven-week incubation period.

	NH_4^+-N	NO_3^--N	SO_4^--S	Cumulative N_2O-N emission	Cumulative CO_2-C emission
			P-value		
Soil	0.0079	0.3222	0.7206	0.0078	< 0.0001
Fertilizer	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Soil x Fertilizer	0.5705	0.6706	0.9314	< 0.0004	0.0499

4.4.1. Effect of Soil Type and N Fertilizer Source Interaction on N_2O-N Emission

N_2O-N emissions showed significant responses to soil fertilization history and fertilizer source, with the greatest amount of N_2O-N produced in the NPKS and NPK soils after addition of UR or UR + S^0 (Fig. 4-1). The soils without long-term applications of N fertilizers (Check and PKS) exhibited the lowest N_2O-N emissions. Smith et al. (1997) have reported that since more N cycling (i.e., nitrification) can occur in soil receiving regular application of N fertilizers, the greater amounts of N_2O-N produced in the NPKS and NPK soils may be a result of greater conversion urea to nitrate (i.e., nitrification).

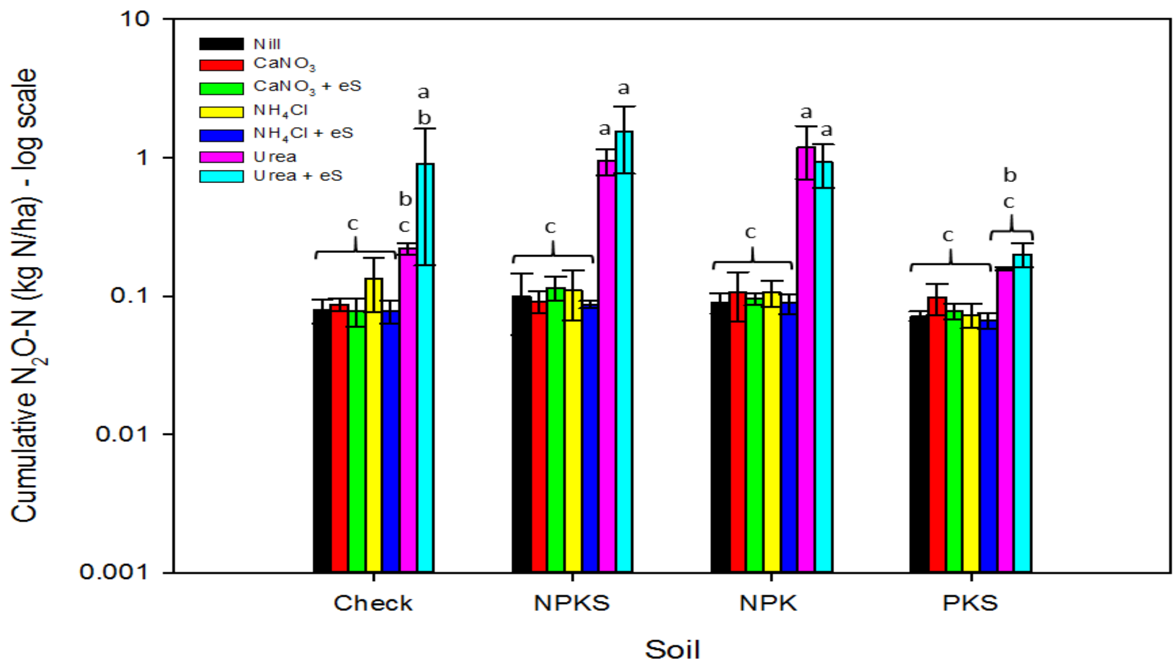

Figure 4-1. Soil and fertilizer treatments interaction effect on cumulative N_2O-N emissions (kg N/ha).

Fig. 4-2 apparently confirms the relationship between N_2O-N emissions and nitrification, but there does not seem to be large differences in the amount of nitrification (as indicated by post-incubation NO_3^-) between the different soils. In Fig. 4-2, a strong linear relationship between post incubation NO_3^--N concentration and N_2O-N flux for UR and UR + S^0 fertilizers is apparent, but the Check and PKS soils have a shallower slope compared to NPKS and NPK soils, which suggests that even though soils with no long-term N fertilization (Check and PKS) showed similar nitrification levels, their N_2O-N emissions were lower compared to the soils with long-term N fertilization (NPKS and NPK). Almost all of the 100 kg N/ha added as NO_3^--N in the CN treatments was recovered as NO_3^- in all soils (Table 4-4) and N_2O-N emissions from these treatments were very low, further suggesting that N_2O was produced during nitrification rather than denitrification.

It is also interesting to note that very little nitrification occurred in the AC treatments – almost all of the 100 kg N/ha applied was recovered as NH_4^+-N (Table 4-4) - likely because chloride significantly inhibits nitrifying bacteria (Souri, 2010; Megda et al., 2014) and the low N_2O-N emissions in the AC treatments lends further evidence to nitrification being the main process producing N_2O. Further, our results are in agreement with Sosulski et al. (2014) who reported that N_2O-N emissions were positively correlated with the soil content of NO_3^--N.

The only other dependent variable significantly influenced by the interaction between soil management history and fertilizer type was cumulative CO_2-C emission. There was also a significant linear relationship between cumulative CO_2-C and cumulative N_2O-N emissions (Fig. 4-3). The overall correlation between N_2O-N and CO_2-C emissions was $r = 0.64$ ($P < 0.0001$), but Fig. 4-3 shows a soil-dependent linear relationship consistent with the soil-dependent linear relationships between post-incubation NO_3^--N and N_2O-N. Soils without long-term N fertilization (Check and PKS) have a shallow slope compared to soils with long-term N fertilization, thereby indicating the relationship between N_2O-N and CO_2-C emissions was stronger in soils with long-term N fertilization. The positive correlation between N_2O-N and CO_2-C emissions suggest that microbial processes, which are responsible for both N_2O-N and CO_2-C production, were influenced by similar environmental factors (Firestone and Davidson, 1989; Adviento-Borbe et al., 2007).

In the present study, since the tested soils were incubated in aerobic conditions, presumably the availability of oxygen (O_2) favored both soil respiration and N_2O emissions via nitrification. In line with this, Azam et al. (2002) reported that the CO_2-N_2O correlation can be influenced by the common controlling factors of microbial processes such as O_2 availability, soil water content and temperature, and shared substrates, for example, availability of N in soil. Garcia-Montiel et al. (2004) also showed the relationship between N_2O-N and CO_2-C emissions in tropical forest soils. However, in their case, higher CO_2-C emissions resulted in higher O_2 consumption and created an aerobic condition, which is favorable for N_2O production via denitrification.

The underlying reason for the large differences in N_2O-N emissions from soils with different fertilization histories, despite very similar amounts of nitrification (Fig. 4-2) and respiration (Fig. 4-3) is unclear. There were no strong correlations between pre-incubation soil properties (Table 4- 2) and cumulative N_2O-N or CO_2-C as a function of soil fertilization history. There is a general trend in the data for the soils with higher total N and SOC to have greater emissions, but the Check soil had greater N_2O-N emissions than the PKS soil despite having much lower levels of total N and SOC. The production of N_2O during the process of nitrification depends on the composition of the microbial communities which produce enzymes that regulate the production of N_2O during nitrification such as nitrite reductase, ammonia mono-oxygenase and nitrous oxide reductase which reduces N_2O to N_2 (Siciliano, 2013). It is possible that the difference in cumulative N_2O-N produced in these soils is a result of differences in microbial community composition. The effects of long-term fertilization on the composition of soil microbial communities involved in N cycling warrant further investigation.

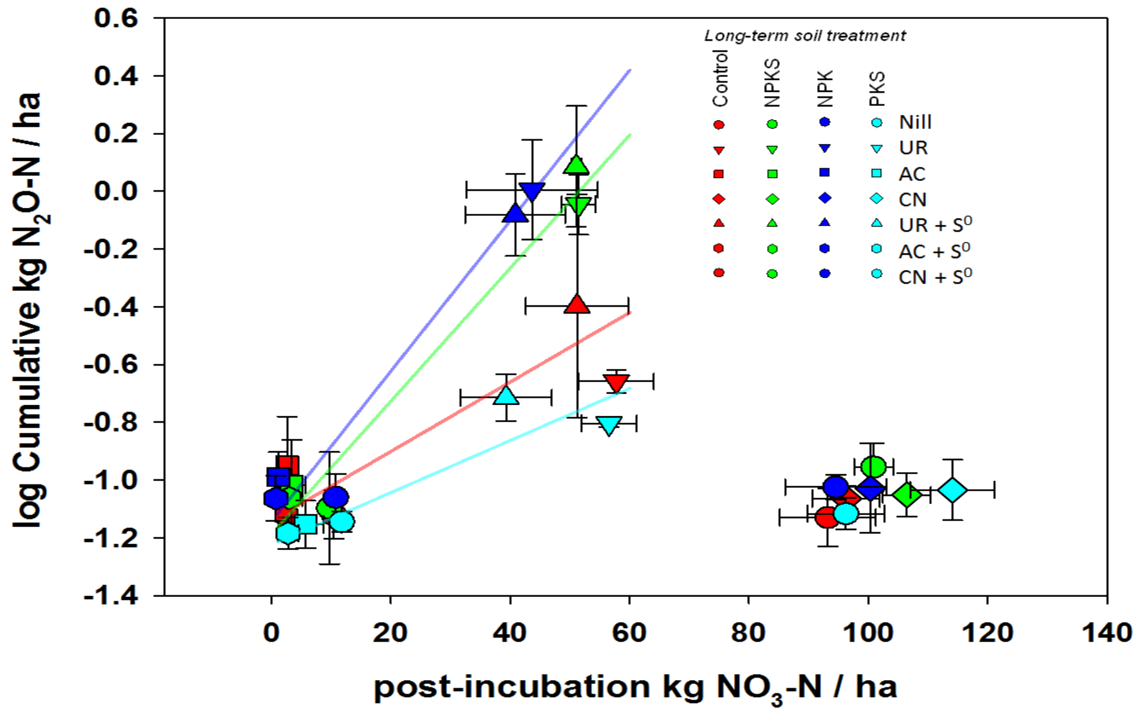

Figure 4-2. Relationship between cumulative N_2O-N emission and post incubation NO_3^--N emission over a seven-week of incubation period from the four soils with different fertilization history, soil without fertilizer application (Control), soil with long-term application of NPKS, soil with long-term application of NPK, and soil with long-term application of PKS. Symbols represent means of variables and error bars represent 1 standard error. Colored lines on the graph correspond to the colors of the symbols and represent the orthogonal regression between post-incubation NO_3-N and cumulative N_2O-N emissions, excluding the measurements from CN and CN + S^0 treatments. The slopes of the regression lines are 0.012, 0.023 0.026 and 0.009 log (kg N_2O-N)/kg NO_3-N for the Control, NPKS, NPK and PKS soils respectively. The intercepts of the regression lines are -1.137, -1.183, -1.139, and 1.219 for the Control, NPKS, NPK and PKS soils respectively. All slope and intercept estimates were highly significant ($P < 0.001$).

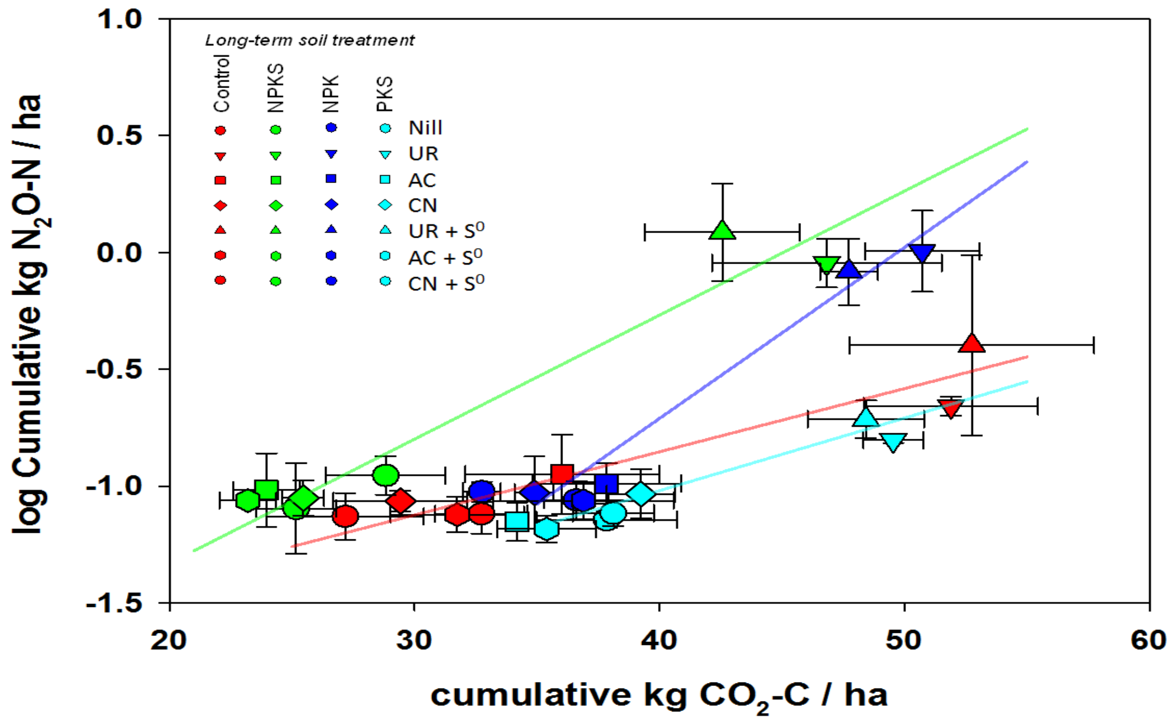

Figure 4-3. Relationship between N_2O-N emission and CO_2-C emission over a seven-week of incubation period from the four soils with different fertilization history, soil without fertilizer application (Control), soil with long-term application of NPKS; soil with long-term application of NPK, and soil with long-term application of PKS. Symbols represent means of variables and error bars represent 1 standard error. Colored lines on the graph correspond to the colors of the symbols and represent the orthogonal regression between cumulative CO_2-C and cumulative N_2O-N emissions. The slopes of the regression lines are 0.027, 0.053, 0.073 and 0.031 log (kg N_2O-N)/kg CO_2-C for the Control, NPKS, NPK and PKS soils respectively. The intercepts of the regression lines are -1.929, -2.385, -3.626, and 2.255 for the Control, NPKS, NPK and PKS soils respectively. All slope and intercept estimates were highly significant ($P < 0.001$).

4.4.2. Interaction of N and S with respect to N_2O-N Emissions

Simultaneous nitrification and oxidation of elemental S were apparent in the UR + S^0 fertilizer treatments (Table 4-4) as indicated by the increased post-incubation NO_3^--N and SO_4^--S in this treatment compared to pre-incubation levels (Table 4-1). Oxidation of elemental S did not appear to have any impact on the amount of nitrification as indicated by similar post-incubation NO_3^--N levels in the UR and UR + S^0 treatments. This is consistent with the observation that the addition of elemental S to urea did not appear to significantly increase cumulative N_2O-N emissions relative to urea alone in any of the soil types (Fig. 4-2) and that most N_2O was produced during nitrification in this incubation (Fig. 4-3). On the other hand, post-incubation SO_4^--S was greater in the UR + S^0 treatment compared to the CN + S^0 and AC + S^0 treatments which suggests that S oxidation was enhanced when active in concert with nitrification. In contrast to these results, other studies have noted that S oxidation inhibits nitrification (Wainwright et al., 1986), and an example where S oxidation was enhanced during co-occurrence of nitrification could not be found in the literature. Based on the amount of recovered NO_3^--N and SO_4^--S post-incubation from the UR + S^0 treatment (Table 4-4), compared to the 100 kg N/ha and 20 kg S/ha application rates, a greater proportion of applied N was nitrified (approximately 40%) compared to the proportion of applied S that was oxidized (approximately 25%). It is unclear whether this difference is a result of a decreased rate of S oxidation compared to the rate of nitrification or a time lag in S oxidizing bacterial populations becoming active compared to nitrifying bacteria. Oxidation of S^0 in soil is a slow process, particularly when applied as a granule (Malhi et al., 2005). Citing few researches, Malhi et al. (2005) suggested that in order to enhance S^0 oxidation, fine S particles need to be dispersed from pellets (granule or prills).

Table 4-4. Effect of fertilizer treatments (Mean (n=6) on soil inorganic N (NH_4^+-N, NO_3^--N), and SO_4^--S (kg N or S/ha) in incubated soils over seven weeks of incubation.

Fertilizer	NH_4^+-N	NO_3^--N	SO_4^--S
Nil	0.77 a	10.6 a	1.2 a
	(0.05)	(0.30)	(0.24)
UR	42.2 b	52.3 b	1.0 a
	(2.54)	(3.39)	(0.14)
CN	9.5 d	104.3 c	0.4 a
	(0.93)	(2.93)	(0.11)
AC	103.6 c	3.2 a	0.8 a
	(2.54)	(0.97)	(0.15)
UR+S^0	45.8 b	45.6 b	6.2 b
	(2.46)	(3.47)	(1.12)
CN+S^0	8.9 d	96.2 c	3.7 c
	(0.96)	(3.05)	(0.82)
AC+S^0	106.9 c	2.2 a	4.2 c
	(3.2)	(0.69)	(0.98)

*Values in the same column by the same letters are not significantly different at ($P < 0.05$) probability level.

Nil: unfertilized, UR: urea, AC: ammonium chloride, CN: calcium nitrate, UR+S^0: urea plus elemental sulfur, AC + S^0: ammonium chloride plus elemental sulfur, CN + S^0: calcium nitrate plus elemental sulfur.

Overall, our results were in agreement with several studies (Bergstrom et al., 2001; Bouwman et al. 2002 and Gangon et al., 2011) that observed higher N_2O emissions from urea fertilizer. Similarly, Pathak and Nedwell (2001) and Tenuta and Beauchamp (2003) observed in their aerobic laboratory incubations, that N_2O-N emissions were greatest under with urea followed by NH_4^+-based fertilizers and least with NO_3^- based fertilizers. However, under anoxic condition, NO_3^- -based fertilizers produced higher N_2O-N emissions. In contrast to our results, Peng et al. (2011) observed higher N_2O-N emissions in soils with nitrate and ammonium-based fertilizers. Breitenbeck et al. (1980) also observed lower emissions from calcium nitrate fertilizers than from urea and ammonium sulfate. In our experiment, no difference was detected in cumulative N_2O-N emissions between NH_4^+ based fertilizers and NO_3^- based fertilizers, and both types of fertilizers recorded the lowest emissions in all types of soils, but because ammonia was applied as NH_4Cl, almost no nitrification occurred in these treatments so the results presented here are not likely comparable to other studies. In treatments where oxidation of elemental S and nitrification were occurring simultaneously, there did not appear to be any significant difference in N_2O or nitrification compared to treatments without elemental S.

4.5. Conclusions

The results reported here support the hypothesis that N_2O-N emissions from contemporary applied fertilizers were significantly influenced by the long-term fertilization history. Long-term soil treatments with a history of N fertilization (NPKS, NPK) had greater cumulative N_2O-N emission compared to soils without a history of N fertilization (Check, PKS). When converted to an N_2O emission factor, the apparent amount of applied N as urea converted to N_2O was 0.14, 0.85, 1.1 and 0.085% for the Check, NPKS, NPK, and PKS soils, respectively (based on treatments without elemental S). When elemental S and urea were applied together, the N_2O emission factors were 0.47, 1.45, 0.84 and 0.13% for the Check, NPKS, NPK and PKS, but there were no statistical differences in the cumulative N_2O-N emitted between the UR and UR + S^0 treatments within a given soil type. Because of the different kinetics and microbial populations associated with nitrification and S oxidation, longer incubation times are recommended in the future in order to better understand the interactions between these two processes. The mechanism for greater N_2O emissions in soil with long-term application of N fertilizers compared to soils without, despite similar nitrification and respiration levels, remains unclear and further investigation on the effects of long-term management history on microbial community composition and enzyme activity is warranted.

Chapter 5. General Discussion and Conclusions

5.1. Overview of the Research Objectives, Questions and Importance

Although the area of S-deficient soils in Western Canada is projected to increase, much past research has been focused on the effects of N fertilization on C sequestration and N_2O emissions, and relatively little data exist to accurately assess the effects of long-term combined N and S fertilization on C sequestration, but no on N_2O emissions.

Taking into account the fact that long-term soil, crop and nutrient management have an impact on C sequestration and N_2O emissions, the overall objective of this research was mainly to explore the interaction of N and S fertilization on soil C sequestration and N_2O emission in S-deficient soils. The thesis presents the results of three studies which seek sought to answer the following main research questions:

a) Does long-term S fertilization in a S-deficient soils increase total soil organic C (SOC) over time? (Chapter 2)
b) Do long-term inorganic (combined application of N and S with other macro nutrients) and organic (manure) fertilization and crop rotation practices significantly influence cumulative growing season N_2O-N emissions? (Chapter 3)
c) Does fertilization history significantly interact with contemporary applied various N and S fertilizer sources with respect to N_2O-N emission potential? (Chapter 4)
d) Are emissions of N_2O-N influenced by the interaction of elemental S-oxidation and nitrification? (Chapter 4)

Understanding the effect of the interaction of N and S fertilization on soil C sequestration and N_2O emissions will contribute to the adoption of fertilizer and crop rotation management practices that can mitigate N_2O-N emissions and increase C sequestration in S-deficient soils. Therefore, in order to answer the research questions and meet the main objective of the research, three field and laboratory experiments are presented in Chapters 2, 3 and 4 of this thesis.

5.2. Synthesis of Empirical Findings, Contribution and Implication of the Research

The main findings of the research are chapter specific and were summarized within the respective chapters (Chapters 2, 3 and 4). This section will synthesize the findings and answers to the study's main research questions.

5.2.1. Brief Summary of the Findings

- We showed the potential of long-term S fertilization in combination with other macro nutrients for SOC sequestration in S-deficient soils of western Canada (Chapter 2). The potential of combined application of S with NPK for SOC sequestration, compared to NPK alone, in the top 15 cm of soil was 0.11 Mg C ha^{-1} yr^{-1}.
- The growing season 3-year cumulative N_2O-N emissions from S-deficient soils at Breton Plots were affected by the interaction of long-term crop rotation systems and soil fertility treatments (Chapter 3).
- N_2O-N emissions from contemporary application of N and S fertilizers were significantly affected by the long-term fertilization history (Chapter 4).
- N_2O-N emissions were not influenced by the interaction of S-oxidation and nitrification processes (Chapter 4).

5.2.2. Synthesis of the Findings

Quantifying the potential growing season N_2O-N emissions from long-term fertility treatments in the 2-yr (WF) and 5-yr (WOBHH) crop rotations at the Breton Classical Plots (Chapter 3) was very complex, including many variables such as yield, N uptake and N_2O emission intensity, but it also provided some input to evaluate the tradeoff between economic (yield) and environmental impacts (N_2O emissions). An interaction between long-term soil fertilization history and rotation significantly influenced the growing season N_2O-N emission. Although WOBHH had higher cumulative growing season N_2O-N emission compared to the WF crop rotation system, the N_2O-N emissions intensity (kg of N_2O-N emissions per kg of grain yield, and kg of N_2O-N emissions per kg of N uptake) of WOBHH was lower than WF. That is, the amount of N loss per kg of wheat gain produced was almost similar in the two crop rotation system, and this is a remarkable result from agronomic and economic perspectives.

The effects of long-term combined application of N and S fertilizers on growing season N_2O-N emissions from the S-deficient soil were obvious in the WOBHH rotation compared to WF. Soils with long-term NPKS fertilization history had higher cumulative growing season N_2O-N emission than soils with long-term history of N or S alone. On the other hand, it was interesting to note that NPKS had the highest crop yield and highest wheat N uptake compared to the soil fertility treatments with long-term fertilization history of either S or N alone. Yield was more sensitive to S fertilization in WOBHH, and confirmed previous studies stating that long term combined application of S with other macro nutrients has the potential to increase yield.

Our results indicated that higher N uptake or NUE does not necessarily decrease growing season N_2O-N emission. The higher yields and N uptake were correlated with greater nitrification of fertilizers, crop residues and soil organic N. That is, when the main process of N_2O production is nitrification, the highest N uptake will not necessarily reduce N_2O-N emissions. Before available NO_3^- -N is taken up by plants, there is a possibility of N_2O emission along the pathway of nitrification. The use of nitrification inhibitors may decrease total growing season N_2O through increased uptake of NH_4.

The findings from this study provides an approach to compare the benefits of long-term combined N and S fertilization in terms of C sequestration, N_2O-N emission and global warming potential (GWP). Although soil with long-term NPKS fertilization history increased SOC sequestration in a wheat-oat-barley-hay-hay (WOBHH) crop rotation system, it also increased the growing season N_2O-N emissions in wheat-phase, and it is interesting to explore the effect of long-term combined N and S fertilization on GWP. Chapter 2 showed that long-term NPKS fertilization has the potential to sequester 300 kg C ha^{-1} (0.3 Mg $ha^{-1}yr^{-1}$), whereas Chapter 3 indicated that the cumulative 3-year growing season N_2O-N emission was 1.36 kg N ha^{-1}.

Therefore, in order to compare and understand the climatic effect of long-term N and S fertilization in the WOBHH rotation system, wheat-phase, the global warming potential was calculated with the following equations (Huang et al., 2013).

$$N2O_{GWP} = \mathrm{N2O}\frac{(kgN2O\!-\!Nha^{-1}\,yr^{-1})}{28} * 44 * 298 \quad [6]$$

Where the molecular weight of N in N_2O is 28 and the molecular weight of N_2O is 44. Based on 100 years, the global warming potential of 1 kg N_2O is equivalent to 298 kg CO_2 (IPCC., 2007).

$$SOC_{GWP} = \frac{SOC(kgCha^{-1}\,yr^{-1})}{12} * 44 \quad [7]$$

Where the molecular weight of C in CO_2 is 12 and the molecular weight of CO_2 is 44.

Using the above equations, the calculations results show that the GWP from N_2O emissions due to the long-term NPKS fertilization was 637 CO_2-eq ha^{-1} yr^{-1}, whereas the GWP from SOC increase was 1100 CO_2-eq ha^{-1} yr^{-1}. Thus, the present study shows that long-term NPKS fertilization in a wheat-oat-barley-hay-hay crop rotation-wheat phase has more benefit in terms of increasing C sequestration compared to reducing N_2O emission. However, even if the long-term NPKS fertilization has offset the N_2O emission with the given management practices, when the soil reaches a maximum soil C capacity (soil C saturation), the trend of increasing SOC might slow down (West and Six., 2007), and may not last forever.

Further to C sequestration, soil with long-term NPKS fertilization history achieved higher yield. However, our findings also indicate that the contributions of long-term S fertilization for soil organic C accumulation can be significantly influenced by previous fertilization management history, crop rotation system and contemporary tillage practices. The present study also shows that since S-oxidation did not affect the nitrification processes, there was no significant difference between treatment with S^0 or without S^0. The effect of contemporary application of N and S fertilizers on N_2O emissions also depends on soil fertilization history.

5.2.3. Contribution and Implication of the Research

The present study increases our understanding of the interactive effects of N and S fertilization on NUE, N_2O emissions and C sequestration in S-deficient soils. The results presented in the thesis underscore the importance of long-term fertilizer and crop rotation system management to increase yield while simultaneously achieving higher yield with reduced N_2O-N emission per kg of yield. Therefore, the findings from this research could be a foundation for further relevant research, and it undoubtedly will add to the existing knowledge of 4R (right fertilizer nutrient source, rate, time and method of application), Nutrient Stewardship, NUE, and N_2O-N emissions from agricultural soils. Moreover, it may have significant implications for sustainable agriculture and can also be considered in N_2O-N reduction, C sequestration and nutrient management strategies in S-deficient soils.

5.3. Recommendations for Future Research

In order to obtain additional information and a complete understanding of the effect of N and S interaction on N_2O emissions and C sequestration, there is need for more laboratory and field studies on S-deficient soils to allow further assessment of various dimensions of the subject. Exploring the following as future research strategies should be worthwhile.

- Although our results indicated that long-term application of S fertilizer in combination with N fertilizer could reduce N_2O-N emissions intensities from S-deficient soils at Breton Classical Plots, Western Canada, further studies are recommended in similar soils at various other locations in Canada and elsewhere.
- Since the N_2O-N in field measurements were done during summer growing seasons, future long-term field measurements during the spring season or year-round are highly recommended to provide a complete insight into the effect of N and S interaction on N_2O emission in other S-deficient soils.
- Since the laboratory incubation experiment was done under aerobic conditions, repeating the experiment both under aerobic and anaerobic soil condition could deliver further information.
- In order better to understand the interaction of nitrification and S-oxidation, microbial composition and enzyme activities, it would be good to continue further research under field conditions in order to determine S^0 oxidation and nitrification interaction effect on N_2O emission.

- Considering the potential of long-term S fertilization for SOC sequestration, further long-term study by taking soil sample deeper than 0-15 cm in long-term experimental plots such as Breton Classica Plots would further confirm the findings.

All these studies are considered worthwhile investigations in the near future, and eventually, will contribute to balanced agricultural production with N_2O emissions mitigation in S-deficient soils.

Unlike earlier studies, which were mainly focused on the effect of N fertilizers on N_2O emissions and C sequestration, the present study provides insight into N_2O emissions and carbon sequestration as affected by N and S interaction in S deficient soils. The N_2O emission dynamic was not only influenced by the interaction of long-term N and S fertilization history and crop rotation but also by the interaction of contemporary N and S application and long-term N and S fertilization. Our findings suggest that long-term crop rotation and soil fertility treatments, which increase crop yield and NUE, are the best management practices to reduce N_2O-N emission. Therefore, the study will encourage adoption of best fertilizer and crop rotation management practices that can mitigate N_2O emissions. Moreover, the results presented in this study, will contribute to the new knowledge in the area of the study.

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Appendices

Appendix 3-A: soil properties of soil at surface soils (0-15 cm) of treatments of series A, B, C, D and E and two crop rotations (wheat-oat-barley-hay-hay - WOBHH and wheat-fallow - WF) at the Breton Classical Plots (samples taken in 2013).

Series	Plot	Half	Rotation	Soil	Total N (Mg ha^{-1})	TOC (Mg ha^{-1})	Total S (Mg ha^{-1})	pH
A	2	East	WOBHH	Manure	4.32	48.83	0.67	6.46
A	2	West	WOBHH	Manure	3.52	37.93	0.71	6.09
A	3	East	WOBHH	NPKS	3.23	35.63	0.38	5.88
A	3	West	WOBHH	NPKS	2.99	33.55	0.44	5.01
A	5	East	WOBHH	Check	1.92	24.56	0.33	6.17
A	5	West	WOBHH	Check	2.45	26.68	0.34	5.77
A	7	East	WOBHH	NPK(-S)	2.54	27.41	0.36	6.15
A	7	West	WOBHH	NPK(-S)	2.69	28.25	0.35	5.56
A	8	East	WOBHH	PKS(-N)	2.86	32.55	0.49	5.78
A	8	West	WOBHH	PKS(-N)	3.10	33.87	0.52	5.28
A	11	East	WOBHH	Check	2.66	29.85	0.37	6.16
A	11	West	WOBHH	Check	2.55	28.14	0.41	5.80
B	2	East	WOBHH	Manure	4.74	52.35	0.41	5.96
B	2	West	WOBHH	Manure	4.38	49.17	0.45	6.07
B	3	East	WOBHH	NPKS	2.88	36.49	0.48	5.80
B	3	West	WOBHH	NPKS	2.86	32.00	0.42	4.90
B	5	East	WOBHH	Check	2.11	28.01	0.42	6.17
B	5	West	WOBHH	Check	2.43	27.76	0.57	5.54
B	7	East	WOBHH	NPK(-S)	2.77	32.42	0.67	6.14
B	7	West	WOBHH	NPK(-S)	2.40	29.86	0.64	5.57
B	8	East	WOBHH	PKS(-N)	3.05	32.73	0.43	5.88
B	8	West	WOBHH	PKS(-N)	2.47	32.39	0.50	5.40
B	11	East	WOBHH	Check	3.06	31.24	0.63	6.05
B	11	West	WOBHH	Check	2.74	27.68	0.43	5.64
C	2	East	WOBHH	Manure	4.29	44.41	0.34	6.30
C	2	West	WOBHH	Manure	4.27	45.40	0.43	5.92
C	3	East	WOBHH	NPKS	3.03	34.15	0.47	5.85
C	3	West	WOBHH	NPKS	3.28	36.07	0.46	4.88
C	5	East	WOBHH	Check	3.08	32.76	0.70	6.21
C	5	West	WOBHH	Check	2.52	25.91	0.69	5.77
C	7	East	WOBHH	NPK(-S)	3.04	31.64	0.35	6.52
C	7	West	WOBHH	NPK(-S)	2.62	28.14	0.34	5.58

C	8	East	WOBHH	PKS(-N)	3.13	32.94	0.46	6.02
C	8	West	WOBHH	PKS(-N)	3.37	35.84	0.52	5.33
C	11	East	WOBHH	Check	3.43	34.94	0.43	6.50
C	11	West	WOBHH	Check	3.07	32.80	0.43	5.96
D	2	East	WOBHH	Manure	4.95	52.51	0.70	6.12
D	2	West	WOBHH	Manure	5.01	51.57	0.70	5.98
D	3	East	WOBHH	NPKS	3.54	37.55	0.76	5.65
D	3	West	WOBHH	NPKS	3.74	38.22	0.62	5.12
D	5	East	WOBHH	Check	3.10	31.55	0.38	5.99
D	5	West	WOBHH	Check	3.22	32.24	0.38	5.70
D	7	East	WOBHH	NPK(-S)	3.49	35.78	0.43	5.88
D	7	West	WOBHH	NPK(-S)	3.66	37.45	0.43	5.46
D	8	East	WOBHH	PKS(-N)	2.98	30.67	0.50	5.86
D	8	West	WOBHH	PKS(-N)	3.69	36.97	0.55	5.27
D	11	East	WOBHH	Check	4.32	43.70	0.52	6.00
D	11	West	WOBHH	Check	3.62	35.86	0.44	5.56
E	2	East	WF	Manure	3.91	40.83	0.64	6.66
E	2	West	WF	Manure	3.26	34.52	0.58	6.59
E	3	East	WF	NPKS	2.10	21.38	0.36	6.09
E	3	West	WF	NPKS	2.39	22.21	0.52	5.63
E	5	East	WF	Check	1.18	12.70	0.28	6.13
E	5	West	WF	Check	1.80	17.43	0.33	6.33
E	7	East	WF	NPK(-S)	1.96	17.23	0.36	6.16
E	7	West	WF	NPK(-S)	2.04	20.07	0.38	6.45
E	8	East	WF	PKS(-N)	1.78	17.76	0.37	6.47
E	8	West	WF	PKS(-N)	1.68	18.68	0.37	6.31
E	11	East	WF	Check	1.81	25.99	0.40	6.38
E	11	West	WF	Check	2.32	20.06	0.37	6.58
F	2	East	WOBHH	Manure	4.73	47.43	0.88	6.82
F	2	West	WOBHH	Manure	4.10	39.44	0.68	6.39
F	3	East	WOBHH	NPKS	3.79	38.38	0.66	5.82
F	3	West	WOBHH	NPKS	3.19	31.40	0.55	5.71
F	5	East	WOBHH	Check	3.16	33.38	0.53	6.26
F	5	West	WOBHH	Check	2.80	28.38	0.42	6.68
F	7	East	WOBHH	NPK(-S)	3.80	37.18	0.56	6.35
F	7	West	WOBHH	NPK(-S)	4.02	41.46	0.53	6.40
F	8	East	WOBHH	PKS(-N)	3.80	38.20	0.65	5.85
F	8	West	WOBHH	PKS	3.55	34.79	0.65	5.80
F	11	East	WOBHH	Check	3.25	39.14	0.57	6.79
F	11	West	WOBHH	Check	2.87	33.18	0.55	6.10

Appendix 3-B: Daily precipitation, daily average air temperature, daily volumetric water content at 5 cm, daily soil temperature at 5 and 20 cm during the 2013- 2015 growing season.

Date	Average Precipitation (mm)	Air Temp. Average (^{0}C)	Soil Moisture @5 cm (Vol. %])	Soil Moisture @20 cm (Vol. [%])	Soil Temp.@ cm (^{0}C)	Soil Temp. @ 20 cm (^{0}C)
1-May-13	0.2	2.79	38.35	39.108	3.157	2.859
2-May-13	0	11.41	38.116	38.939	4.802	3.607
3-May-13	0	10.202	37.88	38.905	6.119	4.754
4-May-13	0	11.77	37.616	38.831	6.628	5.242
5-May-13	0	17.048	37.332	38.742	8.358	6.329
6-May-13	0	18.814	36.971	38.581	9.142	7.262
7-May-13	0	10.302	36.53	38.475	9.493	8.015
8-May-13	0	12.02	36.068	38.369	8.724	7.735
9-May-13	0	15.539	35.497	38.346	9.819	8.168
10-May-13	0	8.654	34.807	38.275	9.478	8.545
11-May-13	0	14.933	34	38.222	9.846	8.509
12-May-13	0	18.361	33.136	38.225	10.596	9.201
13-May-13	0	13.508	32.272	38.167	10.808	9.422
14-May-13	0	11.935	31.319	38.072	10.425	9.442
15-May-13	0	11.51	30.382	37.955	10.391	9.353
16-May-13	0	10.958	29.559	37.851	10.389	9.488
17-May-13	0	11.639	28.829	37.701	10.06	9.314
18-May-13	0	13.605	27.992	37.519	10.31	9.362
19-May-13	0	13.255	27.223	37.327	11.128	9.831
20-May-13	0	14.613	26.443	37.056	11.879	10.357
21-May-13	0	16.27	25.465	36.674	12.068	10.778
22-May-13	0	13.588	24.514	36.207	11.356	10.607
23-May-13	0.5	12.897	23.956	35.819	11.273	10.484
24-May-13	31.3	8.041	29.757	35.958	10.205	10.13
25-May-13	15.4	6.513	39.569	38.293	9.348	9.367
26-May-13	0.2	9.569	38.544	38.343	9.863	9.19
27-May-13	2.3	11.474	37.768	38.271	10.914	9.938
28-May-13	1.3	11.416	37.907	38.305	11.181	10.246
29-May-13	10.2	10.884	38.36	38.515	11.052	10.419
30-May-13	6.4	10.371	38.962	39.04	11.208	10.425
31-May-13	10.3	11.936	39.548	39.245	11.684	10.735
1-Jun-13	0.1	12.313	38.598	39.366	12.308	11.088
2-Jun-13	2.2	11.422	38.251	39.394	12.728	11.556
3-Jun-13	5.1	12.984	38.813	39.432	13.069	11.922
4-Jun-13	0.1	13.308	39.018	39.388	13.045	12.019

5-Jun-13	0.1	13.365	39.348	39.324	13.399	12.379
6-Jun-13	0.1	12.837	38.501	39.21	13.202	12.234
7-Jun-13	0	13.277	37.832	39.093	13.747	12.684
8-Jun-13	0	12.285	37.424	38.979	13.125	12.458
9-Jun-13	1.1	9.698	37.003	38.895	12.497	12.13
10-Jun-13	0.9	7.445	36.773	38.815	11.533	11.614
11-Jun-13	0	9.106	36.47	38.733	11.784	11.298
12-Jun-13	1	11.922	36.073	38.717	12.475	11.682
13-Jun-13	0.2	10.703	35.693	38.692	12.631	11.894
14-Jun-13	2.4	10.809	35.438	38.666	12.634	12.007
15-Jun-13	1.4	11.972	35.415	38.627	12.747	12.075
16-Jun-13	1.1	11.715	35.44	38.581	12.853	12.104
17-Jun-13	0.2	14.041	35.249	38.545	13.609	12.368
18-Jun-13	0	13.272	34.718	38.532	14.094	13.013
19-Jun-13	9.4	14.183	35.866	38.517	14.155	13.225
20-Jun-13	6.4	12.06	39.155	38.616	13.459	13.081
21-Jun-13	0.8	13.782	39.281	38.937	14.318	13.058
22-Jun-13	3.2	13.672	39.154	38.888	14.99	13.737
23-Jun-13	6.9	15.175	37.888	38.861	16.192	14.552
24-Jun-13	0.1	14.174	39.608	38.89	16.204	14.949
25-Jun-13	2	14.075	38.641	38.889	16.085	15.145
26-Jun-13	0.6	15.49	38.21	38.848	16.467	15.088
27-Jun-13	0.2	16.211	37.055	38.782	16.765	15.439
28-Jun-13	0	17.688	35.6	38.688	17.215	15.79
29-Jun-13	0	19.207	33.803	38.597	18.049	16.331
30-Jun-13	0	19.011	32.164	38.519	18.829	16.949
1-Jul-13	0	21.336	30.314	38.336	19.323	17.371
2-Jul-13	15.8	23.6	31.337	38.43	20.653	18.382
3-Jul-13	0.3	17.055	37.913	38.976	20.195	18.728
4-Jul-13	3.1	14.612	36.437	38.753	18.634	17.962
5-Jul-13	1.3	13.963	35.763	38.628	18.487	17.619
6-Jul-13	0.1	12.102	35.055	38.506	17.9	17.333
7-Jul-13	1.2	12.941	34.363	38.365	17.1	16.72
8-Jul-13	0.1	13.835	33.271	38.206	16.852	16.435
9-Jul-13	0	18.361	31.626	38.006	17.429	16.427
10-Jul-13	2.9	17.854	29.828	37.825	18.498	17.115
11-Jul-13	6.8	12.472	32.156	37.686	17.635	17.097
12-Jul-13	0.1	12.085	33.652	37.46	16.654	16.41
13-Jul-13	3.2	9.809	31.902	37.227	15.71	15.886
14-Jul-13	1.1	12.202	31.473	37.108	16.027	15.62
15-Jul-13	33.4	11.386	36.613	38.374	15.398	15.481
16-Jul-13	0.1	14.847	38.49	38.85	15.525	15.066
17-Jul-13	0	16.628	36.678	38.63	16.401	15.595

18-Jul-13	0	18.52	34.863	38.56	17.797	16.373
19-Jul-13	0.7	18.053	33.144	38.475	18.495	17.066
20-Jul-13	7.7	16.385	31.701	38.335	18.407	17.285
21-Jul-13	0.3	15.611	32.878	38.183	18.424	17.475
22-Jul-13	0	16.762	32.996	38.054	18.242	17.403
23-Jul-13	0.1	17.194	32.252	37.923	18.534	17.472
24-Jul-13	0.2	16.422	31.025	37.802	18.335	17.589
25-Jul-13	0.1	14.885	30.118	37.678	17.256	17.093
26-Jul-13	0	16.711	29.3	37.497	17.235	16.696
27-Jul-13	1.6	13.093	28.462	37.328	16.792	16.59
28-Jul-13	0.2	10.845	28.095	37.143	15.437	15.747
29-Jul-13	2	10.683	27.907	36.983	15.14	15.172
30-Jul-13	0.2	12.031	27.636	36.828	14.908	14.887
31-Jul-13	0	14.995	27.017	36.633	15.48	15.005
1-Aug-13	1.8	15.252	26.483	36.464	15.976	15.389
2-Aug-13	0.1	15.712	26.48	36.384	16.2	15.601
3-Aug-13	0	16.01	26.034	36.185	16.166	15.529
4-Aug-13	0.1	15.742	25.278	35.915	16.721	15.803
5-Aug-13	6.3	15.31	24.972	35.753	16.844	16.051
6-Aug-13	0.2	15.562	25.506	35.696	17.181	16.259
7-Aug-13	3.3	12.524	25.555	35.605	16.379	16.162
8-Aug-13	0	13.056	25.858	35.551	15.96	15.753
9-Aug-13	0	14.674	25.905	35.505	15.934	15.587
10-Aug-13	0.1	17.591	25.52	35.384	16.492	15.657
11-Aug-13	27.7	17.638	27.454	35.794	16.7	15.992
12-Aug-13	0.3	17.028	38.283	38.461	16.6	15.68
13-Aug-13	0.1	17.567	36.909	38.492	17.692	16.546
14-Aug-13	0.1	18.785	35.61	38.447	18.135	16.973
15-Aug-13	0	18.031	34.322	38.386	18.109	17.233
16-Aug-13	0	17.37	33.18	38.302	18.3	17.3
17-Aug-13	2.5	17.069	31.736	38.153	18.208	17.333
18-Aug-13	0.3	16.653	30.568	37.977	18.144	17.359
19-Aug-13	2.4	13.558	29.982	37.801	17.331	17.115
20-Aug-13	0.1	12.526	29.515	37.602	16.375	16.472
21-Aug-13	0.1	12.033	28.582	37.323	15.347	15.663
22-Aug-13	0	15.368	27.362	37.042	15.444	15.399
23-Aug-13	0	14.91	26.392	36.818	15.818	15.568
24-Aug-13	0	16.982	25.683	36.586	16.274	15.694
25-Aug-13	0	15.163	24.904	36.325	16.245	15.858
26-Aug-13	3.8	13.875	24.57	36.124	15.725	15.645
27-Aug-13	0.2	15.366	24.619	35.957	16.112	15.6
28-Aug-13	0	15.016	24.545	35.77	15.815	15.57
29-Aug-13	0	16.328	24.386	35.575	16.241	15.648

30-Aug-13	1.9	14.624	24.148	35.407	16.646	15.958
31-Aug-13	0.8	15.429	23.946	35.234	16.476	15.85
1-Sep-13	0.1	15.563	23.528	34.961	16.024	15.684
2-Sep-13	0	16.575	22.893	34.61	15.967	15.618
3-Sep-13	0	16.617	22.268	34.251	16.128	15.68
4-Sep-13	0	19.169	21.701	33.892	16.437	15.75
5-Sep-13	0	17.765	21.077	33.527	16.448	15.865
6-Sep-13	0.1	15.359	20.81	33.357	16.643	16.047
7-Sep-13	2.7	13.546	20.79	33.317	16.052	15.815
8-Sep-13	0	16.22	20.845	33.262	16.399	15.72
9-Sep-13	0.1	14.719	20.597	33.079	15.625	15.524
10-Sep-13	0.1	12.697	20.185	32.723	14.555	14.86
11-Sep-13	0	13.36	19.786	32.371	14.223	14.441
12-Sep-13	0	17.274	19.457	32.103	14.714	14.463
13-Sep-13	0	17.884	19.123	31.895	15.145	14.72
14-Sep-13	0	15.761	18.808	31.682	14.95	14.735
15-Sep-13	0	18.254	18.52	31.451	15.047	14.703
16-Sep-13	0	17.946	18.27	31.259	15.184	14.762
17-Sep-13	0	11.875	17.946	31.044	13.945	14.334
18-Sep-13	0.1	5.861	17.642	30.777	12.338	13.331
19-Sep-13	0.1	8.809	17.455	30.552	11.5	12.473
20-Sep-13	0	12.424	17.338	30.399	11.876	12.356
21-Sep-13	0.2	12.816	17.216	30.298	12.277	12.491
22-Sep-13	0.3	10.925	17.071	30.203	12.009	12.426
23-Sep-13	2	9.594	16.951	30.084	11.748	12.165
24-Sep-13	0.2	6.134	16.882	29.967	10.623	11.629
25-Sep-13	0.1	5.552	16.883	29.872	10.036	11.06
26-Sep-13	0	4.375	16.824	29.785	9.625	10.624
27-Sep-13	0	5.956	16.658	29.634	8.834	10.01
28-Sep-13	0	7.3	16.577	29.549	8.856	9.829
29-Sep-13	0	10.243	16.625	29.56	9.931	10.162
30-Sep-13	1.6	3.76	16.486	29.487	8.773	9.856
1-May-14	0	12.563	36.848	38.506	8.122	6.711
2-May-14	0.4	6.18	36.762	38.464	7.455	6.719
3-May-14	3.2	-0.494	36.601	38.369	5.76	5.948
4-May-14	4.5	-1.302	37.602	38.359	4.646	5.026
5-May-14	0.1	1.872	38.513	38.63	4.371	4.396
6-May-14	0.1	0.451	37.974	38.696	4.106	4.387
7-May-14	0.1	2.708	37.494	38.662	4.466	4.155
8-May-14	0.4	7.286	37.137	38.563	5.632	4.811
9-May-14	0.1	6.817	36.847	38.446	6.58	5.548
10-May-4	1.1	3.094	36.585	38.312	5.752	5.614
11-May-14	0.1	5.449	36.41	38.204	5.795	5.28

12-May-14	0	8.504	36.005	38.18	6.895	5.879
13-May-14	0	11.153	35.586	38.184	8.237	6.771
14-May-14	0.3	13.645	35.166	38.188	8.982	7.525
15-May-14	0.3	8.962	34.915	38.167	8.672	7.88
16-May-14	0.2	7.359	34.729	38.102	8.455	7.616
17-May-14	0	10.294	34.35	38.076	8.638	7.732
18-May-14	0.1	11.017	33.918	38.065	9.259	8.147
19-May-14	0.9	8.743	33.471	38.019	9.4	8.281
20-May-14	0.1	12.864	32.874	37.99	10.22	8.826
21-May-14	0	14.941	31.99	37.958	11.183	9.543
22-May-14	0.1	15.816	30.959	37.904	11.77	10.134
23-May-14	0.1	17.6	29.754	37.82	12.485	10.66
24-May-14	0.9	12.702	28.604	37.693	12.425	11.035
25-May-14	0.3	10.956	28.115	37.558	11.997	10.929
26-May-14	2.2	10.265	27.95	37.453	11.951	10.943
27-May-14	0.6	10.666	27.888	37.335	11.878	10.831
28-May-14	19.9	7.631	33.003	37.403	10.859	10.607
29-May-14	10.5	8.268	38.808	38.658	10.608	10.098
30-May-14	0	13.18	37.258	38.638	11.582	10.357
31-May-14	0	12.634	36.028	38.478	12.438	11.078
1-Jun-14	0.9	11.979	34.865	38.401	12.653	11.419
2-Jun-14	0.2	13.531	33.651	38.339	13.11	11.716
3-Jun-14	0	13.837	32.022	38.279	13.583	12.168
4-Jun-14	13.3	10.63	31.869	38.197	13.41	12.405
5-Jun-14	1.1	5.474	37.989	38.169	12.108	11.754
6-Jun-14	0.1	8.695	36.708	38.17	11.88	11.264
7-Jun-14	0	10.955	35.199	38.135	12.622	11.656
8-Jun-14	0	13.586	33.568	38.078	13.404	12.044
9-Jun-14	4.7	10.66	32.567	38.039	13.493	12.517
10-Jun-14	0	9.866	32.863	37.953	12.925	12.209
11-Jun-14	0.1	11.053	31.957	37.817	13.479	12.296
12-Jun-14	0	14.272	30.257	37.615	13.949	12.736
13-Jun-14	0	11.794	28.941	37.415	13.71	12.864
14-Jun-14	0	13.088	27.829	37.173	14.154	12.853
15-Jun-14	0	12.704	26.112	36.84	14.381	13.209
16-Jun-14	0	12.103	24.839	36.504	14.268	13.285
17-Jun-14	0	11.339	24.108	36.202	14.017	13.159
18-Jun-14	0	13.14	23.185	35.795	14.32	13.144
19-Jun-14	8.9	13.437	23.044	35.615	14.902	13.692
20-Jun-14	30	14.348	28.369	36.053	14.753	13.854
21-Jun-14	11.9	13.765	38.81	38.669	14.565	13.449
22-Jun-14	0	13.975	36.94	38.77	15.1	13.926
23-Jun-14	0	15.871	35.14	38.618	15.612	14.286

24-Jun-14	0	18.528	33.703	38.613	16.291	14.809
25-Jun-14	1.1	14.327	32.799	38.591	15.968	14.88
26-Jun-14	0.1	15.216	31.795	38.522	15.831	14.742
27-Jun-14	0	15.895	30.32	38.441	16.278	14.975
28-Jun-14	20.8	13.446	35.934	38.601	15.712	14.964
29-Jun-14	6.7	12.004	38.871	39.186	15.109	14.67
30-Jun-14	0.5	15.586	38.036	39.175	15.288	14.344
1-Jul-14	0	16.676	36.775	38.986	16.333	14.878
2-Jul-14	0	19.162	35.152	38.898	17.268	15.6
3-Jul-14	0	21.1	33.24	38.833	18.334	16.257
4-Jul-14	0	17.007	31.236	38.737	18.297	16.626
5-Jul-14	0	17	29.548	38.596	18.536	16.815
6-Jul-14	0	16.84	28.045	38.397	18.517	16.935
7-Jul-14	0	17.155	26.538	38.079	18.153	16.836
8-Jul-14	0	20.101	24.947	37.68	18.74	17.013
9-Jul-14	2.6	19.415	23.711	37.289	19.225	17.432
10-Jul-14	0.2	14.169	23.282	37.02	18.051	17.157
11-Jul-14	0.1	15.383	23.053	36.733	17.761	16.635
12-Jul-14	0	20.044	22.56	36.369	18.994	17.094
13-Jul-14	0	20.968	21.907	35.947	19.775	17.68
14-Jul-14	0	20.04	21.346	35.488	19.687	17.895
15-Jul-14	0	20.804	20.948	35.034	19.921	17.948
16-Jul-14	0	21.127	20.614	34.632	20.123	18.223
17-Jul-14	16.1	15.094	26.802	34.415	18.741	17.982
18-Jul-14	0.2	15.154	34.453	34.352	17.85	17.063
19-Jul-14	4.7	15.426	32.76	34.424	18.522	17.385
20-Jul-14	3.8	13.117	35.348	34.455	18.33	17.31
21-Jul-14	0.2	14.037	35.118	34.428	18.05	17.133
22-Jul-14	0	16.837	32.69	34.407	18.032	17.168
23-Jul-14	0	18.107	30.429	34.397	18.489	17.259
24-Jul-14	14.7	16.726	30.081	34.379	18.398	17.522
25-Jul-14	34.7	11.179	38.79	36.386	15.334	15.928
26-Jul-14	0.8	14.582	38.046	38.588	16.169	15.417
27-Jul-14	0	17.133	36.413	38.574	17.346	16.116
28-Jul-14	0	19.276	34.533	38.533	18.446	16.901
29-Jul-14	0.2	20.491	32.358	38.435	19.452	17.648
30-Jul-14	0.1	21.793	30.419	38.3	20.292	18.381
31-Jul-14	0	20.796	28.935	38.15	20.762	18.887
1-Aug-14	0	17.659	27.888	37.969	20.344	18.942
2-Aug-14	0	19.779	26.935	37.759	20.225	18.866
3-Aug-14	0	19.004	26.117	37.565	20.247	18.918
4-Aug-14	0	16.574	25.589	37.385	19.443	18.679
5-Aug-14	0	17.558	24.935	37.126	19.354	18.368

6-Aug-14	3.7	18.253	24.114	36.848	19.837	18.586
7-Aug-14	2	14.214	23.925	36.67	18.639	18.235
8-Aug-14	3	11.612	24.271	36.578	17.332	17.495
9-Aug-14	0.2	13.377	24.439	36.409	16.924	16.644
10-Aug-14	0	17.32	24.216	36.258	18.183	17.082
11-Aug-14	0	19.078	23.717	36.048	18.963	17.638
12-Aug-14	0	20.047	23.125	35.793	19.142	17.982
13-Aug-14	0.5	21.498	22.765	35.609	19.754	18.338
14-Aug-14	0.1	19.879	22.42	35.422	19.963	18.605
15-Aug-14	0	19.045	21.984	35.162	19.445	18.536
16-Aug-14	0	18.695	21.723	34.921	19.363	18.406
17-Aug-14	0	17.359	21.482	34.708	18.858	18.19
18-Aug-14	0	18.958	21.115	34.371	18.769	17.945
19-Aug-14	1.9	15.646	20.879	34.17	18.849	18.085
20-Aug-14	1.4	12.479	20.795	34.062	17.944	17.629
21-Aug-14	0	10.25	20.633	33.869	16.828	16.942
22-Aug-14	0	10.326	20.489	33.665	16.2	16.365
23-Aug-14	0	11.374	20.27	33.364	16.029	15.99
24-Aug-14	0	10.67	19.947	33.006	15.586	15.659
25-Aug-14	0	14.105	19.647	32.688	15.768	15.576
26-Aug-14	0	17.355	19.427	32.449	17.062	16.077
27-Aug-14	3.5	16.45	19.119	32.208	17.355	16.472
28-Aug-14	2.7	12.758	19.142	32.104	16.852	16.423
29-Aug-14	3.2	13.151	19.227	32.029	15.692	15.802
30-Aug-14	1.5	12.05	19.352	32.022	15.888	15.666
31-Aug-14	0	10.624	19.383	31.978	15.169	15.312
1-Sep-14	2.3	9.652	19.33	31.915	14.62	14.892
2-Sep-14	0.1	10.098	19.348	31.892	14.662	14.676
3-Sep-14	0	8.749	19.282	31.851	14.173	14.397
4-Sep-14	0	10.296	19.166	31.784	13.89	14.128
5-Sep-14	0	13.229	19.027	31.707	14.219	14.038
6-Sep-14	0	16.227	18.858	31.655	14.999	14.433
7-Sep-14	7.8	10.736	18.698	31.589	14.399	14.478
8-Sep-14	11.7	0.455	19.443	31.418	11.638	13.233
9-Sep-14	1.2	1.445	24.71	31.215	10.516	11.812
10-Sep-14	3	1.414	32.557	31.162	10.212	11.221
11-Sep-14	0.1	4.116	32.967	31.133	9.667	10.636
12-Sep-14	2.8	4.629	32.081	31.195	9.639	10.497
13-Sep-14	0.8	7.673	33.717	31.333	10.919	10.838
14-Sep-14	0	10.712	32.727	31.498	11.741	11.427
15-Sep-14	0	13.056	30.926	31.63	12.266	11.892
16-Sep-14	0	14.135	29.202	31.732	12.754	12.278
17-Sep-14	0	13.97	27.717	31.835	13.133	12.641

18-Sep-14	4.7	13.613	26.78	31.975	13.762	13.094
19-Sep-14	0.4	13.641	27.009	32.054	13.657	13.165
20-Sep-14	0	12.175	26.723	32.062	13.085	13.01
21-Sep-14	0	16.583	26.02	32.044	13.16	12.888
22-Sep-14	0	18.658	25.115	32.075	13.822	13.165
23-Sep-14	0.1	13.792	24.312	32.158	14.075	13.572
24-Sep-14	0	16.233	23.724	32.16	14.039	13.521
25-Sep-14	0.1	13.62	23.17	32.166	13.979	13.565
26-Sep-14	1.5	8.424	22.709	32.152	13.217	13.315
27-Sep-14	0	5.134	22.469	32.064	12.157	12.565
28-Sep-14	0	7.794	22.212	31.969	11.519	11.992
29-Sep-14	0	10.977	21.865	31.91	11.712	11.804
30-Sep-14	0.9	8.985	21.542	31.913	11.591	11.841
1-May-15	0	5.774	31.899	36.569	6.856	6.501
2-May-15	0.4	5.329	31.489	36.518	6.888	6.489
3-May-15	0	5.336	30.998	36.441	7.001	6.42
4-May-15	0	8.348	30.375	36.375	7.671	6.785
5-May-15	2.4	6.439	29.746	36.312	7.958	7.18
6-May-15	4.2	0.282	30.468	36.24	6.656	6.778
7-May-15	3.2	2.772	34.422	36.17	6.665	6.319
8-May-15	0.1	6.191	35.527	36.155	7.749	6.775
9-May-15	0	10.427	34.329	36.146	8.66	7.493
10-May-15	0	9.568	33.109	36.115	9.091	8.009
11-May-15	0	8.438	31.98	36.046	8.743	8.1
12-May-15	0	8.988	30.863	35.952	8.472	7.96
13-May-15	0	9.612	29.686	35.86	8.682	8.044
14-May-15	0	10.07	28.662	35.768	8.967	8.203
15-May-15	0	11.22	27.833	35.701	9.451	8.502
16-May-15	2.1	5.488	27.372	35.67	8.805	8.523
17-May-15	0.1	5.145	27.164	35.565	8.692	8.042
18-May-15	0	9.209	26.536	35.446	8.767	8.21
19-May-15	0	11.956	25.638	35.28	9.405	8.52
20-May-15	0	14.199	24.518	35.076	10.004	8.96
21-May-15	0	15.266	23.301	34.827	10.706	9.421
22-May-15	0	15.238	22.078	34.533	11.662	9.983
23-May-15	0	15.99	20.96	34.195	12.461	10.669
24-May-15	0	16.925	20.1	33.806	12.659	11.137
25-May-15	0	15.789	19.56	33.418	12.762	11.305
26-May-15	0	14.799	19.224	33.084	13.333	11.617
27-May-15	1.8	15.919	18.959	32.785	14.484	12.257
28-May-15	0.1	9.777	18.763	32.585	14.345	12.698
29-May-15	0.5	8.145	18.554	32.399	11.783	11.807
30-May-15	0	12.881	18.574	32.233	12.285	11.235

31-May-15	7.8	13.725	19.952	32.061	13.453	11.828
1-Jun-15	0	12.116	23.556	32.118	13.56	12.047
2-Jun-15	1	12.048	22.78	32.223	13.77	12.466
3-Jun-15	0	14.52	21.959	32.162	13.881	12.519
4-Jun-15	0.5	13.693	20.917	32.072	14.486	12.836
5-Jun-15	0	14.804	20.067	31.951	14.927	13.11
6-Jun-15	0	17.948	19.248	31.766	16.089	13.834
7-Jun-15	0	18.26	18.522	31.488	16.668	14.385
8-Jun-15	0	17.213	18.028	31.239	16.585	14.665
9-Jun-15	0	16.442	17.688	30.993	16.829	14.725
10-Jun-15	0	15.178	17.347	30.779	16.674	14.865
11-Jun-15	2.3	15.498	17.282	30.725	16.966	15.064
12-Jun-15	0.2	10.283	17.178	30.67	15.412	14.638
13-Jun-15	1	8.349	17.073	30.552	14.168	13.832
14-Jun-15	1.3	10.384	17.105	30.49	14.337	13.438
15-Jun-15	0	11.328	17.068	30.449	13.908	13.239
16-Jun-15	2	13.033	17.061	30.41	14.395	13.323
17-Jun-15	3.8	10.048	17.182	30.428	14.154	13.429
18-Jun-15	0	13.128	17.548	30.451	14.674	13.348
19-Jun-15	2.1	12.384	17.643	30.549	14.485	13.72
20-Jun-15	2.4	10.557	17.62	30.468	13.752	13.132
21-Jun-15	0	12.016	17.79	30.525	14.624	13.325
22-Jun-15	0	14.218	17.82	30.638	15.58	13.979
23-Jun-15	1.3	14.65	17.722	30.725	16.292	14.601
24-Jun-15	0	17.618	17.552	30.665	16.566	14.686
25-Jun-15	0	20.337	17.344	30.636	18.224	15.636
26-Jun-15	0	21.395	17.114	30.525	19.394	16.49
27-Jun-15	0	21.673	16.819	30.352	19.864	16.999
28-Jun-15	0	22.826	16.568	30.163	20.42	17.387
29-Jun-15	4.4	16.183	16.211	30.018	18.498	17.243
30-Jun-15	0.2	16.612	16.372	29.949	17.931	16.48
1-Jul-15	0.9	18.571	16.666	30.039	18.882	16.753
2-Jul-15	0	20.803	16.766	30.149	19.71	17.263
3-Jul-15	1.1	20.718	16.618	30.198	20.142	17.809
4-Jul-15	10.6	14.406	17.21	31.094	17.944	17.137
5-Jul-15	0.1	13.395	18.663	32.095	17.088	16.23
6-Jul-15	0	15.011	18.745	31.885	17.163	16.127
7-Jul-15	0	14.488	18.586	31.802	17.693	16.438
8-Jul-15	0	20.983	18.202	31.634	18.443	16.751
9-Jul-15	0	23.464	17.672	31.369	19.762	17.461
10-Jul-15	0	22.767	17.154	31.097	20.367	18.164
11-Jul-15	0	21.105	16.852	30.847	20.638	18.402
12-Jul-15	0	20.826	16.63	30.645	20.525	18.612

13-Jul-15	5.1	17.602	20.535	30.561	20.265	18.622
14-Jul-15	0	17.552	18.907	30.536	19.8	18.304
15-Jul-15	2	16.724	17.558	30.518	19.89	18.427
16-Jul-15	12.5	11.687	21.78	30.378	17.816	17.706
17-Jul-15	32	14.133	35.43	34.713	16.465	16.503
18-Jul-15	0	18.532	34.41	37.445	17.542	16.546
19-Jul-15	0	18.872	32.769	37.073	19.083	17.527
20-Jul-15	4.6	18.962	31.327	36.75	19.649	18.154
21-Jul-15	0.4	15.381	31.863	36.507	19.276	18.186
22-Jul-15	0.4	12.067	31.14	36.356	17.777	17.543
23-Jul-15	0	14.744	30.289	36.18	17.965	17.105
24-Jul-15	0	16.848	28.973	35.982	18.514	17.409
25-Jul-15	2.7	13.041	27.812	35.797	17.732	17.354
26-Jul-15	0.68	13.085	27.632	35.72	15.882	16.897
27-Jul-15	0.04	14.632	26.504	35.388	18.436	16.722
28-Jul-15	0	15.575	25.77	35.224	17.192	16.564
29-Jul-15	0.08	14.676	24.752	35	17.385	16.653
30-Jul-15	0	16.616	23.85	34.764	18.007	16.83
31-Jul-15	0	20.275	22.484	34.355	18.709	17.322
1-Aug-15	0	17.272	21.358	33.986	19.081	17.815
2-Aug-15	0	19.146	20.585	33.634	19.242	17.856
3-Aug-15	0	20.718	19.862	33.206	19.866	18.181
4-Aug-15	0.1	16.657	19.233	32.841	19.184	18.345
5-Aug-15	0.1	13.686	18.866	32.552	18.187	17.654
6-Aug-15	5	12.393	18.617	32.266	17.383	17.082
7-Aug-15	0	15.628	19.316	32.11	17.608	16.838
8-Aug-15	0	18.438	19.243	32.025	18.5	17.264
9-Aug-15	0	18.752	18.674	31.8	18.64	17.498
10-Aug-15	2.2	18.278	18.167	31.52	18.8	17.602
11-Aug-15	0	19.555	17.956	31.334	18.967	17.703
12-Aug-15	0	20.029	17.715	31.177	19.206	17.905
13-Aug-15	0	20.572	17.295	30.919	19.137	18.007
14-Aug-15	0	15.307	16.91	30.697	18.013	17.643
15-Aug-15	14.4	10.498	18.834	30.503	16.124	16.52
16-Aug-15	0.9	9.915	20.76	30.431	15.728	15.797
17-Aug-15	0.3	12.197	21.104	30.413	15.356	15.382
18-Aug-15	1.2	14.043	20.924	30.525	16.541	15.734
19-Aug-15	0.1	18.096	20.368	30.68	17.442	16.383
20-Aug-15	11.6	13.801	19.848	30.805	16.885	16.394
21-Aug-15	5.2	8.695	30.672	31.331	15.168	15.61
22-Aug-15	0	10.146	30.485	30.962	14.852	14.766
23-Aug-15	0	14.631	28.3	30.929	15.258	14.872
24-Aug-15	0	14.329	26.51	30.992	15.888	15.253

25-Aug-15	0	13.024	25.301	31.019	15.676	15.282
26-Aug-15	0	13.621	24.417	31.049	15.979	15.32
27-Aug-15	0	16.09	23.431	31.122	16.783	15.694
28-Aug-15	0	17.627	22.172	31.165	16.837	16.029
29-Aug-15	0	16.172	20.922	31.127	16.555	15.94
30-Aug-15	0	14.465	19.835	31.025	15.888	15.608
31-Aug-15	0	14.598	18.928	30.871	15.442	15.217
1-Sep-15	1.3	11.264	18.209	30.709	14.928	14.896
2-Sep-15	0.1	10.253	17.853	30.623	14.56	14.641
3-Sep-15	6.4	6.883	17.562	30.448	13.445	13.86
4-Sep-15	20.3	5.72	28.935	30.339	12.376	13.203
5-Sep-15	3.3	7.339	32.86	30.312	12.218	12.567
6-Sep-15	22.1	5.501	37.136	33.799	11.385	12.111
7-Sep-15	2.1	8.238	36.098	38.077	11.74	11.729
8-Sep-15	10.2	9.425	35.141	37.949	12.16	12.065
9-Sep-15	0.6	9.305	36.057	38.382	12.423	12.284
10-Sep-15	0	13.8	34.924	38.209	13.687	12.806
11-Sep-15	0	16.728	33.835	38.053	14.466	13.506
12-Sep-15	2.6	15.955	32.689	37.895	14.887	14.027
13-Sep-15	3.4	9.852	35.247	37.851	14.478	14.15
14-Sep-15	0.2	6.919	34.43	37.844	13.52	13.609
15-Sep-15	9.8	5.28	36.864	38.347	12.225	12.8
16-Sep-15	0.1	6.093	36.204	38.497	12.102	12.263
17-Sep-15	0	6.654	35.175	38.258	11.454	11.816
18-Sep-15	0	9.648	34.373	38.099	11.827	11.816
19-Sep-15	0	11.571	33.707	37.988	11.718	11.83
20-Sep-15	10.3	7.379	34.541	37.962	11.36	11.64
21-Sep-15	0.1	4.72	36.986	38.574	10.308	10.978
22-Sep-15	0	7.039	35.657	38.31	10.138	10.481
23-Sep-15	0	8.12	34.861	38.144	10.707	10.664
24-Sep-15	0	10.786	34.16	38.033	10.669	10.717
25-Sep-15	1	9.425	33.457	37.953	10.932	10.86
26-Sep-15	1.5	7.877	33.031	37.887	11.038	10.981
27-Sep-15	0.1	4.383	32.919	37.773	9.612	10.35
28-Sep-15	0	8.633	32.635	37.678	9.96	10.067
29-Sep-15	0	10.908	32.069	37.613	10.322	10.237
30-Sep-15	0.1	12.942	31.437	37.56	10.929	10.569

Appendix 3-C: Weekly gas fluxes (**N_2O-N** and CO_2-C) from five fertility treatments (Control, Manure, NPKS, NPK and PKS) and two crop rotations (wheat-oat-barley-hay-hay - WOBHH and wheat-fallow - WF) at the Breton Classical Plots during the 2013-2015 growing season.

Date	Treatment	Chamber	Plot half	Rotation	Rotation Phase	Fertility Treatment	Lime Treatment	CO_2 flux (kg/ha/day)	N_2O flux (kg/ha/day)
06/08/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	116.6	0.062
06/11/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	68.0	0.020
06/17/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	98.3	0.022
06/28/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	238.3	0.055
07/03/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	268.2	0.030
07/08/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	191.3	0.023
07/11/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	168.3	0.014
07/17/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	168.3	0.014
07/24/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	254.9	0.048
08/02/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	181.0	0.037
08/09/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	181.8	0.037
08/16/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	158.9	0.032
08/22/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	97.5	0.019
08/29/13	D (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	136.3	0.025
06/08/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	11.6	0.018
06/11/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	26.5	0.010
06/17/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	184.8	0.042
06/28/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	310.0	0.061
07/03/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	228.8	0.023
07/08/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	3.2	0.001
07/11/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	140.4	0.010
07/17/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	140.4	0.010
07/24/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	161.2	0.028

08/02/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	142.8	0.031
08/09/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	104.3	0.022
08/16/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	135.7	0.025
08/22/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	84.4	0.016
08/29/13	D (wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	89.3	0.017
06/08/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	13.9	0.018
06/11/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	13.3	0.000
06/17/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	60.1	0.010
06/28/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	219.8	0.040
07/03/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	195.0	0.015
07/08/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	190.5	0.015
07/11/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	127.1	0.006
07/17/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	157.7	0.009
07/24/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	176.6	0.032
08/02/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	101.2	0.019
08/09/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	36.6	0.005
08/16/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	147.8	0.023
08/22/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	90.7	0.015
08/29/13	D (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	118.3	0.022
06/08/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	33.0	0.059
06/11/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	95.4	0.036
06/17/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	197.9	0.039
06/28/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	349.9	0.061
07/03/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	252.2	0.014
07/08/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	146.1	0.008
07/11/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	173.4	0.006
07/17/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	173.4	0.006
07/24/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	243.5	0.041
08/02/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	95.6	0.019
08/09/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	230.5	0.044
08/16/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	210.3	0.040

08/22/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	133.4	0.025
08/29/13	D (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	158.9	0.028
06/08/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	15.5	0.039
06/11/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	72.8	0.026
06/17/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	166.0	0.034
06/28/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	296.8	0.055
07/03/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	191.6	0.015
07/08/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	156.6	0.012
07/11/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	197.0	0.013
07/17/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	196.3	0.013
07/24/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	258.4	0.049
08/02/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	175.3	0.037
08/09/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	138.0	0.027
08/16/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	191.5	0.036
08/22/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	132.8	0.023
08/29/13	D (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	118.5	0.022
06/08/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	57.8	0.038
06/11/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	27.5	0.011
06/17/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	140.1	0.032
06/28/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	218.6	0.038
07/03/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	216.6	0.011
07/08/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	207.7	0.013
07/11/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	145.1	0.006
07/17/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	145.1	0.006
07/24/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	185.1	0.030
08/02/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	97.2	0.020
08/09/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	158.6	0.029
08/16/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	169.4	0.031
08/22/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	88.0	0.015
08/29/13	D (wheat 11)	6	East	WOBHH	Wheat	Control	Lime	80.1	0.013
06/08/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	193.6	0.221

06/11/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	93.9	0.048
06/17/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	122.1	0.025
06/28/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	265.2	0.043
07/03/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	244.2	0.014
07/08/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	244.2	0.010
07/11/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	235.6	0.014
07/17/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	235.6	0.007
07/24/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	241.2	0.038
08/02/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	163.4	0.029
08/09/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	149.8	0.027
08/16/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	173.8	0.031
08/22/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	83.4	0.011
08/29/13	D (wheat 11)	7	West	WOBHH	Wheat	Control	No Lime	103.6	0.016
06/08/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	72.1	0.071
06/11/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	2.6	0.001
06/17/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	165.6	0.039
06/28/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	290.2	0.048
07/03/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	300.0	0.015
07/08/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	226.2	0.017
07/11/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	193.8	0.015
07/17/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	193.8	0.015
07/24/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	205.4	0.034
08/02/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	47.8	0.004
08/09/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	133.8	0.030
08/16/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	179.2	0.037
08/22/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	46.1	0.008
08/29/13	D (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	115.0	0.020
06/08/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	275.7	0.177
06/11/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	141.4	0.069
06/17/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	172.8	0.037
06/28/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	247.6	0.040

07/03/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	230.4	0.016
07/08/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	257.9	0.018
07/11/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	184.3	0.012
07/17/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	184.3	0.012
07/24/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	232.3	0.060
08/02/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	180.7	0.038
08/09/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	44.8	0.009
08/16/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	156.0	0.031
08/22/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	85.3	0.012
08/29/13	D (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	120.1	0.020
06/08/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	55.7	0.023
06/11/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	43.6	0.009
06/17/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	8.9	0.001
06/28/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	229.4	0.033
07/03/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	23.6	0.005
07/08/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	161.8	0.004
07/11/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	239.8	0.040
07/17/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	239.8	0.040
07/24/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	76.0	0.012
08/02/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	165.3	0.031
08/09/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	101.5	0.021
08/16/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	88.8	0.016
08/22/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	138.2	0.018
08/29/13	D (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	119.8	0.019
06/08/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	105.9	0.196
06/11/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	129.9	0.106
06/17/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	271.8	0.061
06/28/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	339.8	0.056
07/03/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	428.2	0.022
07/08/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	243.0	0.009
07/11/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	315.5	0.050

07/17/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	315.5	0.050
07/24/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	77.6	0.000
08/02/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	236.8	0.045
08/09/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	144.6	0.031
08/16/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	160.3	0.032
08/22/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	119.6	0.018
08/29/13	D (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	81.8	0.015
06/08/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	93.6	0.190
06/11/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	105.1	0.055
06/17/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	205.5	0.037
06/28/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	422.3	0.062
07/03/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	389.1	0.015
07/08/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	279.3	0.009
07/11/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	266.6	0.043
07/17/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	254.4	0.041
07/24/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	210.5	0.032
08/02/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	121.9	0.024
08/09/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	156.2	0.031
08/16/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	194.3	0.034
08/22/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	121.8	0.018
08/29/13	D (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	122.3	0.018
06/08/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	111.7	0.012
06/11/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	94.3	0.014
06/17/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	150.2	0.014
06/28/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	259.7	0.004
07/03/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	306.0	0.014
07/08/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	282.7	0.006
07/11/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	267.0	0.040
07/17/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	266.7	0.040
07/24/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	100.3	0.013
08/02/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	116.5	0.020

08/09/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	89.1	0.016
08/16/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	145.2	0.025
08/22/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	129.6	0.019
08/29/13	E (wheat 2)	13	East	WF	Wheat	Manure	Lime	97.4	0.012
06/08/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	87.2	0.024
06/11/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	55.1	0.011
06/17/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	111.8	0.020
06/28/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	207.9	0.004
07/03/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	143.5	0.005
07/08/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	108.7	0.003
07/11/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	124.7	0.019
07/17/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	124.7	0.019
07/24/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	104.2	0.014
08/02/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	85.7	0.016
08/09/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	30.9	0.016
08/16/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	81.3	0.013
08/22/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	91.8	0.015
08/29/13	E (wheat 3)	14	East	WF	Wheat	NPKS	Lime	71.1	0.011
06/08/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	39.7	0.007
06/11/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	26.9	0.005
06/17/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	46.9	0.006
06/28/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	95.8	0.004
07/03/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	27.3	0.001
07/08/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	83.7	0.001
07/11/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	97.4	0.014
07/17/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	97.4	0.014
07/24/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	51.4	0.008
08/02/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	45.1	0.008
08/09/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	45.5	0.009
08/16/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	38.4	0.007
08/22/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	55.7	0.008

08/29/13	E (wheat 5)	15	East	WF	Wheat	Control	Lime	32.9	0.005
06/08/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	81.4	0.062
06/11/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	34.5	0.011
06/17/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	143.0	0.032
06/28/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	63.2	0.005
07/03/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	306.2	0.030
07/08/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	151.4	0.005
07/11/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	167.9	0.026
07/17/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	167.9	0.026
07/24/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	147.6	0.023
08/02/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	98.7	0.017
08/09/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	40.0	0.008
08/16/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	94.7	0.016
08/22/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	75.9	0.010
08/29/13	E (wheat 7)	16	East	WF	Wheat	NPK	Lime	66.8	0.009
06/08/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	7.7	0.002
06/11/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	49.4	0.009
06/17/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	87.6	0.013
06/28/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	163.3	0.004
07/03/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	167.2	0.005
07/08/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	143.7	0.002
07/11/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	120.6	0.018
07/17/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	120.6	0.018
07/24/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	108.6	0.016
08/02/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	77.4	0.015
08/09/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	76.2	0.012
08/16/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	92.3	0.014
08/22/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	66.4	0.008
08/29/13	E (wheat 8)	17	East	WF	Wheat	PKS	Lime	67.2	0.011
06/08/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	15.6	0.003
06/11/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	25.6	0.005

06/17/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	73.1	0.011
06/28/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	183.2	0.003
07/03/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	148.5	0.006
07/08/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	191.6	0.004
07/11/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	179.5	0.024
07/17/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	179.5	0.024
07/24/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	96.2	0.014
08/02/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	94.5	0.016
08/09/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	87.0	0.015
08/16/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	111.7	0.018
08/22/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	83.2	0.011
08/29/13	E (wheat 11)	18	East	WF	Wheat	Control	Lime	69.8	0.009
06/08/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	25.5	0.004
06/11/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	27.2	0.007
06/17/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	49.9	0.006
06/28/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	84.6	0.000
07/03/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	134.4	0.003
07/08/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	75.3	0.000
07/11/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	87.3	0.011
07/17/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	87.3	0.011
07/24/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	30.4	0.005
08/02/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	28.2	0.004
08/09/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	28.2	0.006
08/16/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	58.7	0.009
08/22/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	56.7	0.007
08/29/13	E (fallow 11)	19	West	WF	Wheat	Control	Lime	44.4	0.007
06/08/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	31.2	0.005
06/11/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	9.5	0.002
06/17/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	65.1	0.010
06/28/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	168.1	0.003
07/03/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	145.2	0.008

07/08/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	134.0	0.003
07/11/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	9.0	0.001
07/17/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	9.0	0.001
07/24/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	44.2	0.008
08/02/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	59.3	0.011
08/09/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	48.6	0.008
08/16/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	63.0	0.011
08/22/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	77.9	0.012
08/29/13	E (fallow 8)	20	West	WF	Wheat	PKS	Lime	97.2	0.012
06/08/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	52.3	0.009
06/11/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	0.8	0.007
06/17/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	124.1	0.017
06/28/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	147.4	0.005
07/03/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	153.0	0.003
07/08/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	98.1	0.003
07/11/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	123.8	0.022
07/17/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	91.4	0.013
07/24/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	71.1	0.011
08/02/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	44.6	0.006
08/09/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	1.9	0.000
08/16/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	49.1	0.005
08/22/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	78.6	0.011
08/29/13	E (fallow 7)	21	West	WF	Wheat	NPK	Lime	31.6	0.007
06/08/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	48.6	0.009
06/11/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	32.9	0.005
06/17/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	1.9	0.000
06/28/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	107.0	0.004
07/03/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	89.8	0.001
07/08/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	47.9	0.002
07/11/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	9.4	0.000
07/17/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	9.4	0.000

07/24/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	66.1	0.011
08/02/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	23.0	0.002
08/09/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	30.8	0.005
08/16/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	38.0	0.005
08/22/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	43.9	0.006
08/29/13	E (fallow 5)	22	West	WF	Control	NPK	Lime	44.8	0.007
06/08/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	4.8	0.001
06/11/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	2.7	0.001
06/17/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	39.0	0.006
06/28/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	54.4	0.000
07/03/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	179.4	0.001
07/08/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	89.6	0.002
07/11/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	46.6	0.005
07/17/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	46.6	0.005
07/24/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	45.9	0.008
08/02/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	39.5	0.004
08/09/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	27.2	0.004
08/16/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	97.1	0.013
08/22/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	65.6	0.008
08/29/13	E (fallow 3)	23	West	WF	Control	NPKS	Lime	24.8	0.003
06/08/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	71.7	0.013
06/11/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	55.4	0.010
06/17/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	107.8	0.016
06/28/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	147.8	0.001
07/03/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	223.7	0.003
07/08/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	151.3	0.005
07/11/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	144.1	0.019
07/17/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	144.1	0.019
07/24/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	116.0	0.018
08/02/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	70.4	0.012
08/09/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	86.8	0.014

08/16/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	111.7	0.017
08/22/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	105.0	0.014
08/29/13	E (fallow 2)	24	West	WF	Control	Manure	Lime	11.7	0.002
22/05/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	14.7	0.005
27/05/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	16.6	0.021
2/6/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	48.8	0.009
10/6/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	69.3	0.035
17/06/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	53.1	0.011
24/06/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	102.2	0.037
1/7/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	186.5	0.095
8/7/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	106.6	0.021
15/07/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	156.1	0.050
22/07/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	161.0	0.086
29/07/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	191.4	0.070
5/8/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	67.0	0.024
12/8/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	85.0	0.015
19/8/2014	E (Fallow 2)	1	East	WF	Fallow	Manure	Lime	55.4	0.019
22/05/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	37.2	0.002
27/05/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	2.7	0.004
2/6/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	6.2	0.004
10/6/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	23.6	0.009
17/06/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	37.8	0.008
24/06/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	4.5	-0.018
1/7/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	123.2	0.036
8/7/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	65.4	0.005
15/07/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	75.0	0.015
22/07/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	39.3	0.000
29/07/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	83.8	0.014
5/8/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	19.8	-0.013
12/8/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	68.6	0.002
19/8/2014	E (Fallow 3)	2	East	WF	Fallow	NPKS	Lime	67.6	0.000

22/05/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	8.3	0.018
27/05/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	4.0	0.010
2/6/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	17.2	0.002
10/6/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	13.5	0.003
17/06/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	16.1	0.002
24/06/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	20.4	-0.008
1/7/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	53.0	0.000
8/7/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	33.1	-0.003
15/07/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	33.1	-0.006
22/07/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	41.2	0.017
29/07/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	51.1	0.006
5/8/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	19.0	0.000
12/8/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	28.5	-0.005
19/8/2014	E (Fallow 5)	3	East	WF	Fallow	Control	Lime	24.5	-0.008
22/05/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	40.9	0.014
27/05/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	2.6	0.001
2/6/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	43.3	0.015
10/6/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	29.3	0.014
17/06/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	40.1	0.010
24/06/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	58.4	0.004
1/7/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	134.2	0.022
8/7/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	96.4	0.001
15/07/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	212.2	0.051
22/07/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	2.8	-0.003
29/07/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	118.5	0.040
5/8/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	93.2	0.027
12/8/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	73.9	0.024
19/8/2014	E (Fallow 7)	4	East	WF	Fallow	NPK	Lime	55.5	0.005
22/05/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	13.8	0.000
27/05/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	13.5	0.009
2/6/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	17.2	0.002

10/6/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	25.2	0.014
17/06/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	24.1	0.010
24/06/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	46.1	0.001
1/7/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	96.1	0.014
8/7/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	48.3	0.009
15/07/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	57.7	0.004
22/07/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	38.1	0.008
29/07/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	46.5	-0.002
5/8/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	18.6	-0.004
12/8/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	28.4	0.003
19/8/2014	E (Fallow 8)	5	East	WF	Fallow	PKS	Lime	13.0	-0.010
22/05/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	27.1	0.005
27/05/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	25.2	0.002
2/6/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	29.8	0.003
10/6/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	33.0	0.010
17/06/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	22.1	0.006
24/06/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	26.2	0.002
1/7/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	94.7	0.033
8/7/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	53.9	0.003
15/07/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	55.5	0.009
22/07/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	145.5	0.033
29/07/2014	E (Fallow	6	East	WF	Fallow	Control2	Lime	85.4	0.011

	11)								
5/8/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	48.4	0.008
12/8/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	39.5	0.001
19/8/2014	E (Fallow 11)	6	East	WF	Fallow	Control2	Lime	76.1	0.013
22/05/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	9.8	0.000
27/05/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	10.8	0.005
2/6/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	4.6	0.001
10/6/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	16.8	0.002
17/06/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	25.9	0.001
24/06/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	40.7	-0.004
1/7/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	78.1	0.004
8/7/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	74.4	0.011
15/07/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	84.9	0.001
22/07/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	64.5	0.014
29/07/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	28.6	-0.005
5/8/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	4.3	-0.006
12/8/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	0.0	0.000
19/8/2014	E (wheat 11)	7	West	WF	Wheat	Control2	Lime	37.2	0.004
22/05/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	27.0	0.002
27/05/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	14.9	0.003
2/6/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	18.8	0.005
10/6/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	26.5	0.011
17/06/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	53.5	0.005
24/06/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	53.6	0.005
1/7/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	103.4	0.018
8/7/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	28.9	0.013
15/07/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	66.0	0.001
22/07/2014	E (wheat 8)	8	West	WF	Wheat	PKS	Lime	75.0	0.018

29/07/2014	E	(wheat 8)	8	West	WF	Wheat	PKS	Lime	109.0	-0.005
5/8/2014	E	(wheat 8)	8	West	WF	Wheat	PKS	Lime	54.3	0.004
12/8/2014	E	(wheat 8)	8	West	WF	Wheat	PKS	Lime	6.8	-0.001
19/8/2014	E	(wheat 8)	8	West	WF	Wheat	PKS	Lime	25.7	0.008
22/05/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	14.1	0.004
27/05/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	2.7	0.005
2/6/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	79.6	0.053
10/6/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	48.3	0.037
17/06/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	152.2	0.044
24/06/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	92.8	0.036
1/7/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	233.9	0.066
8/7/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	106.6	-0.006
15/07/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	135.9	0.000
22/07/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	7.3	0.021
29/07/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	77.6	0.010
5/8/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	85.6	0.008
12/8/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	76.1	0.019
19/8/2014	E	(wheat 7)	9	West	WF	Wheat	NPK	Lime	37.9	0.012
22/05/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	14.5	0.001
27/05/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	13.7	0.002
2/6/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	34.0	0.004
10/6/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	27.4	0.015
17/06/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	49.7	0.018
24/06/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	86.1	0.003
1/7/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	163.4	0.003
8/7/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	49.5	-0.003
15/07/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	75.6	0.001
22/07/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	136.8	0.029
29/07/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	43.1	-0.007
5/8/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	11.9	0.002
12/8/2014	E	(wheat 5)	10	West	WF	Wheat	Control	Lime	10.6	0.003

19/8/2014	E (wheat 5)	10	West	WF	Wheat	Control	Lime	36.9	-0.002
22/05/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	41.2	0.018
27/05/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	27.0	0.000
2/6/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	0.4	0.002
10/6/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	48.5	0.022
17/06/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	121.4	0.054
24/06/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	133.0	0.019
1/7/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	222.9	0.064
8/7/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	12.9	-0.006
15/07/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	117.4	0.000
22/07/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	24.8	-0.001
29/07/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	106.9	-0.008
5/8/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	32.6	0.000
12/8/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	77.0	0.003
19/8/2014	E (wheat 3)	11	West	WF	Wheat	NPKS	Lime	58.8	0.005
22/05/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	27.0	0.008
27/05/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	47.9	0.023
2/6/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	97.2	0.016
10/6/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	41.6	0.015
17/06/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	92.6	0.033
24/06/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	33.4	0.000
1/7/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	220.8	0.013
8/7/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	120.6	-0.006
15/07/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	130.6	-0.002
22/07/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	24.3	0.000
29/07/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	35.4	0.005
5/8/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	95.8	0.016
12/8/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	112.6	0.015
19/8/2014	E (wheat 2)	12	West	WF	Wheat	Manure	Lime	80.6	0.017
22/05/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	90.5	0.036

27/05/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	93.4	0.043
2/6/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	214.9	0.078
10/6/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	120.4	0.048
17/06/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	123.5	0.053
24/06/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	158.4	0.050
1/7/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	320.6	0.037
8/7/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	54.0	0.005
15/07/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	94.6	0.004
22/07/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	17.1	0.000
29/07/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	242.0	0.014
5/8/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	170.4	0.027
12/8/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	141.2	0.023
19/8/2014	F (wheat 2-East)	13	East	WOBHH	Wheat	Manure	Lime	124.1	0.058
22/05/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	76.7	0.067
27/05/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	15.9	0.007
2/6/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	68.3	0.030
10/6/2014	F (wheat 3-	14	East	WOBHH	Wheat	NPKS	Lime	119.2	0.056

	East)								
17/06/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	144.8	0.056
24/06/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	222.4	0.047
1/7/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	264.1	0.030
8/7/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	102.8	0.005
15/07/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	138.2	0.006
22/07/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	151.2	0.031
29/07/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	150.4	0.027
5/8/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	81.3	0.006
12/8/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	110.0	0.002
19/8/2014	F (wheat 3-East)	14	East	WOBHH	Wheat	NPKS	Lime	77.9	0.025
22/05/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	62.0	0.033
27/05/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	71.6	0.025
2/6/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	167.1	0.063
10/6/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	101.2	0.050
17/06/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	166.8	0.072
24/06/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	194.2	0.045

1/7/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	339.6	0.042
8/7/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	133.4	0.020
15/07/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	190.5	0.037
22/07/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	17.6	0.001
29/07/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	182.8	0.000
5/8/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	68.3	0.007
12/8/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	112.2	0.005
19/8/2014	F (wheat 5-East)	15	East	WOBHH	Wheat	Control	Lime	104.2	0.036
22/05/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	63.8	0.008
27/05/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	28.6	0.023
2/6/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	16.8	0.003
10/6/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	104.9	0.052
17/06/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	113.3	0.031
24/06/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	178.8	0.029
1/7/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	303.5	0.023
8/7/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	167.3	0.015
15/07/2014	F (wheat 7-	16	East	WOBHH	Wheat	NPK	Lime	151.4	0.001

	East)								
22/07/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	32.7	0.000
29/07/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	244.1	0.000
5/8/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	89.1	0.019
12/8/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	205.5	0.015
19/8/2014	F (wheat 7-East)	16	East	WOBHH	Wheat	NPK	Lime	203.2	0.055
22/05/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	93.1	0.052
27/05/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	61.9	0.047
2/6/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	34.0	0.002
10/6/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	90.7	0.027
17/06/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	122.4	0.034
24/06/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	189.5	0.031
1/7/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	266.8	0.033
8/7/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	127.3	0.015
15/07/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	179.6	0.006
22/07/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	91.9	0.021
29/07/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	247.2	0.003

5/8/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	202.7	0.034
12/8/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	14.3	0.005
19/8/2014	F (wheat 8-East)	17	East	WOBHH	Wheat	PKS	Lime	77.7	0.024
22/05/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	85.6	0.019
27/05/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	77.6	0.054
2/6/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	80.8	0.001
10/6/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	84.0	0.038
17/06/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	94.8	0.030
24/06/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	190.0	0.024
1/7/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	189.0	0.007
8/7/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	167.6	0.021
15/07/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	151.9	0.014
22/07/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	55.1	0.000
29/07/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	265.0	-0.006
5/8/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	66.8	0.030
12/8/2014	F (wheat 11-East)	18	East	WOBHH	Wheat	Control2	Lime	89.4	0.010
19/8/2014	F (wheat 11-	18	East	WOBHH	Wheat	Control2	Lime	81.9	0.027

	East)								
22/05/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	111.8	0.083
27/05/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	13.4	0.004
2/6/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	80.7	0.028
10/6/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	155.5	0.061
17/06/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	283.0	0.092
24/06/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	319.8	0.063
1/7/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	403.9	0.025
8/7/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	311.1	0.041
15/07/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	293.4	0.016
22/07/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	73.4	0.011
29/07/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	13.4	-0.002
5/8/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	22.3	0.016
12/8/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	81.1	0.000
19/8/2014	F (wheat 11-west)	19	West	WOBHH	Wheat	Control2	No Lime	99.8	0.032
22/05/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	111.6	0.054
27/05/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	91.7	0.061

2/6/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	100.4	0.033
10/6/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	131.6	0.037
17/06/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	146.2	0.049
24/06/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	203.1	0.024
1/7/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	317.8	0.013
8/7/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	123.2	0.007
15/07/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	305.6	0.028
22/07/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	285.5	0.048
29/07/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	144.4	-0.005
5/8/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	205.3	0.032
12/8/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	38.7	0.000
19/8/2014	F (wheat 8-west)	20	West	WOBHH	Wheat	PKS	No Lime	158.4	0.053
22/05/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	2.0	0.002
27/05/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	5.6	0.000
2/6/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	68.5	0.021
10/6/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	175.7	0.070
17/06/2014	F (wheat 7-	21	West	WOBHH	Wheat	NPK	No Lime	195.3	0.063

	west)								
24/06/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	211.2	0.045
1/7/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	346.0	0.039
8/7/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	116.0	0.021
15/07/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	206.9	0.019
22/07/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	5.3	0.000
29/07/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	87.2	0.003
5/8/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	122.2	0.010
12/8/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	81.8	0.004
19/8/2014	F (wheat 7-west)	21	West	WOBHH	Wheat	NPK	No Lime	106.8	0.036
22/05/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	71.3	0.022
27/05/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	57.5	0.023
2/6/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	169.4	0.032
10/6/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	60.9	0.042
17/06/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	118.0	0.040
24/06/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	47.4	0.006
1/7/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	313.2	0.047

8/7/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	129.6	0.000
15/07/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	170.9	0.000
22/07/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	122.4	0.025
29/07/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	80.9	0.000
5/8/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	126.5	0.007
12/8/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	37.4	0.008
19/8/2014	F (wheat 5-west)	22	West	WOBHH	Wheat	Control	No Lime	51.5	0.014
22/05/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	72.5	0.032
27/05/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	54.2	0.013
2/6/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	32.0	0.010
10/6/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	76.6	0.032
17/06/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	133.0	0.038
24/06/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	189.3	0.038
1/7/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	296.4	0.017
8/7/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	30.4	0.014
15/07/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	122.2	-0.003
22/07/2014	F (wheat 3-	23	West	WOBHH	Wheat	NPKS	No Lime	165.9	0.042

	west)								
29/07/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	178.5	0.017
5/8/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	8.4	-0.001
12/8/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	87.2	0.008
19/8/2014	F (wheat 3-west)	23	West	WOBHH	Wheat	NPKS	No Lime	93.4	0.023
22/05/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	34.2	0.001
27/05/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	50.0	0.023
2/6/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	215.5	0.068
10/6/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	70.2	0.031
17/06/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	169.6	0.044
24/06/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	48.6	0.008
1/7/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	268.2	0.015
8/7/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	33.0	-0.002
15/07/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	180.7	0.000
22/07/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	201.6	0.023
29/07/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	163.7	0.002
5/8/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	140.6	0.008

12/8/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	58.5	0.008
19/8/2014	F (wheat 2-west)	24	West	WOBHH	Wheat	Manure	No Lime	104.1	0.041
23/05/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	35.6	0.004
6/6/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	14.4	0.016
13/6/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	42.8	0.012
19/06/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	91.8	0.053
26/06/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	91.1	0.028
3/7/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	132.7	0.041
10/7/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	11.5	-0.027
24/07/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	183.2	0.069
31/07/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	94.4	0.000
14/8/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	58.5	0.011
21/8/2014	E (Fallow 2)	25	East	WF	Fallow	Manure	Lime	69.8	0.000
23/05/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	41.8	0.003
6/6/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	42.1	0.008
13/6/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	44.2	0.011
19/06/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	72.6	0.038
26/06/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	53.9	0.016
3/7/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	93.9	0.019
10/7/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	61.2	0.014
24/07/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	116.2	0.044
31/07/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	9.4	-0.015
14/8/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	83.2	0.017
21/8/2014	E (Fallow 3)	26	East	WF	Fallow	NPKS	Lime	29.3	0.011
23/05/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	21.1	0.001
6/6/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	7.9	0.005
13/6/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	27.1	0.000
19/06/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	47.9	0.022
26/06/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	49.9	0.003

3/7/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	69.0	0.012
10/7/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	-1.4	-0.016
24/07/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	84.3	0.030
31/07/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	56.3	0.000
14/8/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	14.9	-0.009
21/8/2014	E (Fallow 5)	27	East	WF	Fallow	Control	Lime	20.9	0.006
23/05/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	77.1	0.024
6/6/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	3.8	0.006
13/6/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	59.7	0.039
19/06/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	5.4	0.003
26/06/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	130.9	0.032
3/7/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	126.3	0.022
10/7/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	74.7	0.024
24/07/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	111.0	0.017
31/07/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	113.6	0.026
14/8/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	109.7	0.020
21/8/2014	E (Fallow 7)	28	East	WF	Fallow	NPK	Lime	58.4	0.034
23/05/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	37.4	0.005
6/6/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	35.3	0.007
13/6/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	37.0	0.010
19/06/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	69.4	0.038
26/06/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	66.8	0.016
3/7/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	76.8	0.013
10/7/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	28.7	-0.006
24/07/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	108.4	0.026
31/07/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	37.1	0.012
14/8/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	29.0	-0.007
21/8/2014	E (Fallow 8)	29	East	WF	Fallow	PKS	Lime	22.0	0.008
23/05/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	46.6	0.003
6/6/2014	E (Fallow	30	East	WF	Fallow	Control2	Lime	11.7	0.007

	11)								
13/6/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	32.8	0.011
19/06/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	78.2	0.047
26/06/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	82.0	0.011
3/7/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	39.5	0.000
10/7/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	10.5	0.000
24/07/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	104.9	0.028
31/07/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	69.5	0.003
14/8/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	41.9	0.004
21/8/2014	E (Fallow 11)	30	East	WF	Fallow	Control2	Lime	25.8	-0.005
23/05/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	20.1	0.003
6/6/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	4.8	0.014
13/6/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	30.1	0.004
19/06/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	72.1	0.038
26/06/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	48.2	0.000
3/7/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	89.1	0.000
10/7/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	24.1	0.009
24/07/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	134.2	0.021
31/07/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	68.5	-0.010
14/8/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	29.7	-0.003
21/8/2014	E (wheat 11)	31	West	WF	Wheat	Control2	Lime	6.9	-0.001
23/05/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	19.0	0.000
6/6/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	53.0	0.030

13/6/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	60.2	0.019
19/06/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	99.6	0.041
26/06/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	97.0	0.005
3/7/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	119.3	0.026
10/7/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	116.8	0.019
24/07/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	163.8	0.018
31/07/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	104.1	0.010
14/8/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	53.1	-0.002
21/8/2014	E (wheat 8)	32	West	WF	Wheat	PKS	Lime	24.0	-0.006
23/05/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	39.9	0.026
6/6/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	34.9	0.030
13/6/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	90.3	0.034
19/06/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	11.9	0.003
26/06/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	113.2	0.018
3/7/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	174.8	0.019
10/7/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	63.0	0.007
24/07/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	144.6	0.005
31/07/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	115.1	0.000
14/8/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	83.4	0.015
21/8/2014	E (wheat 7)	33	West	WF	Wheat	NPK	Lime	49.4	0.019
23/05/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	20.7	0.003
6/6/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	1.1	0.010
13/6/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	28.4	0.003
19/06/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	74.2	0.038
26/06/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	55.0	-0.002
3/7/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	102.4	0.014
10/7/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	8.7	-0.005
24/07/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	41.3	0.014
31/07/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	7.6	0.000
14/8/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	10.6	-0.009
21/8/2014	E (wheat 5)	34	West	WF	Wheat	Control	Lime	48.6	0.005

23/05/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	45.0	0.009
6/6/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	13.2	0.006
13/6/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	126.8	0.031
19/06/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	89.5	0.058
26/06/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	126.9	0.024
3/7/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	195.4	0.000
10/7/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	67.9	0.032
24/07/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	120.0	0.034
31/07/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	55.2	0.000
14/8/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	50.0	0.000
21/8/2014	E (wheat 3)	35	West	WF	Wheat	NPKS	Lime	38.6	0.013
23/05/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	65.7	0.011
6/6/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	24.5	0.007
13/6/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	89.1	0.019
19/06/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	95.8	0.048
26/06/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	143.1	0.028
3/7/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	151.3	-0.006
10/7/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	-0.2	-0.004
24/07/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	142.5	0.006
31/07/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	162.8	0.004
14/8/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	30.4	-0.024
21/8/2014	E (wheat 2)	36	West	WF	Wheat	Manure	Lime	0.0	0.000
23/05/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	119.0	0.052
6/6/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	27.7	0.002
13/6/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	180.7	0.063
19/06/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	199.4	0.102
26/06/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	238.3	0.027

3/7/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	228.2	0.005
10/7/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	35.1	0.023
24/07/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	141.4	0.025
31/07/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	214.7	0.009
14/8/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	72.5	0.000
21/8/2014	F (wheat 2-East)	37	East	WOBHH	Wheat	Manure	Lime	96.6	0.036
23/05/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	63.7	0.017
6/6/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	85.7	0.043
13/6/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	139.4	0.045
19/06/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	184.0	0.083
26/06/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	159.1	0.028
3/7/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	197.7	0.007
10/7/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	113.0	0.034
24/07/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	85.9	0.030
31/07/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	23.7	0.008
14/8/2014	F (wheat 3-East)	38	East	WOBHH	Wheat	NPKS	Lime	85.3	0.005
21/8/2014	F (wheat 3-	38	East	WOBHH	Wheat	NPKS	Lime	48.1	0.023

	East)								
23/05/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	19.1	0.004
6/6/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	11.2	0.008
13/6/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	167.0	0.053
19/06/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	185.6	0.082
26/06/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	263.2	0.029
3/7/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	311.8	-0.003
10/7/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	160.1	0.036
24/07/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	138.2	0.025
31/07/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	39.4	0.006
14/8/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	126.5	0.003
21/8/2014	F (wheat 5-East)	39	East	WOBHH	Wheat	Control	Lime	74.5	0.030
23/05/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	83.5	0.052
6/6/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	131.6	0.069
13/6/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	194.3	0.068
19/06/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	51.1	0.017
26/06/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	127.0	0.015

3/7/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	192.5	0.014
10/7/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	106.0	0.032
24/07/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	114.8	0.011
31/07/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	175.7	0.029
14/8/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	114.9	0.005
21/8/2014	F (wheat 7-East)	40	East	WOBHH	Wheat	NPK	Lime	-3.0	-0.001
23/05/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	84.0	0.043
6/6/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	124.3	0.039
13/6/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	158.1	0.037
19/06/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	51.5	0.018
26/06/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	206.7	0.030
3/7/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	235.8	-0.007
10/7/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	170.8	0.046
24/07/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	214.9	0.050
31/07/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	191.3	0.032
14/8/2014	F (wheat 8-East)	41	East	WOBHH	Wheat	PKS	Lime	108.7	0.000
21/8/2014	F (wheat 8-	41	East	WOBHH	Wheat	PKS	Lime	75.9	0.036

	East)								
23/05/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	90.4	0.032
6/6/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	105.7	0.036
13/6/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	109.1	0.038
19/06/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	132.4	0.062
26/06/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	218.0	0.022
3/7/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	242.6	-0.002
10/7/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	124.3	0.029
24/07/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	167.3	0.029
31/07/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	100.8	-0.001
14/8/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	125.7	0.000
21/8/2014	F (wheat 11-East)	42	East	WOBHH	Wheat	Control2	Lime	62.9	0.017
23/05/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	115.4	0.059
6/6/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	86.8	0.045
13/6/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	149.2	0.051
19/06/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	233.6	0.148
26/06/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	227.9	0.030

3/7/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	317.7	-0.012
10/7/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	79.4	0.028
24/07/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	223.5	0.046
31/07/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	75.7	0.000
14/8/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	16.8	0.005
21/8/2014	F (wheat 11-west)	43	West	WOBHH	Wheat	Control2	No Lime	64.7	0.026
23/05/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	5.1	0.005
6/6/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	41.3	0.021
13/6/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	167.3	0.055
19/06/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	90.5	0.047
26/06/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	223.2	0.023
3/7/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	291.4	-0.024
10/7/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	19.6	0.003
24/07/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	33.6	0.003
31/07/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	19.2	-0.002
14/8/2014	F (wheat 8-west)	44	West	WOBHH	Wheat	PKS	No Lime	36.9	0.003
21/8/2014	F (wheat 8-	44	West	WOBHH	Wheat	PKS	No Lime	48.5	0.017

	west)								
23/05/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	12.6	0.002
6/6/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	31.4	0.011
13/6/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	203.3	0.066
19/06/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	0.0	0.000
26/06/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	322.3	0.029
3/7/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	281.8	-0.013
10/7/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	65.2	0.022
24/07/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	75.3	0.004
31/07/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	159.7	0.003
14/8/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	18.0	-0.019
21/8/2014	F (wheat 7-west)	45	West	WOBHH	Wheat	NPK	No Lime	36.3	0.013
23/05/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	6.2	0.011
6/6/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	7.8	0.004
13/6/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	not measured	not measured
19/06/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	184.7	0.064
26/06/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	200.5	0.024

3/7/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	270.8	0.040
10/7/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	52.4	0.002
24/07/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	183.9	0.012
31/07/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	180.6	0.011
14/8/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	42.9	-0.011
21/8/2014	F (wheat 5-west)	46	West	WOBHH	Wheat	Control	No Lime	80.4	0.027
23/05/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	83.3	0.027
6/6/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	113.1	0.062
13/6/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	not measured	not measured
19/06/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	207.3	0.074
26/06/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	271.6	0.031
3/7/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	283.6	-0.011
10/7/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	108.8	0.027
24/07/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	239.5	0.013
31/07/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	11.5	0.018
14/8/2014	F (wheat 3-west)	47	West	WOBHH	Wheat	NPKS	No Lime	112.8	0.000
21/8/2014	F (wheat 3-	47	West	WOBHH	Wheat	NPKS	No Lime	51.2	0.016

	west)								
23/05/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	74.3	0.026
6/6/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	101.8	0.044
13/6/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	not measured	not measured
19/06/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	187.6	0.059
26/06/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	239.0	0.035
3/7/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	336.2	-0.024
10/7/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	50.0	0.000
24/07/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	247.9	0.018
31/07/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	95.0	-0.004
14/8/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	76.2	0.002
21/8/2014	F (wheat 2-west)	48	West	WOBHH	Wheat	Manure	No Lime	51.9	0.015
15/05/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	55.4	0.030
19/05/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	3.3	0.017
26/05/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	44.3	0.029
2/6/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	7.7	0.011
9/6/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	10.4	0.016
16/6/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	61.6	0.037
23/6/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	123.0	0.072
30/6/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	136.5	0.089
7/7/2015	A (wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	60.8	0.028

14/7/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	5.3	0.021
21/7/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	112.5	0.076
28/7/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	62.7	0.030
4/8/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	9.7	0.039
11/8/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	31.3	0.006
18/8/2015	A	(wheat 2)	1	East	WOBHH	Wheat	Manure	Lime	84.3	0.066
15/05/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	60.0	0.040
19/05/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	44.8	0.051
26/05/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	47.3	0.040
2/6/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	69.8	0.071
9/6/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	58.1	0.026
16/6/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	96.7	0.059
23/6/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	88.5	0.044
30/6/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	73.3	0.027
7/7/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	13.8	0.002
14/7/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	31.8	0.005
21/7/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	88.9	0.062
28/7/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	43.4	0.015
4/8/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	29.0	0.023
11/8/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	96.3	0.046
18/8/2015	A	(wheat 3)	2	East	WOBHH	Wheat	NPKS	Lime	78.7	0.047
15/05/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	30.5	0.004
19/05/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	29.0	0.015
26/05/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	12.2	0.008
2/6/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	9.2	0.003
9/6/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	50.3	0.031
16/6/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	10.0	0.002
23/6/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	56.3	0.029
30/6/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	22.0	0.001
7/7/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	38.6	0.022
14/7/2015	A	(wheat 5)	3	East	WOBHH	Wheat	Control	Lime	78.4	0.037

21/7/2015	A (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	175.2	0.123
28/7/2015	A (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	16.8	0.007
4/8/2015	A (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	47.2	0.031
11/8/2015	A (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	95.1	0.054
18/8/2015	A (wheat 5)	3	East	WOBHH	Wheat	Control	Lime	21.8	0.004
15/05/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	50.6	0.031
19/05/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	44.2	0.026
26/05/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	57.1	0.042
2/6/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	22.2	0.021
9/6/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	22.8	0.005
16/6/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	38.4	0.001
23/6/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	70.9	0.035
30/6/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	11.1	0.001
7/7/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	69.2	0.040
14/7/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	8.0	0.007
21/7/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	10.7	0.004
28/7/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	3.5	0.017
4/8/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	23.8	0.010
11/8/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	78.2	0.027
18/8/2015	A (wheat 7)	4	East	WOBHH	Wheat	NPK	Lime	46.6	0.016
15/05/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	29.2	0.013
19/05/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	42.2	0.031
26/05/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	25.2	0.017
2/6/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	74.5	0.072
9/6/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	80.7	0.029
16/6/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	7.4	0.002
23/6/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	70.4	0.021
30/6/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	84.4	0.046
7/7/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	6.6	0.003
14/7/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	27.3	0.003
21/7/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	71.4	0.029

28/7/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	58.2	0.027
4/8/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	14.3	0.009
11/8/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	66.2	0.019
18/8/2015	A (wheat 8)	5	East	WOBHH	Wheat	PKS	Lime	66.8	0.034
15/05/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	25.6	0.016
19/05/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	4.9	0.001
26/05/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	35.8	0.017
2/6/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	4.4	0.000
9/6/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	56.0	0.018
16/6/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	3.1	0.002
23/6/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	69.0	0.017
30/6/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	1231.9	0.042
7/7/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	29.9	0.010
14/7/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	98.0	0.044
21/7/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	162.8	0.070
28/7/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	93.8	0.039
4/8/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	12.4	0.010
11/8/2015	A (wheat 11)	6	East	WOBHH	Wheat	Control2	Lime	77.1	0.018
18/8/2015	A (wheat	6	East	WOBHH	Wheat	Control2	Lime	66.3	0.034

	11)								
15/05/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	64.1	0.036
19/05/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	73.2	0.042
26/05/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	12.1	0.002
2/6/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	1.8	0.002
9/6/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	51.5	0.012
16/6/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	124.2	0.048
23/6/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	109.1	0.035
30/6/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	118.5	0.052
7/7/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	85.2	0.039
14/7/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	107.5	0.032
21/7/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	7.4	0.010
28/7/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	154.0	0.038
4/8/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	19.2	0.018
11/8/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	111.4	0.030
18/8/2015	A (wheat 11)	7	West	WOBHH	Wheat	Control2	No Lime	142.6	0.068
15/05/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	48.8	0.015
19/05/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	33.0	0.015

26/05/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	41.7	0.016
2/6/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	55.7	0.043
9/6/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	94.0	0.032
16/6/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	93.0	0.026
23/6/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	32.0	0.009
30/6/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	79.2	0.027
7/7/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	40.1	0.019
14/7/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	21.1	0.008
21/7/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	221.9	0.073
28/7/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	41.8	0.010
4/8/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	21.6	0.001
11/8/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	93.3	0.023
18/8/2015	A (wheat 8)	8	West	WOBHH	Wheat	PKS	No Lime	111.8	0.046
15/05/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	76.7	0.046
19/05/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	101.1	0.042
26/05/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	75.6	0.038
2/6/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	36.8	0.033
9/6/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	65.5	0.021
16/6/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	127.0	0.046
23/6/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	116.2	0.048
30/6/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	46.8	0.014
7/7/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	105.2	0.046
14/7/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	43.4	0.010
21/7/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	94.1	0.035
28/7/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	85.2	0.033
4/8/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	141.5	0.089
11/8/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	143.5	0.034
18/8/2015	A (wheat 7)	9	West	WOBHH	Wheat	NPK	No Lime	160.9	0.077
15/05/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	71.3	0.032
19/05/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	10.2	0.003
26/05/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	4.8	0.006

2/6/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	6.8	0.005
9/6/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	68.7	0.016
16/6/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	94.0	0.014
23/6/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	51.9	0.005
30/6/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	184.9	0.087
7/7/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	92.9	0.028
14/7/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	109.5	0.017
21/7/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	103.8	0.032
28/7/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	39.6	0.013
4/8/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	128.1	0.054
11/8/2015	A (wheat 5)	10	West	WOBHH	Wheat	Control	No Lime	140.5	0.017
18/8/2015	A (wheat 5)	10	West	WOBHH	Wheat	NPKS	No Lime	133.8	0.029
15/05/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	63.8	0.037
19/05/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	39.0	0.034
26/05/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	0.6	0.006
2/6/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	81.1	0.072
9/6/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	99.4	0.053
16/6/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	111.3	0.039
23/6/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	153.2	0.047
30/6/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	93.3	0.048
7/7/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	105.8	0.036
14/7/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	83.7	0.015
21/7/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	201.3	0.062
28/7/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	437.3	0.019
4/8/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	37.4	0.013
11/8/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	136.2	0.003
18/8/2015	A (wheat 3)	11	West	WOBHH	Wheat	NPKS	No Lime	67.2	0.033
15/05/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	43.0	0.036
19/05/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	28.2	0.031
26/05/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	78.9	0.042
2/6/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	151.3	0.110

9/6/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	81.4	0.015
16/6/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	129.0	0.028
23/6/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	143.4	0.036
30/6/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	144.2	0.070
7/7/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	99.3	0.040
14/7/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	86.3	0.019
21/7/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	48.4	0.018
28/7/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	94.3	0.039
4/8/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	37.1	0.010
11/8/2015	A (wheat 2)	12	West	WOBHH	Wheat	Manure	No Lime	32.2	0.019
18/8/2015	A (wheat 2)	12	East	WOBHH	Wheat	Manure	Lime	89.7	0.051
15/05/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	31.5	0.033
19/05/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	5.1	0.007
26/05/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	29.9	0.003
2/6/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	54.4	0.026
9/6/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	91.3	0.017
16/6/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	75.3	0.019
23/6/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	132.5	0.034
30/6/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	99.6	0.041
7/7/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	63.9	0.006
14/7/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	111.0	0.024
21/7/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	2.9	0.015
28/7/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	31.7	0.002
4/8/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	77.7	0.017
11/8/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	63.3	0.006
18/8/2015	E (Wheat 2)	13	East	WF	Wheat	Manure	Lime	99.9	0.026
15/05/2015	E (Wheat 3)	14	East	WF	Wheat	NPKS	Lime	33.3	0.027
19/05/2015	E (Wheat 3)	14	East	WF	Wheat	NPKS	Lime	16.7	0.017
26/05/2015	E (Wheat 3)	14	East	WF	Wheat	NPKS	Lime	11.3	0.003
2/6/2015	E (Wheat 3)	14	East	WF	Wheat	NPKS	Lime	0.9	0.013
9/6/2015	E (Wheat 3)	14	East	WF	Wheat	NPKS	Lime	67.2	0.028

16/6/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	83.8	0.001
23/6/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	67.6	0.017
30/6/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	89.8	0.049
7/7/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	68.3	0.021
14/7/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	30.3	0.005
21/7/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	40.7	0.006
28/7/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	58.6	0.037
4/8/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	17.2	0.011
11/8/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	13.0	0.012
18/8/2015	E	(Wheat 3)	14	East	WF	Wheat	NPKS	Lime	60.9	0.020
15/05/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	4.2	0.002
19/05/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	7.1	0.003
26/05/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	8.2	0.002
2/6/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	0.2	0.008
9/6/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	0.1	0.005
16/6/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	11.2	0.016
23/6/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	25.9	0.005
30/6/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	40.0	0.017
7/7/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	28.1	0.006
14/7/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	15.7	0.010
21/7/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	68.4	0.019
28/7/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	3.6	0.006
4/8/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	8.6	0.028
11/8/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	21.2	0.008
18/8/2015	E	(Wheat5)	15	East	WF	Wheat	Control	Lime	38.2	0.015
15/05/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	32.9	0.017
19/05/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	1.8	0.001
26/05/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	37.4	0.014
2/6/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	35.7	0.026
9/6/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	52.9	0.024
16/6/2015	E	(Wheat 7)	16	East	WF	Wheat	NPK	Lime	23.8	0.013

23/6/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	102.5	0.023
30/6/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	100.1	0.050
7/7/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	64.2	0.020
14/7/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	74.1	0.031
21/7/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	3.3	0.007
28/7/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	51.8	0.005
4/8/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	26.4	0.018
11/8/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	63.4	0.002
18/8/2015	E (Wheat 7)	16	East	WF	Wheat	NPK	Lime	95.6	0.032
15/05/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	3.5	0.003
19/05/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	7.6	0.013
26/05/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	9.6	0.004
2/6/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	0.2	0.007
9/6/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	29.8	0.014
16/6/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	29.1	0.011
23/6/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	46.3	0.003
30/6/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	73.1	0.025
7/7/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	47.1	0.011
14/7/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	14.3	0.008
21/7/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	5.6	0.001
28/7/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	52.0	0.006
4/8/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	12.7	0.016
11/8/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	44.1	0.015
18/8/2015	E (Wheat 8)	17	East	WF	Wheat	PKS	Lime	13.7	0.003
15/05/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	15.7	0.017
19/05/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	11.6	0.013
26/05/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	15.8	0.009
2/6/2015	E (Wheat	18	East	WF	Wheat	Control2	Lime	0.9	0.007

	11)								
9/6/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	25.7	0.001
16/6/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	51.3	0.023
23/6/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	58.5	0.001
30/6/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	55.1	0.016
7/7/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	61.6	0.012
14/7/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	24.4	0.008
21/7/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	110.3	0.031
28/7/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	19.0	0.000
4/8/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	23.5	0.025
11/8/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	4.1	0.004
18/8/2015	E (Wheat 11)	18	East	WF	Wheat	Control2	Lime	64.1	0.028
15/05/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	20.1	0.024
19/05/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	27.2	0.002
26/05/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	3.3	0.002
2/6/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	8.2	0.005
9/6/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	31.0	0.001

16/6/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	28.8	0.002
23/6/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	55.6	0.023
30/6/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	61.8	0.030
7/7/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	59.4	0.012
14/7/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	12.9	0.015
21/7/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	198.3	0.059
28/7/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	0.9	0.014
4/8/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	154.0	0.030
11/8/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	39.4	0.017
18/8/2015	E (Fallow 11)	19	West	WF	Fallow	Control2	No Lime	90.3	0.028
15/05/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	27.4	0.018
19/05/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	26.4	0.015
26/05/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	26.7	0.019
2/6/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	1.4	0.001
9/6/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	32.8	0.001
16/6/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	29.3	0.005
23/6/2015	E (Fallow	20	West	WF	Fallow	PKS	No Lime	56.7	0.031

	8)								
30/6/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	50.5	0.014
7/7/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	50.0	0.002
14/7/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	16.3	0.010
21/7/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	69.9	0.023
28/7/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	54.2	0.019
4/8/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	0.3	0.002
11/8/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	41.8	0.010
18/8/2015	E (Fallow 8)	20	West	WF	Fallow	PKS	No Lime	15.5	0.022
15/05/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	34.0	0.017
19/05/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	9.8	0.001
26/05/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	32.7	0.024
2/6/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	69.1	0.034
9/6/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	45.0	0.002
16/6/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	5.5	0.000
23/6/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	65.1	0.034
30/6/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	32.1	0.020

7/7/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	53.2	0.006
14/7/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	112.3	0.013
21/7/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	2.7	0.002
28/7/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	47.0	0.019
4/8/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	24.6	0.006
11/8/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	60.3	0.014
18/8/2015	E (Fallow 7)	21	West	WF	Fallow	PKS	No Lime	87.5	0.027
15/05/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	9.1	0.005
19/05/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	22.9	0.001
26/05/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	1.3	0.003
2/6/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	10.3	0.005
9/6/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	33.5	0.006
16/6/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	53.3	0.011
23/6/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	36.4	0.000
30/6/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	69.7	0.018
7/7/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	18.0	0.007
14/7/2015	E (Fallow	22	West	WF	Fallow	Control	No Lime	12.6	0.001

	5)								
21/7/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	78.9	0.016
28/7/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	13.6	0.007
4/8/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	8.8	0.000
11/8/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	18.6	0.002
18/8/2015	E (Fallow 5)	22	West	WF	Fallow	Control	No Lime	48.8	0.021
15/05/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	35.4	0.019
19/05/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	14.2	0.011
26/05/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	31.3	0.010
2/6/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	1.2	0.012
9/6/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	25.3	0.015
16/6/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	19.3	0.015
23/6/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	53.1	0.013
30/6/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	71.8	0.034
7/7/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	79.6	0.015
14/7/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	46.3	0.006
21/7/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	0.2	0.031

28/7/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	41.2	0.003
4/8/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	5.6	0.001
11/8/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	66.4	0.016
18/8/2015	E (Fallow 3)	23	West	WF	Fallow	NPKS	No Lime	21.2	0.009
15/05/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	52.7	0.038
19/05/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	2.3	0.004
26/05/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	36.9	0.009
2/6/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	4.3	0.014
9/6/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	68.6	0.020
16/6/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	56.4	0.029
23/6/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	13.2	0.003
30/6/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	58.0	0.008
7/7/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	101.9	0.009
14/7/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	82.4	0.013
21/7/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	3.5	0.013
28/7/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	8.3	0.001
4/8/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	75.8	0.015
11/8/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	62.0	0.004
18/8/2015	E (Fallow 2)	24	West	WF	Fallow	Manure	No Lime	142.0	0.066
21/05/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	8.0	0.008
28/05/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	53.9	0.058
4/6/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	27.6	0.018
11/6/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	51.4	0.018
18/6/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	132.3	0.128
25/6/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	132.5	0.063
2/7/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	134.7	0.050
9/7/2015	A (wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	61.0	0.043

16/7/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	98.5	0.063
23/7/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	100.6	0.057
28/7/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	45.0	0.025
6/8/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	42.1	0.034
13/8/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	39.7	0.002
20/8/2015	A	(wheat 2)	25	East	WOBHH	Wheat	Manure	Lime	34.2	0.004
21/05/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	0.6	0.018
28/05/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	34.6	0.034
4/6/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	16.7	0.011
11/6/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	92.8	0.073
18/6/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	108.9	0.094
25/6/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	106.9	0.050
2/7/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	43.6	0.003
9/7/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	64.6	0.035
16/7/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	60.9	0.043
23/7/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	22.9	0.005
28/7/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	22.3	0.016
6/8/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	13.8	0.009
13/8/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	32.6	0.012
20/8/2015	A	(wheat 3)	26	East	WOBHH	Wheat	NPKS	Lime	8.1	0.011
21/05/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	7.7	0.012
28/05/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	44.4	0.038
4/6/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	49.2	0.025
11/6/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	60.1	0.040
18/6/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	39.4	0.029
25/6/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	53.2	0.022
2/7/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	45.9	0.003
9/7/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	69.9	0.029
16/7/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	51.4	0.030
23/7/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	58.7	0.021
28/7/2015	A	(wheat 5)	27	East	WOBHH	Wheat	Control	Lime	92.8	0.052

6/8/2015	A (wheat 5)	27	East	WOBHH	Wheat	Control	Lime	27.2	0.012
13/8/2015	A (wheat 5)	27	East	WOBHH	Wheat	Control	Lime	20.2	0.003
20/8/2015	A (wheat 5)	27	East	WOBHH	Wheat	Control	Lime	29.3	0.010
21/05/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	30.1	0.022
28/05/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	64.5	0.058
4/6/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	115.7	0.105
11/6/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	68.5	0.041
18/6/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	109.1	0.081
25/6/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	82.0	0.029
2/7/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	86.2	0.006
9/7/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	57.1	0.026
16/7/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	106.3	0.074
23/7/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	129.4	0.058
28/7/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	56.9	0.039
6/8/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	54.0	0.035
13/8/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	60.3	0.016
20/8/2015	A (wheat 7)	28	East	WOBHH	Wheat	NPK	Lime	60.7	0.028
21/05/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	63.2	0.041
28/05/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	67.8	0.054
4/6/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	47.3	0.018
11/6/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	30.0	0.016
18/6/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	126.4	0.100
25/6/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	99.6	0.037
2/7/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	83.4	0.018
9/7/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	43.4	0.003
16/7/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	124.3	0.101
23/7/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	31.3	0.012
28/7/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	80.5	0.050
6/8/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	25.2	0.010
13/8/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	44.0	0.006
20/8/2015	A (wheat 8)	29	East	WOBHH	Wheat	PKS	Lime	32.7	0.020

21/05/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	14.4	0.007
28/05/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	2.5	0.003
4/6/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	81.1	0.023
11/6/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	41.4	0.016
18/6/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	87.0	0.047
25/6/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	83.5	0.018
2/7/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	111.9	0.029
9/7/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	92.4	0.011
16/7/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	20.2	0.008
23/7/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	175.9	0.069
28/7/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	80.4	0.029
6/8/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	40.4	0.023
13/8/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	35.7	0.005
20/8/2015	A (wheat 11)	30	East	WOBHH	Wheat	Control2	Lime	67.1	0.013
21/05/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	0.2	0.009
28/05/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	4.6	0.007
4/6/2015	A (wheat	31	West	WOBHH	Wheat	Control2	No Lime	84.0	0.034

	11)								
11/6/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	30.8	0.015
18/6/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	106.8	0.043
25/6/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	55.2	0.010
2/7/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	111.7	0.015
9/7/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	148.4	0.019
16/7/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	24.9	0.011
23/7/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	172.6	0.050
28/7/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	109.9	0.028
6/8/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	46.0	0.019
13/8/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	9.6	0.012
20/8/2015	A (wheat 11)	31	West	WOBHH	Wheat	Control2	No Lime	55.3	0.021
21/05/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	8.9	0.007
28/05/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	22.2	0.015
4/6/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	4.9	0.012
11/6/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	93.8	0.048
18/6/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	170.8	0.076
25/6/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	117.7	0.022
2/7/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	63.1	0.010
9/7/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	74.6	0.005
16/7/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	137.0	0.092

23/7/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	42.3	0.012
28/7/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	83.6	0.024
6/8/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	0.1	0.001
13/8/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	40.3	0.016
20/8/2015	A (wheat 8)	32	West	WOBHH	Wheat	PKS	No Lime	15.7	0.011
21/05/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	32.3	0.009
28/05/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	16.3	0.002
4/6/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	124.5	0.052
11/6/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	118.1	0.059
18/6/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	178.3	0.086
25/6/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	106.9	0.029
2/7/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	105.8	0.013
9/7/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	120.5	0.023
16/7/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	136.6	0.112
23/7/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	133.8	0.047
28/7/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	44.8	0.117
6/8/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	50.7	0.021
13/8/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	88.4	0.029
20/8/2015	A (wheat 7)	33	West	WOBHH	Wheat	NPK	No Lime	62.8	0.026
21/05/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	7.0	0.003
28/05/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	56.7	0.020
4/6/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	13.7	0.015
11/6/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	96.1	0.025
18/6/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	48.7	0.000
25/6/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	95.1	0.016
2/7/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	195.0	0.036
9/7/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	130.1	0.015
16/7/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	130.5	0.076
23/7/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	204.2	0.019
28/7/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	117.2	0.023
6/8/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	65.6	0.034

13/8/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	93.0	0.025
20/8/2015	A (wheat 5)	34	West	WOBHH	Wheat	Control	No Lime	92.1	0.026
21/05/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	61.6	0.061
28/05/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	91.9	0.067
4/6/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	17.0	0.014
11/6/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	96.3	0.156
18/6/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	185.6	0.076
25/6/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	194.3	0.043
2/7/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	187.3	0.032
9/7/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	74.5	0.011
16/7/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	134.1	0.092
23/7/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	51.2	0.024
28/7/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	121.8	0.044
6/8/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	44.1	0.019
13/8/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	84.0	0.030
20/8/2015	A (wheat 3)	35	West	WOBHH	Wheat	NPKS	No Lime	17.7	0.017
21/05/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	11.1	0.011
28/05/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	96.5	0.077
4/6/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	142.2	0.070
11/6/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	57.6	0.016
18/6/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	70.2	0.026
25/6/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	161.4	0.039
2/7/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	207.9	0.062
9/7/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	111.9	0.031
16/7/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	35.8	0.018
23/7/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	246.8	0.096
28/7/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	73.8	0.029
6/8/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	51.3	0.021
13/8/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	95.9	0.022
20/8/2015	A (wheat 2)	36	West	WOBHH	Wheat	Manure	No Lime	81.4	0.027
21/05/2015	A (wheat 2)	37	East	WF	Wheat	Manure	Lime	0.1	0.004

28/05/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	67.8	0.035
4/6/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	33.1	0.003
11/6/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	66.0	0.004
18/6/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	105.8	0.037
25/6/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	150.5	0.018
2/7/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	58.1	0.003
9/7/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	122.2	0.020
16/7/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	38.9	0.002
23/7/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	43.5	0.004
28/7/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	31.4	0.034
6/8/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	27.8	0.000
13/8/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	22.4	0.015
20/8/2015	A	(wheat 2)	37	East	WF	Wheat	Manure	Lime	51.2	0.009
21/05/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	0.6	0.010
28/05/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	42.6	0.014
4/6/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	59.4	0.021
11/6/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	62.4	0.006
18/6/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	73.0	0.041
25/6/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	33.3	0.007
2/7/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	2.9	0.011
9/7/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	70.4	0.021
16/7/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	105.2	0.045
23/7/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	43.1	0.017
28/7/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	73.3	0.003
6/8/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	33.1	0.013
13/8/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	22.2	0.002
20/8/2015	E	(Wheat 3)	38	East	WF	Wheat	NPKS	Lime	44.4	0.001
21/05/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	9.4	0.001
28/05/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	4.3	0.006
4/6/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	4.9	0.005
11/6/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	32.3	0.008

18/6/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	15.1	0.008
25/6/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	42.5	0.002
2/7/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	27.3	0.017
9/7/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	31.6	0.006
16/7/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	69.6	0.026
23/7/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	63.9	0.027
28/7/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	26.9	0.001
6/8/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	18.5	0.003
13/8/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	9.6	0.003
20/8/2015	E	(Wheat5)	39	East	WF	Wheat	Control	Lime	4.5	0.005
21/05/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	1.4	0.005
28/05/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	3.9	0.006
4/6/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	61.5	0.030
11/6/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	34.7	0.020
18/6/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	60.4	0.021
25/6/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	108.8	0.022
2/7/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	92.5	0.022
9/7/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	106.3	0.007
16/7/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	107.4	0.045
23/7/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	44.2	0.025
28/7/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	15.9	0.002
6/8/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	31.8	0.014
13/8/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	52.4	0.012
20/8/2015	E	(Wheat 7)	40	East	WF	Wheat	NPK	Lime	8.2	0.000
21/05/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	4.9	0.011
28/05/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	19.2	0.001
4/6/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	38.8	0.013
11/6/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	46.6	0.012
18/6/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	71.7	0.024
25/6/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	16.7	0.012
2/7/2015	E	(Wheat 8)	41	East	WF	Wheat	PKS	Lime	77.3	0.014

9/7/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	40.3	0.009
16/7/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	57.3	0.015
23/7/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	16.8	0.008
28/7/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	38.6	0.013
6/8/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	27.1	0.019
13/8/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	35.8	0.007
20/8/2015	E (Wheat 8)	41	East	WF	Wheat	PKS	Lime	15.5	0.021
21/05/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	12.7	0.015
28/05/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	1.0	0.009
4/6/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	13.2	0.004
11/6/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	23.9	0.006
18/6/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	60.6	0.016
25/6/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	56.2	0.003
2/7/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	46.4	0.022
9/7/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	78.5	0.014
16/7/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	14.6	0.007
23/7/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	87.4	0.029
28/7/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	43.2	0.027
6/8/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	17.3	0.014
13/8/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	2.5	0.026

20/8/2015	E (Wheat 11)	42	East	WF	Wheat	Control2	Lime	45.4	0.011
21/05/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	25.0	0.001
28/05/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	6.3	0.010
4/6/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	12.2	0.000
11/6/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	26.1	0.001
18/6/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	51.7	0.020
25/6/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	25.4	0.004
2/7/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	60.0	0.006
9/7/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	69.6	0.010
16/7/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	3.4	0.004
23/7/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	79.0	0.035
28/7/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	15.7	0.001
6/8/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	6.5	0.007
13/8/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	14.4	0.001
20/8/2015	E (Fallow 11)	43	West	WF	Fallow	Control2	No Lime	32.1	0.012
21/05/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	4.4	0.010
28/05/2015	E (Fallow	44	West	WF	Fallow	PKS	No Lime	45.1	0.014

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4/6/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	69.3	0.023
11/6/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	26.3	0.007
18/6/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	60.4	0.018
25/6/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	12.6	0.001
2/7/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	47.9	0.024
9/7/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	8.7	0.013
16/7/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	96.2	0.028
23/7/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	9.9	0.007
28/7/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	66.3	0.013
6/8/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	30.5	0.003
13/8/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	52.4	0.010
20/8/2015	E (Fallow 8)	44	West	WF	Fallow	PKS	No Lime	78.4	0.025
21/05/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	1.7	0.005
28/05/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	57.9	0.017
4/6/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	83.5	0.008
11/6/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	92.3	0.023

18/6/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	99.2	0.037
25/6/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	32.7	0.004
2/7/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	112.2	0.035
9/7/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	81.3	0.005
16/7/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	87.8	0.026
23/7/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	42.4	0.022
28/7/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	15.8	0.014
6/8/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	32.9	0.012
13/8/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	54.5	0.009
20/8/2015	E (Fallow 7)	45	West	WF	Fallow	NPK	No Lime	13.0	0.004
21/05/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	13.4	0.008
28/05/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	16.5	0.006
4/6/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	25.4	0.002
11/6/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	8.6	0.002
18/6/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	37.0	0.011
25/6/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	19.1	0.005
2/7/2015	E (Fallow	46	West	WF	Fallow	Control	No Lime	18.6	0.004

	5)								
9/7/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	46.5	0.012
16/7/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	108.7	0.040
23/7/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	53.9	0.007
28/7/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	33.6	0.021
6/8/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	33.1	0.026
13/8/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	39.4	0.003
20/8/2015	E (Fallow 5)	46	West	WF	Fallow	Control	No Lime	20.1	0.009
21/05/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	3.7	0.011
28/05/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	72.0	0.047
4/6/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	84.4	0.026
11/6/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	8.2	0.005
18/6/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	89.8	0.016
25/6/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	71.2	0.021
2/7/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	109.9	0.013
9/7/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	12.5	0.002
16/7/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	114.3	0.052

23/7/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	22.7	0.959
28/7/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	107.3	0.034
6/8/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	1.4	0.002
13/8/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	86.0	0.005
20/8/2015	E (Fallow 3)	47	West	WF	Fallow	NPKS	No Lime	59.2	0.014
21/05/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	62.5	0.021
28/05/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	48.5	0.030
4/6/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	62.9	0.015
11/6/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	94.5	0.025
18/6/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	140.1	0.036
25/6/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	43.9	0.018
2/7/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	131.8	0.009
9/7/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	94.5	0.001
16/7/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	14.1	0.014
23/7/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	176.0	0.040
28/7/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	51.3	0.026
6/8/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	52.8	0.013
13/8/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	82.9	0.024
20/8/2015	E (Fallow 2)	48	West	WF	Fallow	Manure	No Lime	73.8	0.017

Appendix 4-A: Pre-incubation soil properties for the 0 to 10 cm depth for each soil treatments of the sampling site (Breton Classical Plots).

Soil	Replication	TC (kg/ha)	TOC kg/ha	LF-C (kg/ha)	LF-N (kg/ha)	TN kg N/ha	NH_4-N (kg/ha)	NO_3-N (kg/ha)	Total S (Kg/ha)	SO_4-S (kg/ha)	pH
Control	1	2136	2052	94.46	5.60	206	0.95	0.57	26.87	0.79	6.32
Control	2	1990	1948	119.88	7.36	197	0.91	0.59	25.39	0.76	6.3
Control	3	1970	1939	80.65	4.89	200	0.93	0.58	25.65	0.78	6.36
NPKS	1	2448	2390	177.19	11.48	240	1.73	4.45	39.54	2.51	5.4
NPKS	2	2448	2408	155.01	9.90	239	1.59	4.14	37.39	2.62	5.48
NPKS	3	2583	2473	146.55	9.32	248	1.62	4.19	36.54	2.46	5.47
NPK	1	2279	2268	114.65	6.62	226	0.83	0.55	28.07	0.70	6.02
NPK	2	2332	2278	143.68	8.65	225	0.84	0.69	27.12	0.77	6
NPK	3	2287	2192	109.24	6.10	230	0.85	0.63	27.45	0.70	6.03
PKS	1	2589	2535	183.36	10.87	245	0.69	0.54	35.35	2.22	5.47
PKS	2	2470	2427	164.90	9.87	239	0.68	0.61	35.81	2.30	5.48
PKS	3	2521	2465	140.52	9.02	245	0.65	0.58	39.72	2.42	5.49

Appendix 4-B: Post-incubation soil properties (kg ha^{-1}) for the 0 to 10 cm depth for each soil treatments of the sampling site (Breton Classical Plots).

Soil	Fertilizer	Replication	TN	NO_3	NH_4	TS	SO_4	TOC
Control	Nil	1	204	10.30	0.67	22.40	0.53	2064.00
Control	UR	1	259	52.98	37.12	22.29	0.56	2044.00
Control	CN	1	265	85.08	7.42	24.36	0.40	1970.00
Control	AC	1	291	1.30	94.56	22.69	0.47	2156.00
Control	UR + S^0	1	281	61.25	29.58	37.06	3.48	2003.00
Control	CN + S^0	1	282	87.53	6.03	36.33	2.80	2026.00
Control	AC + S^0	1	295	1.25	99.99	33.40	2.38	2116.00
NPKS	Nil	1	177	9.34	0.59	23.05	0.52	2107.00
NPKS	UR	1	269	56.23	38.23	20.90	0.60	1872.00
NPKS	CN	1	303	98.50	7.81	23.52	0.43	1961.00
NPKS	AC	1	289	1.18	104.67	23.10	0.46	2039.00
NPKS	UR + S^0	1	278	52.77	45.57	35.13	5.49	2073.00
NPKS	CN + S^0	1	274	102.78	8.08	34.98	2.38	2065.00
NPKS	AC + S^0	1	289	1.03	86.70	32.48	2.29	2061.00
PKS	Nil	1	201	10.94	0.51	22.52	0.48	2048.00
PKS	UR	1	254	54.74	40.22	18.49	0.40	1543.00
PKS	CN	1	280	101.00	8.16	23.88	0.44	2043.00
PKS	AC	1	278	1.06	97.16	20.98	0.37	1863.00
PKS	UR + S^0	1	284	46.18	47.29	33.49	3.99	1973.00
PKS	CN + S^0	1	278	81.98	7.26	30.26	1.96	2079.00
PKS	AC + S^0	1	291	0.95	96.85	30.36	2.27	1948.00
NPK	Nil	1	249	11.16	0.62	34.25	2.71	2648.00
NPK	UR	1	321	51.22	36.15	30.78	1.29	2657.00
NPK	CN	1	312	127.35	6.56	33.78	1.32	2430.00
NPK	AC	1	352	5.70	96.22	31.19	1.75	2465.00
NPK	UR + S^0	1	318	29.86	45.89	41.44	5.43	2578.00
NPK	CN + S^0	1	338	83.65	4.81	41.81	8.37	2610.00
NPK	AC + S^0	1	337	6.07	103.21	38.72	10.93	2462.00
Control	Nil	2	254	11.03	0.83	35.34	2.11	2679.00
Control	UR	2	321	70.24	30.88	31.97	1.34	2447.00
Control	CN	2	327	103.16	5.00	33.82	0.77	2441.00
Control	AC	2	331	4.80	107.63	31.22	1.11	2470.00
Control	UR + S^0	2	307	34.09	42.78	40.89	8.14	2426.00
Control	CN + S^0	2	322	109.05	4.01	37.50	10.50	2502.00
Control	AC + S^0	2	335	4.97	109.71	36.60	10.87	2502.00
NPKS	Nil	2	252	9.73	0.71	34.94	2.42	2579.00
NPKS	UR	2	306	51.58	32.62	34.76	1.51	2342.00

NPKS	CN	2	319	111.41	5.28	31.96	0.95	2478.00
NPKS	AC	2	320	7.87	106.58	38.64	1.47	2422.00
NPKS	UR + S^0	2	326	49.81	36.86	33.74	3.48	2409.00
NPKS	CN + S^0	2	354	105.33	6.12	41.74	4.62	2517.00
NPKS	AC + S^0	2	319	7.21	105.74	21.85	6.70	2465.00
PKS	Nil	2	229	12.05	0.71	25.79	0.45	2377.00
PKS	UR	2	302	21.58	45.62	30.36	0.69	2396.00
PKS	CN	2	307	100.09	10.51	23.43	0.26	2488.00
PKS	AC	2	280	1.57	103.31	23.85	0.29	2252.00
PKS	UR + S^0	2	246	24.44	47.66	29.62	4.59	2179.00
PKS	CN + S^0	2	324	90.88	10.08	34.99	2.40	2410.00
PKS	AC + S^0	2	310	0.70	110.83	31.32	2.03	2256.00
NPK	Nil	2	228	12.19	0.94	25.67	0.45	2381.00
NPK	UR	2	303	52.58	41.89	25.16	0.47	2372.00
NPK	CN	2	295	111.81	10.97	27.02		2316.00
NPK	AC	2	312	10.90	100.10	26.28	0.55	2376.00
NPK	UR + S^0	2	312	33.55	53.07	33.98	4.96	2376.00
NPK	CN + S^0	2	286	100.50	11.37	34.58	1.93	2404.00
NPK	AC + S^0	2	305	1.67	107.71	30.48	2.09	2210.00
Control	Nil	3	227	9.93	0.82	24.26	0.51	2254.00
Control	UR	3	298	50.03	39.78	24.00	0.63	2230.00
Control	CN	3	303	100.64	11.16	27.06		2288.00
Control	AC	3	326	1.79	106.13	24.31	0.29	2363.00
Control	UR + S^0	3	317	58.16	37.37	31.02	3.00	2347.00
Control	CN + S^0	3	311	83.02	9.51	30.49	1.67	2301.00
Control	AC + S^0	3	309	1.19	116.16	28.24	1.71	2265.00
NPKS	Nil	3	257	9.95	0.84	33.17	1.58	2628.00
NPKS	UR	3	332	46.53	48.97	33.90	1.60	2558.00
NPKS	CN	3	333	109.49	14.98	33.46	0.66	2615.00
NPKS	AC	3	334	0.98	90.36	31.23	1.43	2616.00
NPKS	UR + S^0	3	345	50.59	58.40	39.19	6.15	2581.00
NPKS	CN + S^0	3	331	94.55	12.66	39.29	3.05	2518.00
NPKS	AC + S^0	3	327	0.64	107.42	36.00	3.36	2505.00
PKS	Nil	3	250	9.22	0.98	32.92	1.14	2557.00
PKS	UR	3	331	54.59	56.65	32.05	1.28	2497.00
PKS	CN	3	334	99.77	12.75	33.74	0.76	2508.00
PKS	AC	3	342	0.67	122.17	31.51	1.07	2536.00
PKS	UR + S^0	3	332	51.86	58.44	44.94	8.13	2477.00
PKS	CN + S^0	3	343	110.71	12.55	44.00	2.48	2691.00
PKS	AC + S^0	3	325	0.60	122.32	35.09	3.25	2469.00
NPK	Nil	3	246	11.92	1.07	31.67	1.02	2612.00
NPK	UR	3	329	65.80	58.80	29.99	1.68	2408.00
NPK	CN	3	349	103.14	12.92	33.13	1.04	2617.00

NPK	AC	3	314	0.53	114.07	28.02	0.87	2234.00
NPK	UR + S^0	3	334	54.47	46.90	42.97	17.25	2491.00
NPK	CN + S^0	3	341	104.64	14.12	35.57	2.05	2608.00
NPK	AC + S^0	3	331	0.56	116.76	32.77	2.29	2600.00

Appendix 4-C: Weekly gas fluxes (**N_2O-N** and CO_2-C) from four fertility treatments (Control, NPKS, NPK and PKS) and seven fertilizer treatments (Nil (not fertilized), UR, CN, AC, UR + S^0, CN + S^0, AC + S^0) after seven weeks of incubation.

Soil	Fertilizer	Replication	week	N_2O-N flux (kg N ha^{-1})	CO_2-flux (kg C ha^{-1})
Control	Nil	1	1	0.018	8.721
Control	Nil	1	2	0.020	6.631
Control	Nil	1	3	0.020	5.476
Control	Nil	1	4	0.018	5.476
Control	Nil	1	5	0.010	2.936
Control	Nil	1	6	0.010	2.698
Control	Nil	1	7	0.011	3.272
Control	Nil	2	1	0.012	7.354
Control	Nil	2	2	0.017	8.730
Control	Nil	2	3	0.014	5.644
Control	Nil	2	4	0.011	4.471
Control	Nil	2	5	0.008	2.910
Control	Nil	2	6	0.006	1.807
Control	Nil	2	7	0.008	3.025
Control	Nil	3	1	0.009	6.358
Control	Nil	3	2	0.009	5.238
Control	Nil	3	3	0.010	5.458
Control	Nil	3	4	0.010	4.929
Control	Nil	3	5	0.006	3.113
Control	Nil	3	6	0.005	1.615
Control	Nil	3	7	0.006	2.310
Control	UR	1	1	0.031	16.023
Control	UR	1	2	0.016	4.529
Control	UR	1	3	0.049	9.047
Control	UR	1	4	0.067	8.130
Control	UR	1	5	0.058	10.652
Control	UR	1	6	0.021	3.510
Control	UR	1	7	0.022	3.245
Control	UR	2	1	0.016	13.712
Control	UR	2	2	0.025	7.875
Control	UR	2	3	0.058	10.220
Control	UR	2	4	0.054	11.605
Control	UR	2	5	0.030	7.725
Control	UR	2	6	0.008	2.160
Control	UR	2	7	0.010	2.462

Control	UR	3	1	0.012	9.100
Control	UR	3	2	0.012	6.120
Control	UR	3	3	0.044	7.857
Control	UR	3	4	0.078	10.696
Control	UR	3	5	0.020	4.929
Control	UR	3	6	0.009	2.081
Control	UR	3	7	0.025	4.012
Control	CN	1	1	0.008	2.443
Control	CN	1	2	0.022	8.104
Control	CN	1	3	0.017	4.612
Control	CN	1	4	0.020	5.203
Control	CN	1	5	0.014	3.527
Control	CN	1	6	0.011	2.742
Control	CN	1	7	0.010	2.108
Control	CN	2	1	0.010	6.517
Control	CN	2	2	0.019	7.663
Control	CN	2	3	0.016	6.658
Control	CN	2	4	0.015	5.326
Control	CN	2	5	0.013	3.977
Control	CN	2	6	0.007	1.882
Control	CN	2	7	0.008	2.425
Control	CN	3	1	0.007	4.197
Control	CN	3	2	0.014	5.361
Control	CN	3	3	0.011	4.312
Control	CN	3	4	0.014	4.506
Control	CN	3	5	0.006	2.390
Control	CN	3	6	0.006	1.628
Control	CN	3	7	0.014	2.681
Control	AC	1	1	0.014	5.123
Control	AC	1	2	0.019	5.635
Control	AC	1	3	0.058	4.885
Control	AC	1	4	0.077	5.441
Control	AC	1	5	0.036	3.227
Control	AC	1	6	0.023	1.623
Control	AC	1	7	0.019	2.240
Control	AC	2	1	0.012	8.448
Control	AC	2	2	0.014	8.130
Control	AC	2	3	0.013	7.328
Control	AC	2	4	0.013	5.899
Control	AC	2	5	0.011	5.247
Control	AC	2	6	0.007	2.756
Control	AC	2	7	0.008	2.981
Control	AC	3	1	0.007	4.383

Control	AC	3	2	0.018	10.264
Control	AC	3	3	0.014	9.197
Control	AC	3	4	0.012	5.494
Control	AC	3	5	0.009	4.206
Control	AC	3	6	0.006	2.213
Control	AC	3	7	0.009	3.360
Control	UR + S^0	1	1	0.019	10.405
Control	UR + S^0	1	2	0.036	8.130
Control	UR + S^0	1	3	0.636	10.547
Control	UR + S^0	1	4	0.920	12.857
Control	UR + S^0	1	5	0.381	8.421
Control	UR + S^0	1	6	0.230	5.053
Control	UR + S^0	1	7	0.133	3.598
Control	UR + S^0	2	1	0.017	14.638
Control	UR + S^0	2	2	0.014	6.755
Control	UR + S^0	2	3	0.040	10.608
Control	UR + S^0	2	4	0.058	9.559
Control	UR + S^0	2	5	0.030	7.037
Control	UR + S^0	2	6	0.014	4.136
Control	UR + S^0	2	7	0.014	3.624
Control	UR + S^0	3	1	0.010	7.883
Control	UR + S^0	3	2	0.014	7.319
Control	UR + S^0	3	3	0.032	8.069
Control	UR + S^0	3	4	0.048	8.624
Control	UR + S^0	3	5	0.020	5.159
Control	UR + S^0	3	6	0.010	3.201
Control	UR + S^0	3	7	0.012	2.637
Control	CN + S^0	1	1	0.012	3.730
Control	CN + S^0	1	2	0.022	5.388
Control	CN + S^0	1	3	0.022	5.714
Control	CN + S^0	1	4	0.020	4.797
Control	CN + S^0	1	5	0.014	2.848
Control	CN + S^0	1	6	0.010	2.056
Control	CN + S^0	1	7	0.012	2.338
Control	CN + S^0	2	1	0.009	6.164
Control	CN + S^0	2	2	0.014	7.425
Control	CN + S^0	2	3	0.013	6.137
Control	CN + S^0	2	4	0.013	5.264

Control	CN + S^0	2	5	0.009	3.395
Control	CN + S^0	2	6	0.007	2.275
Control	CN + S^0	2	7	0.007	2.201
Control	CN + S^0	3	1	0.007	3.607
Control	CN + S^0	3	2	0.008	3.792
Control	CN + S^0	3	3	0.009	4.196
Control	CN + S^0	3	4	0.009	3.962
Control	CN + S^0	3	5	0.005	2.011
Control	CN + S^0	3	6	0.005	1.466
Control	CN + S^0	3	7	0.008	2.751
Control	AC + S^0	1	1	0.016	7.416
Control	AC + S^0	1	2	0.020	7.152
Control	AC + S^0	1	3	0.020	7.107
Control	AC + S^0	1	4	0.016	5.026
Control	AC + S^0	1	5	0.012	4.136
Control	AC + S^0	1	6	0.010	2.791
Control	AC + S^0	1	7	0.012	3.527
Control	AC + S^0	2	1	0.008	4.815
Control	AC + S^0	2	2	0.010	4.568
Control	AC + S^0	2	3	0.013	6.790
Control	AC + S^0	2	4	0.010	4.303
Control	AC + S^0	2	5	0.008	3.386
Control	AC + S^0	2	6	0.006	1.814
Control	AC + S^0	2	7	0.008	2.972
Control	AC + S^0	3	1	0.007	4.753
Control	AC + S^0	3	2	0.009	5.370
Control	AC + S^0	3	3	0.014	7.072
Control	AC + S^0	3	4	0.012	4.083
Control	AC + S^0	3	5	0.009	3.686
Control	AC + S^0	3	6	0.007	2.222
Control	AC + S^0	3	7	0.007	2.236
NPKS	Nil	1	1	0.008	3.298
NPKS	Nil	1	2	0.027	4.356
NPKS	Nil	1	3	0.055	5.670
NPKS	Nil	1	4	0.032	4.735
NPKS	Nil	1	5	0.010	3.369
NPKS	Nil	1	6	0.040	3.563
NPKS	Nil	1	7	0.020	3.183

NPKS	Nil	2	1	0.006	2.884
NPKS	Nil	2	2	0.010	4.630
NPKS	Nil	2	3	0.009	4.259
NPKS	Nil	2	4	0.010	3.915
NPKS	Nil	2	5	0.007	2.919
NPKS	Nil	2	6	0.009	3.695
NPKS	Nil	2	7	0.007	2.417
NPKS	Nil	3	1	0.005	2.795
NPKS	Nil	3	2	0.007	3.248
NPKS	Nil	3	3	0.009	5.229
NPKS	Nil	3	4	0.008	3.951
NPKS	Nil	3	5	0.005	2.381
NPKS	Nil	3	6	0.005	2.222
NPKS	Nil	3	7	0.006	2.778
NPKS	UR	1	1	0.017	9.815
NPKS	UR	1	2	0.050	8.950
NPKS	UR	1	3	0.140	9.374
NPKS	UR	1	4	0.280	9.665
NPKS	UR	1	5	0.323	9.241
NPKS	UR	1	6	0.206	4.727
NPKS	UR	1	7	0.200	4.145
NPKS	UR	2	1	0.011	8.245
NPKS	UR	2	2	0.033	7.081
NPKS	UR	2	3	0.055	7.152
NPKS	UR	2	4	0.184	6.587
NPKS	UR	2	5	0.078	3.051
NPKS	UR	2	6	0.069	3.430
NPKS	UR	2	7	0.129	4.735
NPKS	UR	3	1	0.008	6.208
NPKS	UR	3	2	0.034	6.058
NPKS	UR	3	3	0.209	11.816
NPKS	UR	3	4	0.302	8.404
NPKS	UR	3	5	0.225	5.450
NPKS	UR	3	6	0.114	2.725
NPKS	UR	3	7	0.177	3.633
NPKS	CN	1	1	0.008	2.866
NPKS	CN	1	2	0.015	4.103
NPKS	CN	1	3	0.020	4.436
NPKS	CN	1	4	0.024	3.546
NPKS	CN	1	5	0.015	4.127
NPKS	CN	1	6	0.017	2.848
NPKS	CN	1	7	0.023	4.197
NPKS	CN	2	1	0.006	2.496

NPKS	CN	2	2	0.011	3.817
NPKS	CN	2	3	0.014	4.435
NPKS	CN	2	4	0.018	3.891
NPKS	CN	2	5	0.009	2.901
NPKS	CN	2	6	0.012	2.543
NPKS	CN	2	7	0.017	3.651
NPKS	CN	3	1	0.005	2.557
NPKS	CN	3	2	0.008	4.312
NPKS	CN	3	3	0.010	4.965
NPKS	CN	3	4	0.012	4.894
NPKS	CN	3	5	0.011	4.215
NPKS	CN	3	6	0.008	2.487
NPKS	CN	3	7	0.012	3.060
NPKS	AC	1	1	0.009	2.742
NPKS	AC	1	2	0.011	2.936
NPKS	AC	1	3	0.049	4.647
NPKS	AC	1	4	0.038	3.585
NPKS	AC	1	5	0.062	2.919
NPKS	AC	1	6	0.017	3.139
NPKS	AC	1	7	0.012	2.399
NPKS	AC	2	1	0.007	3.210
NPKS	AC	2	2	0.011	4.462
NPKS	AC	2	3	0.010	4.806
NPKS	AC	2	4	0.016	4.559
NPKS	AC	2	5	0.007	3.598
NPKS	AC	2	6	0.010	2.443
NPKS	AC	2	7	0.012	3.563
NPKS	AC	3	1	0.005	2.346
NPKS	AC	3	2	0.008	4.488
NPKS	AC	3	3	0.012	4.524
NPKS	AC	3	4	0.015	4.444
NPKS	AC	3	5	0.006	3.183
NPKS	AC	3	6	0.006	1.564
NPKS	AC	3	7	0.009	2.302
NPKS	UR + S^0	1	1	0.018	6.658
NPKS	UR + S^0	1	2	0.238	6.790
NPKS	UR + S^0	1	3	0.669	9.277
NPKS	UR + S^0	1	4	0.661	5.184
NPKS	UR + S^0	1	5	0.480	5.573
NPKS	UR + S^0	1	6	0.557	3.483
NPKS	UR + S^0	1	7	0.510	3.201
NPKS	UR + S^0	2	1	0.015	12.284

NPKS	UR + S^0	2	2	0.036	7.204
NPKS	UR + S^0	2	3	0.091	7.028
NPKS	UR + S^0	2	4	0.241	7.866
NPKS	UR + S^0	2	5	0.171	5.846
NPKS	UR + S^0	2	6	0.228	5.485
NPKS	UR + S^0	2	7	0.109	3.122
NPKS	UR + S^0	3	1	0.008	6.578
NPKS	UR + S^0	3	2	0.015	4.330
NPKS	UR + S^0	3	3	0.097	8.986
NPKS	UR + S^0	3	4	0.221	7.266
NPKS	UR + S^0	3	5	0.130	5.397
NPKS	UR + S^0	3	6	0.043	2.205
NPKS	UR + S^0	3	7	0.133	3.933
NPKS	CN + S^0	1	1	0.009	3.298
NPKS	CN + S^0	1	2	0.018	5.996
NPKS	CN + S^0	1	3	0.021	5.256
NPKS	CN + S^0	1	4	0.026	5.203
NPKS	CN + S^0	1	5	0.039	4.753
NPKS	CN + S^0	1	6	0.023	3.148
NPKS	CN + S^0	1	7	0.026	3.333
NPKS	CN + S^0	2	1	0.006	2.575
NPKS	CN + S^0	2	2	0.012	5.141
NPKS	CN + S^0	2	3	0.014	5.749
NPKS	CN + S^0	2	4	0.016	5.326
NPKS	CN + S^0	2	5	0.018	5.150
NPKS	CN + S^0	2	6	0.012	3.060
NPKS	CN + S^0	2	7	0.022	4.533
NPKS	CN + S^0	3	1	0.006	2.990
NPKS	CN + S^0	3	2	0.009	4.197
NPKS	CN + S^0	3	3	0.012	4.727
NPKS	CN + S^0	3	4	0.020	4.762
NPKS	CN + S^0	3	5	0.015	2.540
NPKS	CN + S^0	3	6	0.007	1.637
NPKS	CN + S^0	3	7	0.017	3.103
NPKS	AC + S^0	1	1	0.007	2.522
NPKS	AC + S^0	1	2	0.015	4.577
NPKS	AC + S^0	1	3	0.016	4.100

NPKS	AC + S^0	1	4	0.017	4.541
NPKS	AC + S^0	1	5	0.015	3.439
NPKS	AC + S^0	1	6	0.011	2.601
NPKS	AC + S^0	1	7	0.015	3.457
NPKS	AC + S^0	2	1	0.005	2.596
NPKS	AC + S^0	2	2	0.008	3.060
NPKS	AC + S^0	2	3	0.011	4.259
NPKS	AC + S^0	2	4	0.016	3.704
NPKS	AC + S^0	2	5	0.017	2.513
NPKS	AC + S^0	2	6	0.017	2.240
NPKS	AC + S^0	2	7	0.012	2.839
NPKS	AC + S^0	3	1	0.005	2.319
NPKS	AC + S^0	3	2	0.009	2.961
NPKS	AC + S^0	3	3	0.016	4.427
NPKS	AC + S^0	3	4	0.020	4.233
NPKS	AC + S^0	3	5	0.007	3.510
NPKS	AC + S^0	3	6	0.012	3.510
NPKS	AC + S^0	3	7	0.008	2.197
NPK	Nil	1	1	0.014	8.104
NPK	Nil	1	2	0.018	7.813
NPK	Nil	1	3	0.019	6.834
NPK	Nil	1	4	0.016	5.450
NPK	Nil	1	5	0.010	2.795
NPK	Nil	1	6	0.008	1.878
NPK	Nil	1	7	0.011	3.536
NPK	Nil	2	1	0.010	8.166
NPK	Nil	2	2	0.015	7.610
NPK	Nil	2	3	0.030	9.259
NPK	Nil	2	4	0.025	6.129
NPK	Nil	2	5	0.014	3.589
NPK	Nil	2	6	0.006	1.862
NPK	Nil	2	7	0.012	2.354
NPK	Nil	3	1	0.010	8.430
NPK	Nil	3	2	0.010	6.349
NPK	Nil	3	3	0.010	5.494
NPK	Nil	3	4	0.010	4.471
NPK	Nil	3	5	0.007	3.995
NPK	Nil	3	6	0.006	2.072
NPK	Nil	3	7	0.008	3.615
NPK	UR	1	1	0.023	7.945

NPK	UR	1	2	0.097	8.148
NPK	UR	1	3	0.364	13.077
NPK	UR	1	4	0.433	8.668
NPK	UR	1	5	0.251	4.973
NPK	UR	1	6	0.363	5.300
NPK	UR	1	7	0.646	7.972
NPK	UR	2	1	0.016	6.993
NPK	UR	2	2	0.041	7.390
NPK	UR	2	3	0.158	12.257
NPK	UR	2	4	0.154	9.153
NPK	UR	2	5	0.082	7.566
NPK	UR	2	6	0.066	4.003
NPK	UR	2	7	0.051	3.333
NPK	UR	3	1	0.013	3.871
NPK	UR	3	2	0.054	8.139
NPK	UR	3	3	0.148	11.957
NPK	UR	3	4	0.148	8.077
NPK	UR	3	5	0.220	7.566
NPK	UR	3	6	0.103	3.845
NPK	UR	3	7	0.152	5.238
NPK	CN	1	1	0.012	6.543
NPK	CN	1	2	0.024	7.892
NPK	CN	1	3	0.035	6.702
NPK	CN	1	4	0.044	6.067
NPK	CN	1	5	0.034	4.268
NPK	CN	1	6	0.016	2.716
NPK	CN	1	7	0.025	2.795
NPK	CN	2	1	0.010	6.975
NPK	CN	2	2	0.012	7.090
NPK	CN	2	3	0.012	6.596
NPK	CN	2	4	0.012	6.155
NPK	CN	2	5	0.009	4.039
NPK	CN	2	6	0.006	1.980
NPK	CN	2	7	0.007	2.157
NPK	CN	3	1	0.009	6.931
NPK	CN	3	2	0.010	6.596
NPK	CN	3	3	0.012	7.143
NPK	CN	3	4	0.011	5.194
NPK	CN	3	5	0.007	2.593
NPK	CN	3	6	0.003	0.996
NPK	CN	3	7	0.011	4.012
NPK	AC	1	1	0.010	5.185
NPK	AC	1	2	0.014	6.843

NPK	AC	1	3	0.017	8.148
NPK	AC	1	4	0.014	5.652
NPK	AC	1	5	0.010	3.492
NPK	AC	1	6	0.009	3.333
NPK	AC	1	7	0.010	3.580
NPK	AC	2	1	0.012	9.638
NPK	AC	2	2	0.012	6.552
NPK	AC	2	3	0.014	8.095
NPK	AC	2	4	0.043	6.552
NPK	AC	2	5	0.026	5.070
NPK	AC	2	6	0.026	3.730
NPK	AC	2	7	0.020	3.845
NPK	AC	3	1	0.009	7.046
NPK	AC	3	2	0.012	5.794
NPK	AC	3	3	0.018	6.896
NPK	AC	3	4	0.014	5.370
NPK	AC	3	5	0.009	2.654
NPK	AC	3	6	0.011	3.007
NPK	AC	3	7	0.010	2.357
NPK	UR + S^0	1	1	0.023	4.921
NPK	UR + S^0	1	2	0.101	8.130
NPK	UR + S^0	1	3	0.295	9.532
NPK	UR + S^0	1	4	0.420	8.324
NPK	UR + S^0	1	5	0.372	4.171
NPK	UR + S^0	1	6	0.106	3.033
NPK	UR + S^0	1	7	0.242	4.735
NPK	UR + S^0	2	1	0.021	13.042
NPK	UR + S^0	2	2	0.041	6.296
NPK	UR + S^0	2	3	0.207	12.769
NPK	UR + S^0	2	4	0.194	7.742
NPK	UR + S^0	2	5	0.112	4.365
NPK	UR + S^0	2	6	0.023	1.878
NPK	UR + S^0	2	7	0.098	3.968
NPK	UR + S^0	3	1	0.017	8.360
NPK	UR + S^0	3	2	0.062	7.928
NPK	UR + S^0	3	3	0.138	10.661
NPK	UR + S^0	3	4	0.082	6.243
NPK	UR + S^0	3	5	0.064	4.365
NPK	UR + S^0	3	6	0.087	5.229
NPK	UR + S^0	3	7	0.073	4.083

NPK	CN + S^0	1	1	0.010	5.891
NPK	CN + S^0	1	2	0.013	4.938
NPK	CN + S^0	1	3	0.016	6.437
NPK	CN + S^0	1	4	0.016	6.005
NPK	CN + S^0	1	5	0.010	7.601
NPK	CN + S^0	1	6	0.007	1.706
NPK	CN + S^0	1	7	0.011	2.963
NPK	CN + S^0	2	1	0.008	4.921
NPK	CN + S^0	2	2	0.011	6.014
NPK	CN + S^0	2	3	0.014	5.688
NPK	CN + S^0	2	4	0.019	5.988
NPK	CN + S^0	2	5	0.012	3.633
NPK	CN + S^0	2	6	0.009	3.113
NPK	CN + S^0	2	7	0.016	3.924
NPK	CN + S^0	3	1	0.011	5.344
NPK	CN + S^0	3	2	0.010	6.852
NPK	CN + S^0	3	3	0.016	6.420
NPK	CN + S^0	3	4	0.019	4.906
NPK	CN + S^0	3	5	0.023	3.739
NPK	CN + S^0	3	6	0.012	3.044
NPK	CN + S^0	3	7	0.023	3.404
NPK	AC + S^0	1	1	0.014	8.166
NPK	AC + S^0	1	2	0.018	9.003
NPK	AC + S^0	1	3	0.017	7.390
NPK	AC + S^0	1	4	0.015	5.891
NPK	AC + S^0	1	5	0.011	4.374
NPK	AC + S^0	1	6	0.012	4.056
NPK	AC + S^0	1	7	0.014	4.242
NPK	AC + S^0	2	1	0.007	4.488
NPK	AC + S^0	2	2	0.011	5.943
NPK	AC + S^0	2	3	0.011	5.926
NPK	AC + S^0	2	4	0.010	4.533
NPK	AC + S^0	2	5	0.007	3.607
NPK	AC + S^0	2	6	0.006	2.381
NPK	AC + S^0	2	7	0.008	3.527
NPK	AC + S^0	3	1	0.009	7.945
NPK	AC + S^0	3	2	0.012	6.455

NPK	AC + S^0	3	3	0.019	7.178
NPK	AC + S^0	3	4	0.018	5.203
NPK	AC + S^0	3	5	0.020	3.527
NPK	AC + S^0	3	6	0.013	3.712
NPK	AC + S^0	3	7	0.016	3.130
PKS	Nil	1	1	0.010	5.529
PKS	Nil	1	2	0.013	6.376
PKS	Nil	1	3	0.016	7.487
PKS	Nil	1	4	0.014	5.203
PKS	Nil	1	5	0.010	3.254
PKS	Nil	1	6	0.007	2.187
PKS	Nil	1	7	0.009	2.434
PKS	Nil	2	1	0.008	6.393
PKS	Nil	2	2	0.015	9.629
PKS	Nil	2	3	0.016	8.157
PKS	Nil	2	4	0.014	7.240
PKS	Nil	2	5	0.010	5.503
PKS	Nil	2	6	0.006	2.284
PKS	Nil	2	7	0.007	3.095
PKS	Nil	3	1	0.007	6.032
PKS	Nil	3	2	0.009	6.702
PKS	Nil	3	3	0.011	8.113
PKS	Nil	3	4	0.009	4.912
PKS	Nil	3	5	0.009	5.688
PKS	Nil	3	6	0.006	2.416
PKS	Nil	3	7	0.009	4.894
PKS	UR	1	1	0.011	7.487
PKS	UR	1	2	0.036	7.980
PKS	UR	1	3	0.039	10.582
PKS	UR	1	4	0.022	7.231
PKS	UR	1	5	0.015	4.444
PKS	UR	1	6	0.014	3.959
PKS	UR	1	7	0.020	5.988
PKS	UR	2	1	0.010	9.312
PKS	UR	2	2	0.035	7.698
PKS	UR	2	3	0.061	13.465
PKS	UR	2	4	0.017	6.640
PKS	UR	2	5	0.010	3.854
PKS	UR	2	6	0.017	5.829
PKS	UR	2	7	0.016	5.035
PKS	UR	3	1	0.016	8.324
PKS	UR	3	2	0.053	13.492

PKS	UR	3	3	0.038	10.414
PKS	UR	3	4	0.014	6.146
PKS	UR	3	5	0.008	3.289
PKS	UR	3	6	0.007	2.637
PKS	UR	3	7	0.013	4.824
PKS	CN	1	1	0.014	7.416
PKS	CN	1	2	0.015	7.407
PKS	CN	1	3	0.025	8.236
PKS	CN	1	4	0.026	6.296
PKS	CN	1	5	0.027	4.100
PKS	CN	1	6	0.013	4.021
PKS	CN	1	7	0.028	2.986
PKS	CN	2	1	0.007	5.203
PKS	CN	2	2	0.017	9.832
PKS	CN	2	3	0.018	8.430
PKS	CN	2	4	0.014	6.816
PKS	CN	2	5	0.010	4.744
PKS	CN	2	6	0.006	2.281
PKS	CN	2	7	0.009	3.483
PKS	CN	3	1	0.009	7.592
PKS	CN	3	2	0.012	6.252
PKS	CN	3	3	0.013	8.289
PKS	CN	3	4	0.011	6.270
PKS	CN	3	5	0.007	2.857
PKS	CN	3	6	0.006	2.187
PKS	CN	3	7	0.008	3.007
PKS	AC	1	1	0.021	4.180
PKS	AC	1	2	0.017	7.363
PKS	AC	1	3	0.020	7.090
PKS	AC	1	4	0.018	6.137
PKS	AC	1	5	0.010	4.048
PKS	AC	1	6	0.007	2.249
PKS	AC	1	7	0.009	3.245
PKS	AC	2	1	0.007	5.088
PKS	AC	2	2	0.010	5.256
PKS	AC	2	3	0.013	5.970
PKS	AC	2	4	0.012	6.270
PKS	AC	2	5	0.008	4.894
PKS	AC	2	6	0.006	2.205
PKS	AC	2	7	0.007	3.615
PKS	AC	3	1	0.008	6.737
PKS	AC	3	2	0.009	6.437
PKS	AC	3	3	0.009	6.032

PKS	AC	3	4	0.009	5.062
PKS	AC	3	5	0.007	4.277
PKS	AC	3	6	0.005	2.293
PKS	AC	3	7	0.007	4.100
PKS	UR + S^0	1	1	0.023	7.363
PKS	UR + S^0	1	2	0.038	8.457
PKS	UR + S^0	1	3	0.031	8.183
PKS	UR + S^0	1	4	0.017	8.051
PKS	UR + S^0	1	5	0.019	6.208
PKS	UR + S^0	1	6	0.012	3.430
PKS	UR + S^0	1	7	0.013	3.818
PKS	UR + S^0	2	1	0.015	5.855
PKS	UR + S^0	2	2	0.068	11.675
PKS	UR + S^0	2	3	0.128	12.769
PKS	UR + S^0	2	4	0.029	11.040
PKS	UR + S^0	2	5	0.019	5.591
PKS	UR + S^0	2	6	0.006	1.931
PKS	UR + S^0	2	7	0.013	4.282
PKS	UR + S^0	3	1	0.015	5.626
PKS	UR + S^0	3	2	0.046	10.432
PKS	UR + S^0	3	3	0.040	8.968
PKS	UR + S^0	3	4	0.015	5.538
PKS	UR + S^0	3	5	0.013	4.497
PKS	UR + S^0	3	6	0.011	3.695
PKS	UR + S^0	3	7	0.028	7.866
PKS	CN + S^0	1	1	0.012	7.160
PKS	CN + S^0	1	2	0.020	10.282
PKS	CN + S^0	1	3	0.018	7.293
PKS	CN + S^0	1	4	0.018	6.684
PKS	CN + S^0	1	5	0.012	4.462
PKS	CN + S^0	1	6	0.009	3.000
PKS	CN + S^0	1	7	0.009	2.414
PKS	CN + S^0	2	1	0.008	6.323
PKS	CN + S^0	2	2	0.010	5.776
PKS	CN + S^0	2	3	0.015	8.351
PKS	CN + S^0	2	4	0.014	6.393
PKS	CN + S^0	2	5	0.008	3.263
PKS	CN + S^0	2	6	0.007	2.809

PKS	$CN + S^0$	2	7	0.008	2.831
PKS	$CN + S^0$	3	1	0.008	6.508
PKS	$CN + S^0$	3	2	0.011	7.125
PKS	$CN + S^0$	3	3	0.014	8.659
PKS	$CN + S^0$	3	4	0.011	5.697
PKS	$CN + S^0$	3	5	0.007	3.139
PKS	$CN + S^0$	3	6	0.007	3.158
PKS	$CN + S^0$	3	7	0.007	2.998
PKS	$AC + S^0$	1	1	0.011	5.397
PKS	$AC + S^0$	1	2	0.015	6.649
PKS	$AC + S^0$	1	3	0.017	8.607
PKS	$AC + S^0$	1	4	0.014	6.464
PKS	$AC + S^0$	1	5	0.008	3.457
PKS	$AC + S^0$	1	6	0.010	4.330
PKS	$AC + S^0$	1	7	0.010	4.162
PKS	$AC + S^0$	2	1	0.009	6.640
PKS	$AC + S^0$	2	2	0.010	6.473
PKS	$AC + S^0$	2	3	0.011	6.155
PKS	$AC + S^0$	2	4	0.011	5.891
PKS	$AC + S^0$	2	5	0.008	5.115
PKS	$AC + S^0$	2	6	0.005	2.011
PKS	$AC + S^0$	2	7	0.006	2.663
PKS	$AC + S^0$	3	1	0.008	6.667
PKS	$AC + S^0$	3	2	0.011	6.261
PKS	$AC + S^0$	3	3	0.010	6.587
PKS	$AC + S^0$	3	4	0.009	4.797
PKS	$AC + S^0$	3	5	0.006	3.130
PKS	$AC + S^0$	3	6	0.005	2.028
PKS	$AC + S^0$	3	7	0.006	2.690