ORGANIC AMENDMENT TO REDUCE NITROGEN LOSS IN SANDY SOILS

By

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To all who nurtured my intellectual curiosity, academic interests, and sense of scholarship throughout my lifetime, making this milestone possible

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Nitrogen (N) is a nutrient often associated with accelerated eutrophication of surface water. The extremely low holding capacity for nutrients and moisture is the fundamental problem of sandy soil in Florida, which causes losses of nutrients into waterways. Soil organic amendment can improve soil quality by increasing soil's holding capacity for nutrients and moisture and is, therefore, a promising approach to reduce loads of nutrients and toxic metals in surface runoff water and/or leachate. Organic amendment can increase or decrease mineral N in soil, depending on the C/N ratio of the organic materials and N availability in the soil. Hydra-Hume is a commercial product, which shows the potential in enhancing soil N availability or reducing fertilizer N loss. In this study, incubation, column leaching, and laboratory analysis were conducted to examine the effects of Hydra-Hume on transformation dynamics and leaching potential of mineral N in two representative soils (Alfisol and Spodosol) under citrus production in south Florida. The obtained results indicated that Hydra-Hume amendment enhanced assimilationof mineral N, when it is applied to the soil, however, soil orginal C/N ratio also need to be considered. Hydra-Hume application reduced NO_3-N leaching regardless of chemical fertilizer addition. Significant reduction in total NO_3-N amount could be observed when Hydra-Hume applied alone in both of the soils, but an application rate of 44.8 kg ha^{-1} is required. If

fertilizer was incorporated with the treatments, significant reduction of total NO_3-N amounts and total mineral N amount could be observed, but a minimal application rate of 44.8 kg ha^{-1} is required to accomplish significant results in Spodosol and 22.4 kg ha^{-1} in Alfisol.

CHAPTER 1
LITERATURE REVIEW

Nitrogen and Plant Nutrition

Numerous mineral elements are needed for plant normal growth and adequate food and fiber production. Among these elements, Nitrogen (N) is an essential element for plant growth and a comparative larger amount is required by most agricultural crops than the other soil-borne elements (Stevenson, 1982). Nitrogen is a major part of all amino acid and the component of nucleic acid and chlorophyll. Also, It is essential for carbohydrate use within plants. Therefore, almost all the vital biological processes are related to N, which is a basic constituent of the functional plasma (protein, nucleic acids). A good supply of N is necessary for normal plant growth, but also uptake of other nutrients (Brady, 2008).

Many legumes and some other plant species can obtain N directly from the atmosphere, but in agriculture system, most N is obtained from the soil and external sources, such as fertilizers, or through mineralization process. An optimal supply of N will bring optimal crop yields. Therefore, maintaining a balance of N availability according to the needs of the plant is a hot point for sustainable agriculture. Plants respond quickly when supply of N is adequate in the soil. Their leaves turn dark green and the productivity can be dramatically stimulated. A deficiency of N in plants limits the synthesis of proteins and chlorophyll. It inhibits plants to assimilate CO_2 and synthesize carbohydrates, and consequently exhibits chlorosis (yellowish or pale green leaf colors) and stunted growth (Zhao et al., 2005). Timing of N application is also important. Late application of N may cause early-stage lack of N, which may have adverse effects on annual crop yield (Jansson et al., 1982).

It is recognized that some crops are well adapted to unfavorable conditions, growing improver when soil has high nutrient levels. Excessive N promotes development of aerial organs with relatively poor root growth. The presence of N in excess promotes development of the aerial organs with relatively poor root growth. This increase may cause excessive vegetable growth and the risk of lodging. It may also reduce the plant's resistance to harsh climatic conditions and to foliar diseases (FAO, 1984).

To meet the food demands of a growing world population, global use of N fertilizers in intensive agricultural systems has increased dramatically in the last decades, especially for greenhouse vegetable production systems (Ju et al., 2005). Due to the relatively high economic value of the higher yields and difficulties in the precise management of nutrient supply, growers tend to use extra large amounts of fertilizers in order to obtain maximum yield. However, the efficiency of fertilizer N is limited, with often less than 50% of the applied N taken up by the crop (Raun et al., 1999). Ju et al. (2007) mentioned, only in one of the vegetable production areas in China, fertilizer N is often applied at rates > 1200 kg N ha^{-1} per crop, and two or three crops are grown each year. The huge fertilizer load and extremely low crop recoveries of fertilizer nutrients may increase the risk of environmental pollution of both air and water and marked deterioration in soil (Wiesler et al., 2001). To improve N efficiency and achieve the optimal crop yield in agriculture, integrated N management strategies, which contain improved fertilizer, soil, and crop management practices, must be taken into consideration.

The Role of Nitrogen in Sustainable Agriculture

The global human population, currently 7.5 billion, is projected to reach 10.5 billion by 2050. The vast majority increase will occur in the developing countries of Asia and Africa, according to United Nations estimates. Increased urbanization and industrialization bring rapidly growing population, which result in greater food demands. Meeting the nutrition requirement and food demand of the growing population has become a big challenge due to decreased irrigational water supplies and other environmental concerns (Singh et al., 2011). Moreover, population growth and expanding demand for agricultural products constantly increase the pressure on land resources. The pressure on land may cause land degradation and intensification of the cultivation of arable lands, and also expansion of cultivation into marginal areas. Mismanagement of arable areas by farmers and grazing areas by livestock owners is one of the major causes of soil degradation (FAO, 2000). Various sources suggest that 5 to 10 million hectares are being lost annually to severe degradation. If this trend continues, 1.4 to 2.8 percent of total agricultural, pasture, and forestland will have been lost by 2020 (Scherr and Yadav, 1996). Losses of N by land degradation are estimated to range from 1 to 100 kg ha^{-1} per year (White, 1986; Rose and Dalal, 1988), which makes land degradation a major cause of long-term decline in the fertility of agricultural soils. Land degradation may also have negative effects on the farm, such as deposition of eroded soil in streams or behind dams, contamination of drinking water by agricultural chemicals, diversion of water sources from other users by irrigation, health problems caused by wind-eroded soil or loss of habitat, which will affect the livelihood and economic wellbeing and nutritional status of over a billion people (Scherr and Yadav, 1996). Therefore, it seems sensible to consider alternative approaches, like sustainable agriculture.

Continuous cultivation with inappropriate farming practices may result in severe depletion of nutrients and soil organic matter. Henao and Baanante (2001) reported that soils of most countries in North Africa are being depleted of nutrients at rates ranging from 20 to 50 kg NPK/ha/year. Lal (2001) reported that the depletion of soil organic matter in tropical regions could be as high as 70% as a result of cultivation for 10 years. Sustainable agriculture is vital in today’s world as it offers the potential to meet our agricultural needs. A switch from “conventional” to sustainable” agriculture involves more than just simple substitutions, such as replacing chemical fertilizers with green manure. It attempts to require more information about environmental characteristics and the environmental impacts of agricultural practices in order to make sure the environmental resources can be fully utilized and no harm was done to it. The techniques need to be environmental friendlyto ensure safe and healthy agricultural products (Singh et al., 2010; Hue and Silva, 2000). Erenstein et al. (2012) reported that sustainable agricultural practice, such as zero tillage (ZT) practice, could drastically reduce tillage intensity and loss of nutrients for the wheat crop from eight to a single tractor, save 15–16% on operational costs and boost 4% yield increase over average farmer reported conventional yields of 4.2 tons ha^{-1} in the rice-wheat systems in South Asia.

From 1950's, the concerns of scientists and consumers about the large-scale use of chemical external inputs, such as fertilizer N, led to movements that searched for alternatives to sustainable agricultural practices. However, the use of N is mainly determined by economic incentives such as profitability and subsidies, and less by environmental costs (Spiertz, 2009). To manage nutrients and productivity of agro-ecosystems, Drinkingwater and Snapp (2007) proposed an ecosystem-based approach, which minimizes N loss and maintain soil reserves with nutrient inputs equal to harvested exports.

To maintain long-term fertility in sustainable agroecosystem, soil organic matter (SOM) is a key factor, which has great influences on many readily measurable soil functions or processes (Yilmaz, 2011). It drives biological processes involved in nutrient cycling as a reservoir of nutrients and energy and also has a profound influence on soil basic properties, such as cation exchange capacity, chelation of metals and stabilization of soil structure. Agricultural production cannot be sustained if nutrients removed during cropping are not replenished or if appropriate agricultural practices are not implemented to maintain or increase soil organic matter. Therefore there is a surge of research on organic farming in recent years and it is seen as a sustainable alternative to conventional intensive agricultural systems (Stockdale et al., 2001) Nutrient management in organic systems is based on fertility building soils to fix atmospheric N, combined with recycling of nutrients by organic materials, such as farmyard manure and crop residues, with only limited inputs of permitted fertilizers (Loes and Ogaard, 2001).

Nitrogen also plays a very important role in determining crop yield. Rasmussen et al. (1998) reported that in the long-term experiments in UK, wheat yields with fertilizers exceed those without external N input by a factor of 2–3. Dobermann and Cassman (2002) reported that grain yields of maize increased from 3 to 14 t ha^{-1} with an increase in plant N accumulation from 50 to 300 kg N ha^{-1} and rice yields increased from 2 to 8 t ha^{-1} with an increase in plant N accumulation from 25 to 200 kg N ha^{-1}. It means with an increased amount of fertilizers, especially N, crop yield will be greatly enhanced. However, more external N inputs may bring more environmental impacts. The N inputs are among the first constituents to be removed by soil erosion because they are concentrated in the surface soil and are less dense than other soil constituents (DeBano and Conrad, 1976). Before 1960s, N fertilizer was used at a relatively low rate and crop N uptake was mainly dependent on manure applications, biological N fixation and indigenous N supply through mineralization of soil organic matter. Since the early 1960s, the use of N fertilizers has dramatically increased and nowadays 30%-80% of N applied to farmland is lost to surface and groundwater, and to the atmosphere (Goulding et al., 2008). Goudriaan et al. (2001) reported that fertilizer N accounted for 60% of the net primary production in 1990, thus resulting in over-application of fertilizer N from the economic response. Since 1980, the amount of fertilizer N has exceeded the amount taken up by crops globally. It means that only yield improvement was considered and not environmental sustainability.

Under the current global background, sustainable food security draws lots of attraction. Sustainable agriculture combines economic profitability, environmental health and ethical soundness as three main objects. It focuses on meeting productivity, efficiency and efficacy aims. Eickhout et al. (2006) explored the role of N in future world food production and environmental sustainability, and concluded that despite improvements in N-use efficiency of food production systems in developed countries, total reactive N loss would grow strongly to 2030 because of the intensification of crop production systems in developing countries. Therefore, there is a need in balancing the use of fertilizer N and the key challenges are to develop global capacity to produce adequate food in a sustainable manner, and establish communication about the risks of N excess in agroecosystems and implement legislation (Spiertz, 2009). Current knowledge for achieving sustainable crop intensification through measuring both optimal use of external inputs and make conservations for natural resources within an agroecosystem is inadequate. In order to increase intensification and diversification of agricultural production systems, innovative sustainable technologies, appropriate policies, and economic incentives will have to be developed (Keerthisinghe et al., 2003). In the case of N, there is a need to gain refined information on N-cycling processes and to assess the value of the crop, soil or fertilizer management practices designed to improve overall N use efficiency of the agroecosystem, with the ultimate goal of enhancing sustainable intensification of agricultural production while conserving the natural resource (Chalk et al., 2002).

Spiertz (2009) also put forward two strategies to meet sustainability goals in food production, with a safe and profitable use of N: One is developing low-input, high-diversity agricultural systems. Agricultural system diversity, such as crop choice and crop rotation, may minimize the risks of yield reduction by abiotic and biotic stress. The other one is developing high-input, low-diversity agricultural systems. Some crops with high yield and high N-response are chosen to achieve a maximum productivity per unit of land. An optimized N management during the whole crop cycle may control N losses.

Soil Nitrogen

Most of the N in terrestrial systems is found in the soil. Normally, A horizons have about 0.02 to 0.5% N and a value of about 0.15% N in cultivated soils (Brady, 2008). Nitrogen in soil is largely bound to organic matter and mineral materials that protect it from loss but make it unavailable to the plants. Generally, only a small amount of N exists in available mineral forms, such as NO_3^- and exchangeable NH_4^+. Therefore, N cycling in soil is closely related to organic matter turnover. Microorganisms are responsible for soil N transformations, which play a vital role in determining the availability of N for plant growth and crop production (Stevenson, 1982; Powlson, 1998). Some studies have shown approximately 1.5 to 3.5% of the organic N mineralized in soils annually (Hue and Silva, 2000; Wilson and Jefferies, 1996). After the land is first placed under cultivation, the amount of N decline, and N removed by harvested crops must be compensated with an equivalent amount of fixed N into organic matter to form equilibrium with the characteristics of local weather, tillage and cultivated practice, and soil types (Stevenson, 1982).

Since mineral N is highly mobile and limited in the soil, if it is cannot be taken up by plant roots and microorganisms, it may be lost through gaseous emission, mainly by denitrification and volatilization, or leaching to the groundwater, both of which may create environmental hazards (Hauck, 1990; Jenkinson, 1990). The main method scientists applied to maintain or restore soil nutrients and increase crop yields is the application of N fertilizers (Hirel, 2011). Fertilizer N can greatly improve crop quality by enhancing the protein content of the grain and forage crops. Also, some researches showed the role of applied fertilizer N in facilitating crop uptake of other essential nutrients (Whitehead et al., 1986; Pederson et al., 2002; Fageria et al., 2005). For example, the physical association of NH_4^+ with P can increase the uptake of fertilizer P. Murphy (1978) reported that the placement of anhydrous NH_3 with an ammonium phosphate solution is soil may significantly enhance uptake of the fertilizer P. Moreover, in calcareous soils, fertilizer may band with Zn and thus improve Zn uptake by plants.

Tilman (2002) showed that with the amount of mineral N fertilizers applied in soils increased by 7.4 fold, the overall yield increased only by 2.4 fold. It means that the fertilizer N use efficiency has declined sharply. It is true that there is a genetic variability for both N absorption efficiency and for N utilization efficiency in most of the crops (Hirel et al., 2007). However, the main reason is probably the severely disturbed N balance due to the intensification of agricultural activities and the application of chemical fertilizers. Over 50% and up to 75% of the N applied to the field is lost by leaching into the soil (Hodge et al., 2000; Asghari et al., 2011).

With yearly applications of N fertilizer, excessive amounts of N are brought into the environment and have a number of undesirable impacts on water, terrestrial, and atmospheric resources (Ribaudo et al., 2011). Also, changes in the N cycle associated with excessive soil N loading may bring ecological impacts, such as changes in the structure of ecosystems and biodiversity, and economic impacts (Matson, 1998; UNEP, 2004). Similarly, the use of N fertilizer may also affect human health both in positive and in negative ways, depending on the rates of N fertilizer used in the ecosystem. Crop yield may be greatly increased by applying high rates of N fertilizer, while negative health effects may occur in direct (pollution of air and water) and indirect (ecological feedback to disease) ways (INI, 2004).

Nitrogen Transformation and Availability in Soil

Nitrogen is the element that controls most of the biological activity in soil. The movement of N between the land, water, and atmosphere defines the cycling of N on a global scale. Soil also has an internal N cycle where N is converted from one form to another (Rosewell, 1976). Mineral soils in the temperate regions of the world contain between 0.06 to 0.3% N and approximately 90% of the N is in organic forms (Matthews, 1992). Inorganic forms exist primarily as ammonium (NH_4^+) and nitrate (NO_3^-). Once in the mineral form, N is easily transported between air, water and soils. The internal N cycle in soils is constantly changing due to biological, chemical and physical processes. The rate at which N becomes available is determined by the complexity and stability of organic matter and by microbial activity. It may occur in days or, if the N is in a very stable form, it may take years.

Microorganism cannot metabolize elemental N (N_2), which means N becomes biologically active when it is fixed or bound, such as incorporating into ammonium (NH_4^+) and nitrate (NO_3^-). Fixed N flows through the food web (plant–animal–humans/predators). This fixation process distinguishes the N cycle from the carbon (C) cycle. From a global environmental point of view, there is a serious concern about the excessive growing fixed-N. Agriculture accounts the largest fraction (some 86%) of the total human-released fixed N (Jordan and Weller, 1996). Nitrogen fixed by human activity now exceeds the amount by all terrestrial natural processes combined. Balance studies have reported that the ways of N loss from soil due to uptake, leaching, erosion, and denitrification are replenished to varying extents by biological N_2-fixation processes. When agriculture is introduced into these systems, this nutrient cycle is broken and the normal supply of nutrients for any agricultural activity comes mainly from the soil. Additional nutrients must be supplied as external inputs to maintain crop growth and yield. Organic wastes, such as human, animal, and crop wastes, are used an sources of nutrients added to the soil. There are many examples of the disappearance of whole civilizations due to diminished soil fertility and productivity.

Rivas et al. (2012) studied soil N dynamics after a severe forest fire and reported that the inorganic N concentrations were typically greater or equal to those of control sites in the first years after fire (Smithwick et al.; 2005; Turner et al., 2007; Boerner et al., 2009). An increase in net mineral N in forest soil after fires can be attributed to higher soil pH, N release from dead roots and previously inaccessible N forms, increased anion exchange capacity and decreased N immobilization due to a loss of C inputs after fire. There were dynamics in the N cycling. A decrease in net N mineralization would be the result of increased C/N ratio of the remaining soil organic matter (SOM), a decrease in SOM quantity and quality occurred as a result of pyrolysis, and recalcitrant char production or an increase in N immobilization due to enhanced microbial activity and/or increases in organic C and phosphorus (P) concentration. Therefore, changes in the composition or abundance of microbial and plant communities are crucial in influencing internal N cycling in soil.

Nitrogen Losses into the Environment

In modern society, when the natural organic waste additions cannot meet the need of crop production, fertilizers and several other materials have been used as additional sources of nutrients, especially for the N. The significance of N originating from fertilizer inputs for annual crop N requirements has been evaluated by growing a test crop under unfertilized conditions (Glendining et al., 1996; Bhogal et al., 2000; Sieling et al., 2006). The excessive N loads may cause an increase of N loss from the soils though denitrification (nitrous oxide (N_2O) emission), volatilization, and leaching, *etc*.

It is estimated that the anthropogenic N_2O emissions to the atmosphere are about 3–8 Tg N annually and agricultural systems impart a large portion of anthropogenic emissions (Mosier and

Kroeze, 1998). Bouwman (1996) reported a simple linear relationship to relate the total annual direct N_2O emission (E) from fertilized fields to the N fertilizer applied (F): $E=1+1.25\times F$. The emission factor, 1.25± 1% of N fertilizer applied, given by Bouwman, has been adopted by Intergovernmental Panel on Climate Change (IPCC) as the "default emission factor" to calculate the emission of N_2O affected by N fertilizer applied. This emission factor makes the methodology for calculating emissions simple and transparent. However, there are still disadvantages on the large uncertainties and impossibility to distinguish various regions, crop type and weather patterns (Ruser et al., 2001; Kuikman et al., 2006). Smith (1998) reported that in Scotland the average emission factor was less than the default value of 1.25% of the mineral N applied, and suggested a lower temperature may account for this difference. Dobbie (1999) reported that the emission factor differed greatly among grassland, potato, broccoli, and grain cereal crops. Therefore, IPCC in 2001 suggests that the direct N_2O emission from soil may require a better calculation based on different regions.

Organic amendment, as a practical manner, has been widely used for improving soil fertility. The type of amendment is a vital factor affecting nitrous oxide emission (Shelp et al., 2003). Aulakh (1991) reported that the C/N ratio of the organic amendments greatly affect the amount of N_2O emission, by affecting mineralization and immobilization rate of N in soil. Higher C/N ratios (>30) may lead to immobilization of mineral N and microorganisms decompose organic residue and incorporate mineral N into their biomass. A relative low C/N ratio (<20) in plant residue shows a high mineralization rate, which NO3 can be taken up by the plants. C/N ratios could be a good predictor for N_2O emission. In the early stage, Bremner and Blackmer (1981) reported a negative relationship between these two factors. Huang et al. (2004) reported that the relationship between N_2O emission and C/N ratio is linearly negative, with correlation coefficient (R^2) ranging from 0.783 to 0.986. Amendment of organic residues may significantly increase the rate of soil respiration and develop anaerobic environment more rapidly, which will trigger more N_2O emission (Ding et al., 2006). Huang et al. (2004) and McKenney et al. (1993) reported that the emission rate of N_2O decreased significantly by adding wheat straw and sugarcane stalk, as compared with other materials in clay soils. Also, in sandy clay loams, animal manure and slurry generated more N_2O emission than mineral N fertilizer (Laughlin, 2001; Khalil et al., 2002). By integrating N immobilization data, Vigil and Kissel (1991) reported the break-even point between net N immobilization and mineralization of organic residues was at a C/N ratio of 41. Therefore, some organic amendments, such as sugarcane stalk and wheat straw, which have C/N ratio greater than 41, may stimulate NH_4^+ immobilization and N_2O consumption, and hence reduce N_2O emission.

Senbayram et al. (2012) and Jahangir et al. (2011) studied the relationships between N and C sources in reducing N_2O emissions by pot incubations in the lab. A microscale for exploring processes that occur in deep soil horizons was used in both of their studies. Additions of different C sources to the soil via fertilization or crop residue incorporation may increase denitrification. Senbayram et al. (2009) quantified the increase in denitrification and concluded that application of organic matter with high labile C content to fertilized agricultural soils may lead to denitrification-derived N_2O emissions. Organic amendments used as alternatives to mineral N fertilizers may have contrasting effects on greenhouse gas emissions, depending on soil C/N ratio.

Leaching and erosion are another major way for N loss in terrestrial systems, which are estimated to range from 1 to 100 kg ha^{-1} year^{-1} (Teixeira et al., 2004). Microorganisms play an important role in improving soil fertility by metabolizing N, which cannot be uptaken by plants directly. Once organic N is mineralized and converted into NH_4^+ and subsequently into $NO_3^−$, it can be lost via leaching. The mineral forms of N are very soluble and can be easily leached into surface run-off and groundwater, especially nitrate (NO_3^-) and urea ($CO(NH_2)_2$) (Redhaiman, 2000; Umar and Iqbal, 2007)). However, the process of biological conversion is time-consuming and the movement of NH_4^+ in the soil is limited by binding to the cation exchange complex (CEC) of clay particles and soil organic matter. Inappropriate N fertilizer application and management, which exceed the need of crop production, may trigger large N leaching losses. During leaching, the losses of mineral N are often accentuated by an abundance of precipitation combined with low evapotranspiration losses, which enhance water saturation, leading to subsurface or surface water flow, especially in fallow period (Legg, 1982).

Leaching loss of N from organic material depends mainly on two factors. The first is the net amount of organic N that is mineralized and converted into $NO_3^−$. Secondly, once the organic N is nitrified to $NO_3^−$, sufficient water has to be present to allow downward movement (Legg, 1982). However, if there is too much water, the soil becomes waterlogged and $NO_3^−$ will be lost by denitrification. Soil texture is an important property that determines how much $NO_3^−$ is lost by leaching or denitrification. A clay soil with a heavy texture has a lower hydraulic conductivity than a lighter, sandy soil. Therefore, in a heavy textured soil, $NO_3^−$ is more susceptible to denitrification, whereas in a sandy soil, leaching is more likely to be the main mechanism of $NO_3^−$ loss.

The leached nitrate from agricultural lands is considerable and contaminates groundwater, rendering it unfit for human consumption. The increase of N in surface water will have increased biological productivity and brings about eutrophication, which generate undesirable changes including proliferation of algae and aquatic macrophytes, dissolved oxygen depletion, and a decrease in water clarity (Conley et al., 2009).

While several real and potential health and environmental impacts of N exist, agriculture and environmental practices have major effects only on those impacts which involve excessive nitrate in drinking water, eutrophication, and perhaps on O_3 depletion (Mahvi et al., 2005; Ju et al., 2007). Few studies did intelligent risk assessment analyses of these impacts, especially when human health as well as social goals and values are involved. The growing worldwide demands for food will involve a continued increase in the use of fixed N in agriculture, most of which must come from fertilizers. However, the great willing of making a better world with environmental safety tell us the importance in managing N both in agriculture and environmental quality (James et al., 2011; Stevenson, 1982).

Implication of C/N Ratio in Nitrogen Management

The key problem in managing N for agriculture is to achieve the balance between N supply and crop demand without excess or deficiency (Cassman et al., 2002). A definition of nutrient management can be reported at USDA's Natural Resources Conservation Service (NRCS) practice standards: managing the amount, source, placement, form, and timing of the application of plant nutrients to the soil (USDA, NRCS, 2006). Several scientists studied N-use efficiency (NUE, always assessed by C/N ratio) as an indicator to check the management of N in agriculture. They define NUE of a cropping system as the proportion of all N inputs that are removed in harvested crop biomass, contained in recycled crop residues, and incorporated into soil organic matter and inorganic N pools. The excessive N is lost from the cropping system and thus contributes to the reactive N load to the environment. (Hussain et al., 1996; Timsina et al., 2001; Zheng et al., 2007; Gaju et al., 2011).

Since Calvert (2004) presented the idea of proportionality between C and N, C/N ratios have been considered an important soil characteristic. The C/N ratio of the organic material added to the soil influences the rate of decomposition of organic matter and this results in the mineralization or immobilization of soil N. If the added organic material contains more N in proportion to C, then N is released into the soil from the decomposing organic material. On the other hand, if the organic material has a less amount of N in relation to the C, then the microorganisms will utilize the soil N for further decomposition and the soil N will be immobilized and become unavailable to plant. The soil C/N ratio is an important soil fertility indicator due to the close relationships between soil organic C and total N. Generally, the C/N ratio of the surface soil falls within narrow ranges, usually about 10 to 12 for cultivated, agriculturally soils of temperate regions. However, there are many factors which affect soil C/N ratio, such as climate (Miller et al., 2004), soil conditions (Diekow et al., 2005; Galantini et al., 2004; Ouédraogo et al., 2006; Yamashita et al., 2006), vegetation types (Franzluebbers et al., 2000; Puget and Lal, 2005), and agricultural managements (Raun et al., 1998; Dalal et al., 2011; Liang et al., 2011).

Boberg (2009) stated that the C/N ratio of an organism in soil reflects how much C, which microorganisms requires for biomass production, in relation to N. For plants, C can be used as energy source and thereby lost as carbon dioxide. To produce biomass and balance the need, the C/N ratio of the substrate must be higher than that of the microorganism and the C/N ratio of the new organism will be lower than the substrate. Moreover, N is essential to produce the protein rich microbial cells. Inorganic N is immobilized into bacterial cell when the metabolized organic substrate has a high C/N ratio (Azim et al., 2008; Kirkby et al., 2011). The C/N ratios of microbial organisms are relative constant and the range of fungi and bacteria is in the range 8-25 and 5-18, respectively (Chapin et al., 2002; Rousk, 2009). For a general soil, microbial biomass may vary with the fungal/bacterial ratio, while a range of 10:1 to 12:1 is recommended (Griffin, 1972). Therefore, when applying N fertilizers or organic amendments, such ratio range can provide a reliable basis with which to determine the extent of available C and the stabilizing nutrients and to consider implications for management strategies to optimize retention of stable available N in soils.

Nitrogen mineralization depends not only N concentration of the substrate, but also the decomposability (Janssen, 1996). Although plants can only take up the inorganic forms (NH_4 and NO_3), it may also return organic N compounds to the soil in litter fall. Vegetation therefore influences N mineralization and nitrification through competition with microbes for nutrients and through litter quality and quantity (Vitousek et al., 1982). The break down of organic residues by microbes is dependent upon the C/N ratio. Hoorman and Islam (2010) conducted a study on comparing two separate feed sources, a young tender alfalfa plant and oat or wheat straw. Young alfalfa plant has more crude protein, amino acids, and a lower C/N ratio, which make it much easier for microbe to digest. However, oat and wheat straw has more lignin, less crude protein, and less sugars in the stalk and a high C/N ratio. It needs more time and N to break down the high carbon source and be decomposed by microbes. Therefore, a relative low N content or a high C/N ratio is associated with slow soil organic matter decay and generally, immature or young plants have a higher N content, lower C/N ratios, and faster soil organic matter decay (Lewis and Papavizas, 1974).

As well for composting, the initial C/N ratio is one of the most important factors (Michel et al., 1996). A C/N ratio less than 20 allows the organic materials to decompose quickly while a C/N ratio greater than 20 requires additional N and slows down decomposition. If a considerable amount of C is in the form of lignin or other resistant materials, the actual C/N ratio could be larger than 20. Generally, initial C/N ratios of 25–30 are considered ideal for composting (Kumar et al., 2010). If a high C based material with low N content is applied to the soil, the microbes will tie up soil N, though it will be eventually released. Recently some researchers have successfully conducted composting at lower initial C/N ratios from 15-20 (Huang et al., 2004; Zhu, 2007; Ogunwande et al., 2008; Kumar et al., 2010). Composting at lower initial C/N ratios can increase the amount of manure treated, but can also increase the loss of N as ammonia gas. As the soil organic matter decomposes, the C/N ratio of most plant residues tends to decrease due to the gaseous loss of CO_2. Therefore, the percentage of N in the residual SOM rises as decomposition progresses.

The C/N ratio influences the two main decomposing groups, bacteria and fungi, in soils. Bacteria are the first microbes to digest newly input organic plant and animal residues in the soil. Bacteria have a high N content in their cells and are generally less efficient at converting organic C to new cells. The relative importance of decomposition by fungi is that it can help decrease the application of N fertilizer (van Groenigen et al., 2007), while organic matter with a high C/N ratio is believed to stimulate the fungal contribution to decomposition (Henriksen and Breland, 1999; Thiet et al., 2006). For most of the soil, the typical C/N ratio is around 10, which means the N is available to the plants. The 10:1 C/N ratio of most soils reflects an equilibrium value associated with most soil microbes (Bacteria 3:1 to 10:1, Fungi 10:1 C/N ratio).

The C/N ratio theory also applied in many agricultural practices in N management, such as cover crops, crop rotation, organic amendments, *etc*. Many crop production practices have the potential to create adverse environmental impacts with respect to N. Due to the intensified crop management, such as greater inputs of N fertilizers (Tilman et al., 2002; Erisman et al., 2008), the global cereal production doubled in the past 40 years. However, not all of the applied N can be taken up by plants. When the natural capacity of a system to cycle N is exceeded in a given locality, the excessive N may be accumulated in the ground or surface waters and large amounts of NH_3 or N_2O may be lost to the atmosphere. The sources of N are diverse. Usually, exogenous N is from the residues of plant, animal origin and fertilizers. Techniques are established for minimizing N losses and maximizing N efficiency, including efficient agricultural management, innovative applications of agricultural technology, regulations limiting fertilizer applications, and possible even changes in fundamental patterns of land use and crop production (Stevenson, 1982). In general, practices which decrease soil erosion and surface runoff will also reduce the amount of N lost from croplands by these routes.

As a nutrient management tool, the use of cover crops in cropping systems is an important strategy. Cover crops, also called green manure, can be defined as close-growing crops that provide soil cover, and soil improvement between periods of normal crop production (SSSA, 1997). They are not grown for market purpose and are well suited for conservation agriculture. Growing cover crops in a rotation can reduce erosion through greater levels of soil cover as well as improve soil fertility and suppress weeds (Flower, 2011).

Cover crops can be leguminous or nonleguminous. Legume cover crops fix atmospheric N into a form plants and microorganisms can use and thus they are used as a source of N (Smith et al., 1987). Non-legume species recycle existing soil N and can reduce the risk of excess N leaching into groundwater (Meisinger, 1991). There is interest in growing leguminous cover crops, such as red clover (Trifolium pratense L.) and hairy vetch (Vicia villosa L.), particularly on erodible soils (Goss et al., 1995). These leguminous cover crops apply one more potential on N fixation through biological pathways, which can benefit in reducing the need of N fertilizer for succeeding crops (Singh et al., 2004). Nonleguminous cover crop can accumulate inorganic soil N and hold it as an organic form, which can reduce the mineral N leached from the soil and leave the soil bare. Cover crops can reduce the potential for percolation by extracting water from the soil, reducing the potential for percolation and consequent leaching (Chapot et al., 1990). The holding N will be released after decomposition of the cover crops.

Black oat (*avena strigosa* Schreb.) is widely used as a cereal cover crop due to its rapid growth, high biomass production in southern Brazil and some area in USA. As a cereal, it has a high C/N ratio, which leads to slower decomposition rate and hence possible immobilization of soil N following some cereal cover crops (Flower, 2011). Rye (*S. cereale* L.), a cereal, had great potential on accumulating the residual inorganic N after corn harvest (McCracken et al., 1994).

In addition to fixing N, several studies reported that cover crop could reduce the potential for nitrate leaching from the farm fields (Owens, 1990; Brandi-Dohrn et al., 1997; Staver and Brinsfield, 1998). Meisinger et al. (1991) conducted a study on the impacts of cover crop on nitrate leaching and showed that cover crops reduced both the mass of N leached and NO_3 concentration of leachate by 20 to 80% are compared with no cover crop control. Francis et al. (1998), Shepherd (1999), and Rasse et al. (2000) reported that incorporating a nonleguminous cover crop in a cropping system has reduced nitrate leaching since the cover crop can reduce water percolation and also effectively use of nitrate.

Cover crops are sometimes planted after the principal crop has been removed to control erosion. Reduction in soil erosion by cover crops is associated with increasing in soil organic matter content, which improve soil water infiltration and holding capacity. However, there are still some possible disadvantages of cover crop. If cover crop has a very high C/N ratio, it may create N deficiency for the succeeding crop if excessive N is immobilized and not released in a timely manner (Vyn et al., 1999). Moreover, adverse weather often prevents planting or growth of the cover crop.

Crop rotation is a practice, which can reduce the requirement of N fertilizer. Crop rotation is to plant different crops on the same field in successive years and usually, the cropping sequences change with specialized farming. For example, corn-soybean is a common rotation group. Soybean can scavenge residual fertilizer N from the corn crop. John et al. (1975) estimate that about 40% residual N is removed by soybean. A recent study by Hons (2005) reported that the 60% increase in lint yield of unfertilized cotton under rotation was attributed to increased soil organic matter (SOM), total N, residual nitrate N, and water content. Reddy et al.. (2006) also reported that the improved cotton growth in rotation with corn was attributed to increase SOM. The sequence of crop rotation is very crucial. Root exudates from plants cause change in microbial community composition and biomass and may depend on plant species-specific differences in the quality of resources (e.g. carbon) input (Ladygina and Hedlund, 2010). Plants that have a high C/N ratio may increase N immobilization and use up the residual N, which may decrease the yield of next crop.

Organic amendments, including farmyard manures, slurries, sewage sludge, green wastes and composts, can increase soil fertility and quality to improve crop productivity and yields (Lupwayi et al., 2005; Fageria, 2007). Organic amendments can improve the physical properties of the soil, such as water-retention capacity, bulk density and soil structure. Moreover, the application of organic amendments increases soil nutrients, which can reduce the need for inorganic fertilizers (Bellamy et al., 1995; Burgos et al., 1996; Barker, 1997).

Several types of organic amendments have been used for improving crop production. Steffen et al. (1995) discussed comparative tomato yields of conventional agriculture system and an ecologically oriented system, which emphasized the building up of organic amendments. The latter system hada greater soil water holding capacity and sharply reduced irrigation requirements. Moreover, the yield of NO.1 fruit was 55%-60% greater than the other one. Webb and Biggs (1988) examined the effects of adding humate as organic amendment on the growth of citrus. Trees treated with humate exhibited higher water uptake and produced more vigorous growth flushes. Foley et al. (2002) studied the paper mill residue applied as an organic amendment to increase vegetation production. Paper mills waste are the residues combining the primary residues from paper making process with the secondary wastewater treatment sludge and have a C/N ratio less than 20:1. It was applied in the Central Sands region of Wisconsin increased the water holding capacity and plant-available water by 33%-80%. The utilization of organic wastes as amendments had an efficient and low cost-effective method of disposal these products. Sharifi et al. (2008) compared the field with or without a history of organic amendment (Solid beef (Bos taurus) manure) in potato (Solanum tuberosum L.) production. The results showed that historically amended soil had 35% higher values of potentially mineral N and 8% higher proportion of mineral N partitioned to the stable mineral N pool. The long-term addition of amendments results in important changes in active and stable soil organic-C and -N fractions that can influence soil N dynamics. Single applications of organic amendments contribute a small amount to mineralized N in the subsequent year, the combined contributions of organic N from repeated applications can lead to a substantial increase in soil N mineralization potential (Eghball et al.., 2004; Flavel and Murphy, 2006; Mallory and Griffin, 2007). The increased soil N mineralization potential can lead to higher soil N supply and subsequently reduce the need for fertilizer N.

Organic amendments may also affect crop yield through disease suppression. In some cases, organic amendment may release toxic compounds to directly inhibit the pathogens, such as isothiocyanates released from degradation of brassicaceous material (Lazzeri and Manici, 2001), or increase microbial biomass and activity to suppress disease (Bailey and Lazarovits, 2003). Ayongwa et al. (2011) studied the organic amendment impact on host-parasite dynamics of sorghum bicolor and striga hermonthica and high quality amendment will have a negative impact on S.hermonthica severity and incidence. C/N ratio describes the organic matter quality; where-in high-quality organic matter has a low C/N ratio and low-quality organic matter a high C/N ratio.

Some organic wastes that are rich in N can release large amounts of mineral N through mineralization and improve fertilizer efficiency. When mineral N exceeds the amount needed to fill the gap between crop uptake needs and the supply from theses sources, Excessive N may be lost by leaching and denitrification to the environment. Therefore, the change of N dynamics after applying organic wastes need to be recorded to access effective use of the material, minimizing the losses of nitrate in leachates and avoiding negative environmental effects that it may cause in groundwater. Burgos et al. (2006) compared 3 organic materials, municipal solid waste compost, non-composted paper mill sludge, and agroforestry compost on the N dynamic of a sandy soil. All of these three amendments had different immobilization N periods followed by positive mineralization. Due to the different C/N ratios, the first amendment had a higher nitrate-leaching rate. Nevertheless, the nitrate losses represented a low amount compared with the total N added to soil. Radersma and Smit (2010) evaluated the effect of paper pulp as organic amendments on the N loss from fodder radish and found that adding paper pulp lead to a strong decrease in denitrification and N leaching.

Conclusions and Perspectives

Nitrogen is an essential macronutrient for plant growth. A deficiency of N may cause symptoms in plant leaves and stunt plant growth, while an adequate supply of N in the soil greatly promotes rapid plant growth and crop yield.

Nitrogen undergoes a wide variety of transformations in soil, most of which involve the organic fractions. An internal N cycle exists in soil apart from the overall cycle of N in nature. Even if N gains and losses are equal, the N cycle is not static. Continuous turnover of N occurs through mineralization and immobilization. Soils vary greatly in their N contents. Nitrogen content of the soil decline greatly during continued cultivation. Human activities, particularly fertilizer N use, may enhance biological N fixation and increase mass flow of fixed N. Excessive accumulations of N may bring adverse effects from the global environmental point of view. Therefore, agricultural practices in the future will focus more on conserving energy and minimizing adverse environmental effects arising from the use of N fertilizers. Appropriate N management and fertilizer application should be concerned so as to protect N from leaching and denitrification. Conventional N fertilizer will continue to be used but in a efficient method, and new fertilizers will be developed to achieve a specific release rate with active uptake by the plants.

Nitrogen in organic materials is gradually mineralized after applied to the soil, and part of that plant available N is taken up by crops, immobilized in the SOM pool, or lost in gaseous form or through leaching. Release of a substantial amount of N from medium to low quality organic resources often continues beyond a growth season, potentially resulting in significant residual effects.

Many techniques, such as erosion control, improved irrigation, increased use of legume crops, cover crops, and organic amendments, can be applied to improve the efficiency of N use.

Their effective utilization involves application of systems analysis approaches to farming, and also alters biological activity by changing C/N ratio in the soils. More studies are needed to identify effective amendment to soils in order to reduce N loss, and other techniques will be developed as the social and economic pressure for efficient N management increases.

While several real and potential health and environmental impacts of N exist, agriculture and environmental practices have major effects only on those impacts which involve excess nitrate in drinking water, eutrophication, and perhaps on O_3 depletion (Mahvi et al., 2005; Ju et al., 2007). Seldom researches indicated intelligent risk assessment analyses of these impacts, especially when human health and social goals and values are involved. However, the growing worldwide demands for food will involve a continued increase in the use of fixed N in agriculture. Most of this increase must come from fertilizer. Moreover, the great willing of making a better world with environmental safety tell us the importance in managing N both in agriculture and environmental quality (James et al., 2011, Stevenson, 1982).

CHAPTER 2
ORGANIC AMENDMENT EFFECT ON NITROGEN TRANSFORMATION IN SOILS

Introduction

Nitrogen (N) is a major nutrient element for citrus production. In United States, about 75% of the citrus production comes from Florida and about 28% of Florida citrus acreage is on sandy Entisols along the central Florida ridge (Mattos et al., 2003). In sandy soils, application of N in excess of tree requirements, inadequate placement and timing, or irrigation scheduling may result in leaching of nitrate (NO_3^-) below the root zone (Alva and Tucker, 1999).

For citrus growth, the mineralization of N from soil organic matter, crop residues, composts, and animal manure contribute significantly to the soil mineral-N reserve. The application of organic amendments increases soil nutrients, thus reducing the need for inorganic fertilizers (Bellamy et al.. 1995; Baker, 1997). Moreover, the use of organic amendment is a common practice to improve soil conditions and physical properties, such as water retention capacity, bulk density and soil structure (Entry et al., 1997).

For environmental management of N from organic amendment, factors and processes that affect the extent and rate of conversion of organic N to plant available N or loss to the environment should be accounted for (He et al., 2000). Plant available N is defined as the sum of the mineral N, mainly as initial nitrate nitrogen (NO_3-N) and ammonium nitrogen (NH_4-N) content in soil, plus the organic N mineralized (Gilmour and Skinner, 1999). During the mineralization process, soil microorganisms transform organic N to inorganic forms (NO_3-N and NH_4-N). At the same time, a process of immobilization of inorganic N takes place with the synthesis of proteins by microorganisms (Brady, 1990). This N dynamic system has been described as a mineralization-immobilization turnover (Jansson and Persson, 1982). This turnover can be used to estimate a net mineralization rate or a net immobilization rate under different soil conditions or types. Better description and knowledge on N dynamics can provide a more efficient use of organic and inorganic fertilizers and minimize the N losses.

Different characteristics of the organic materials, soil texture and properties, environmental factors, can influence the rate of N mineralization in soils (Sims, 1995). The C/N ratio of the organic matter is inversely proportional to the net N mineralization (Appel and Mengel, 1990). The optimum C/N ratio has been reported to be between 15 and 40 (Cabrera et al., 2005). For the influence of soil texture, Scott et al. (1996) suggested that small pores protect organic matter from microbial attack whereas large pores facilitate N mineralization.

The soil microbial biomass is another important component of the soil organic matter that regulates the transformation and storage of nutrients (Martens, 1995). K_2SO_4-extractable organic C increased after soil fumigation with chloroform ($CHCl_3$) suggested that a procedure developed for evaluation of biomass C could be used to measure the dynamics of N in soils (Sotta et al., 2007).

The organic amendment used in this study is Hydra-Hume, a commercial product from Helena chemical company. Webb and Biggs (1988) studied the effects of humate-amended soils on the growth of citrus. Humate, a humic acid, implies these substances are acidic, while they actually are colloidal and behave like clays in soil. Humate can be a source of inorganic nutrients that are held by exchange matrices and has a fundamental effect on water holding capacity. However, the effect of this new commercial product to the N dynamics in soil is still unknown. The main aim of this study is to investigate how Hydra-Hume affects N dynamics and determine the decomposition and nutrient release kinetics after the organic amendment is applied to different soils. An incubation experiment was conducted to estimate the N mineralization.

Materials and Methods

Soil Collection and Characterization

Two soils (one Alfisol and one Spodosol) were collected from representative commercial citrus groves in the Indian River area, south Florida. They were selected based on soil properties. For each location triplicate samples were randomly collected at 0-15 cm depth, with 3 soil cores being combined to make a composite sample. After removing plant material and stones, the soil was dried and then sieved (<2 mm). General characteristics of the study sites are presented in Table 2-1 and Figure 2-1.

The soil samples were air-dried, ground, and passed through a 2-mm sieve prior to physical and chemical analyses. Soil pH (1:1 soil: water ratio) and electrical conductivity (1:2 soil: water ratio) were measured in deionized water using a pH/ion/conductivity meter (Denver Instrument, CO). Total soil carbon (C) was determined by combustion using a C/N analyzer (Vario MAX CN Macro Elemental Analyzer; Elemental Analysensystem GmbH, Hanau, Germany).

Incubation Study and Soil N Dynamics Analysis

Portions of soil sample (each 500g oven-dry basis) were weighed into Ziplock plastic bags (28× 26.7 cm, 3.74 L capacity). The pellet organic amendment was ground to pass a 1-mm sieve before it was mixed into the soil. The application rates of organic amendment were: 0, 112, 224, 448, 560 kg ha^{-1} soil, respectively. The mixtures were incubated at 25 °C in after its moisture was adjusted to 70% of its field-water capacity. Water losses were compensated by the addition of distilled water during the experiment. At the intervals of 0, 7, 14, 21 and 28 d, subsamples were taken from the incubation bags and analyzed for pH, electrical conductivity (EC), soil available N and microbial biomass. For each treatment, there were three replications and the experiment was followed completely randomized design, in order to reduce the other influences.

Soil pH was measured in slurry with deionized water and 1 M KCl solution at a solid: solution ratio of 1:1 using a pH/ion/conductivity meter (pH/ Conductivity Meter, Model 220, Denver Instrument, Denver, Co). Electrical conductivity was measured in slurry with deionized water at a solid: water ratio of 1:2 using the same pH/EC meter. Extractable NH_4-N and NO_3-N was determined by shaking a 5 g air-dried sample in 25 ml 2 M KCl for 1 h. Concentrations of NH_4-N and NO_3-N in the filtrate were analyzed with a N/P Discrete Auto-analyzer (EasyChem, Systea Scientific LLC, Oak Brook, IL). The net N mineralized due to the applied organic amendment was calculated by the difference between inorganic N in each treatment and the control soil.

Data Analysis

All data were analyzed using SAS program (version 8.2, SAS Institute, 2004). Differences in the soils with different organic amendment applications were tested by means of a one-way analysis of variance (ANOVA). Significant statistical differences of the mean values of the dependent variables between treatments were established analysed to Tukey's test (P<0.05).

Results and Discussion

Effects of Organic Amendment on Soil pH and EC

The Alfisol is calcareous and contained slightly less available N than the Spodosol (Table 2-1). The Spodosol is acidic in nature, but the pH was raised by liming to close being neutral. Both soils are very sandy, with more than 90% sand, and had low organic matter (<1% organic C). Application of organic amendment slightly increased soil pH initially due to the release of alkaline substances from decomposition of the product (Butterly et al., 2010; Xu et al., 2006). The soil pH decreased with the incubation time, probably due to release of organic acids with further decomposition of the organic matter (Fig. 2-2, Fig. 2-3). In addition, Ca and Mg from the organic amendment can replace hydrogen ion (H^+) on the soil exchange complex, thus decreasing soil solution pH. However, even at the highest application, soil pH was about 7.3 to 7.5, which is suitable for most crops. Fertilizers containing NH_4^+ can induce soil acidification due to nitrification of NH_4^+ to NO_3^-, which produces H^+ (Chien et al., 2010). Therefore, for the treatments with chemical fertilizer, pH decreased more than those receiving Hydra-Hume alone. The pH changes in Spodosol had similar trends.

The sandy soils had a low EC (<500 μS/cm) because of its low holding capacity. Organic amendment addition didn't have a significant influence on soil EC values (Figs.2-4 and 2-5). The soil EC values greatly increased with addition of fertilizer, because of the increased amounts of mineral ions. Even at the highest application rate, the EC values of the amended soil were still below 800 μS/cm, which is a critical level for most crop growth. Therefore, application of Hydra-Hume at the rates <560 kg ha^{-1} should not have any significant negative impact on crop growth based onsoil pH and EC. The EC changes in Spodosol had similar trends.

Effects on N Dynamics in Soils

In the first two weeks, application of organic amendment slightly increased KCl extractable NH_4-N in the Alfisol (Fig. 6). Compared with other organic materials, Hydra-Hume had a relative small N content (1.31%), thus, no significant difference was observed among the different treatments. The increase in NH_4-N is probably attributed to the mineralization of organic amendment and release of NH_4-N from decomposition of organic matter. The concentration of NH_4-N in the third week decreased markedly initially and continued to decrease with time to almost zero for all the treatments. This behavior has been reported in aerobic incubation experiments (Sanchez et al., 1997; Madrid et al., 2001; Burgos et al., 2005). The decrease in NH_4-N was generally accompanied by a corresponding increase in NO_3-N, indicating that the NH_4-N released from the organic amendment mineralization was nitrified into the NO_3-

N (He et al., 2000), as was shown in Figures 2-6 and 2-7. Nitrate contents in the treatments tended to increase until the end of incubation period.

The difference in original C/N ratio between the two soils affected the mineralization rates of organic amendment in the soils. The C/N ratio of Spodosol is 13.58, which is below the critical level for net mineralization process, while the C/N ratio for Hydra-Hume is 42.13 (greater than 30), which may induce net immobilization of mineral N in soil. Therefore, in the first two weeks, application of organic amendment in Spodosol slightly decreased KCl extractable NH_4-N (Fig. 7). With the incubation time, application of organic amendment slightly increased NH_4-N content, due to the mineralization of organic material and release of NH_4-N from decomposition of organic matter. The general trend of NH_4-N change in Spodosol is similar to that in Alfisol.

The organic amendment appeared to have a minimal effect on NO_3-N, as there was no difference in NO_3-N concentration between the amended soil and the control (without amendment) when it was measured on the first day (measured immediately after being mixed). For Alfisol, treatments with only Hydra-Hume tended to decrease NO_3-N content in the first two weeks at an application rate of 224 kg ha^{-1} and above, because of net immobilization induced by addition of Hydra-Hume (Fig. 8). However, when the soil was amended with fertilizer and Hydra-Hume, the additional mineral N from fertilizer may promote mineralization, thus offsetting the effects of organic amendment, while the control still had the highest NO_3-N contents, indicating a net immobilization during the incubation period (Fig. 9). The difference of soil C/N ratio itself may have impacts on N dynamics in soils. For Spodosol, application of Hydra-Hume only markedly decrease NO_3-N contents, while when amended with Hydra-Hume together with chemical fertilizer, a net mineralization process occurred. Statistical analyses are listed in Tables 2-2 and 2-3.

Conclusion

Application of Hydra-Hume, an organic amendment with a C/N ratio around 42.13, induced immobilization when applied alone in both of the test soils. For Alfisol, the immobilization process only occurred in the first two weeks with the application rates of Hydra-Hume of 224 kg ha^{-1} or above. Soil original properties have an effect on N dynamics. The difference of C/N ratios in the two soils determined the different N dynamic trends when fertilizer and organic amendment applied together. The N dynamics in Alfisol, which had the C/N ratio around 22, showed a net immobilization, while in Spodosol, there was a net mineralization curve instead.

Figure 2-1. Sampling site

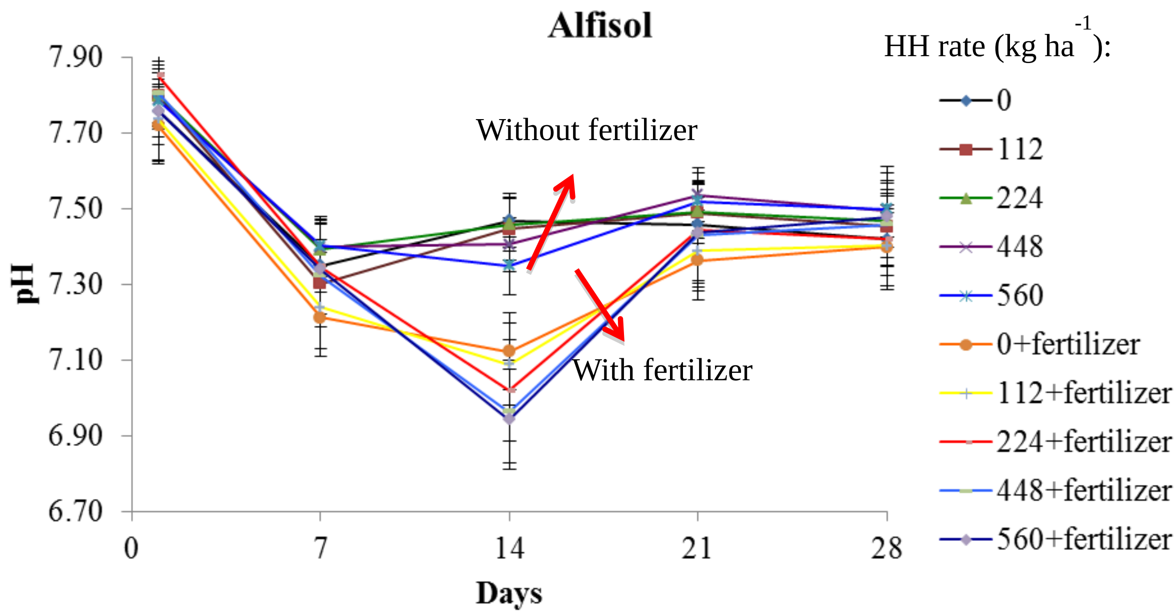

Figure 2-2. Effect of organic amendment on Alfisol pH as a function of incubation time

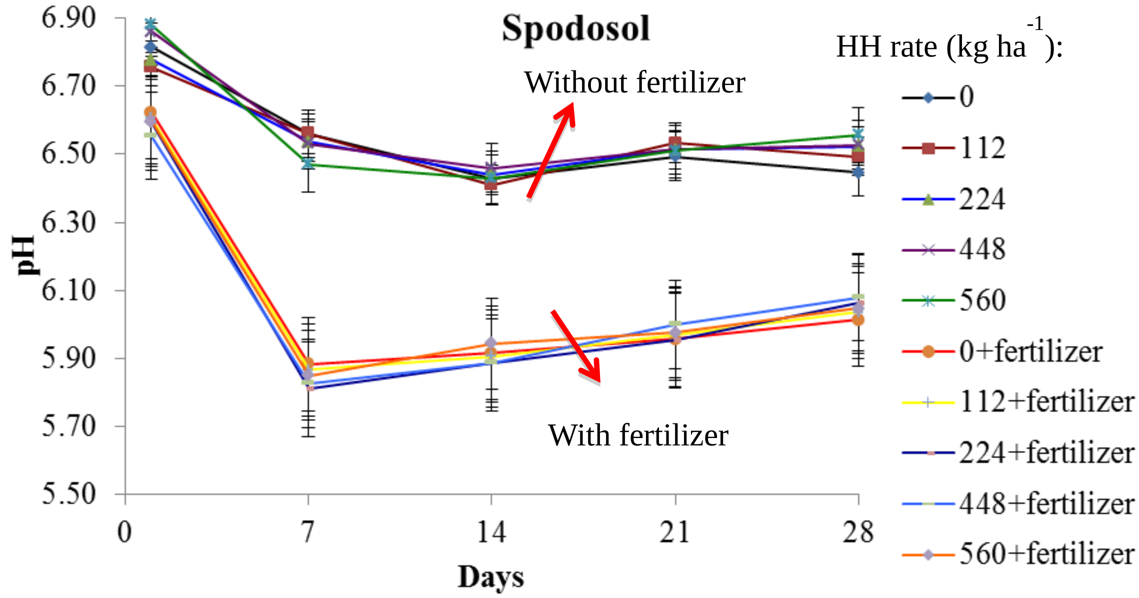

Figure 2-3. Effect of organic amendment on Spodosol pH as a function of incubation time

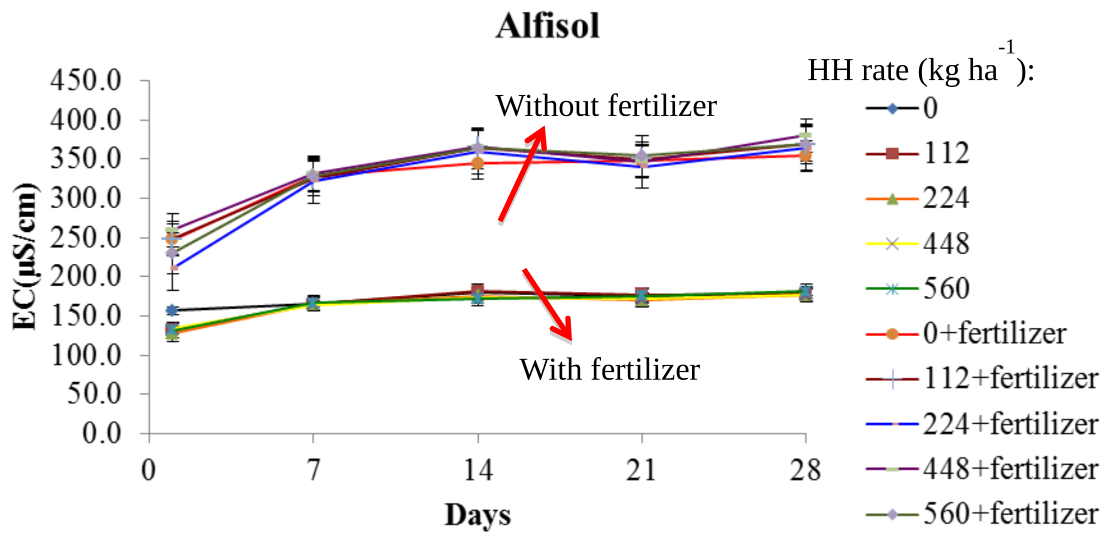

Figure 2-4. Effect of organic amendment on Alfisol Electrical conductivity (EC) as a function of incubation time

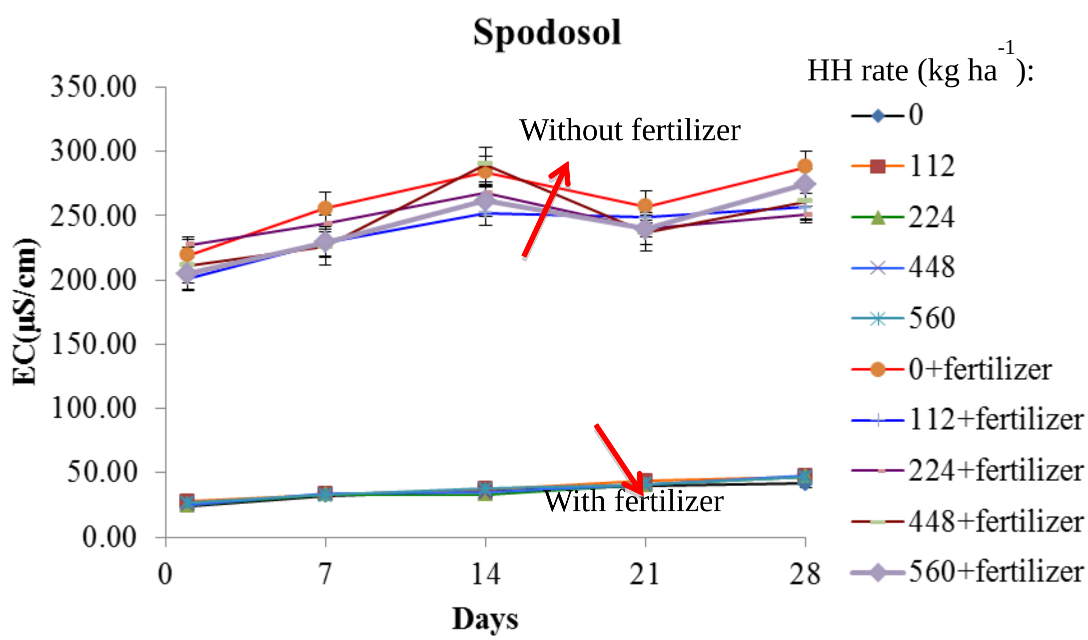

Figure 2-5. Effect of organic amendment on Spodosol electrical conductivity (EC) as a function of incubation time

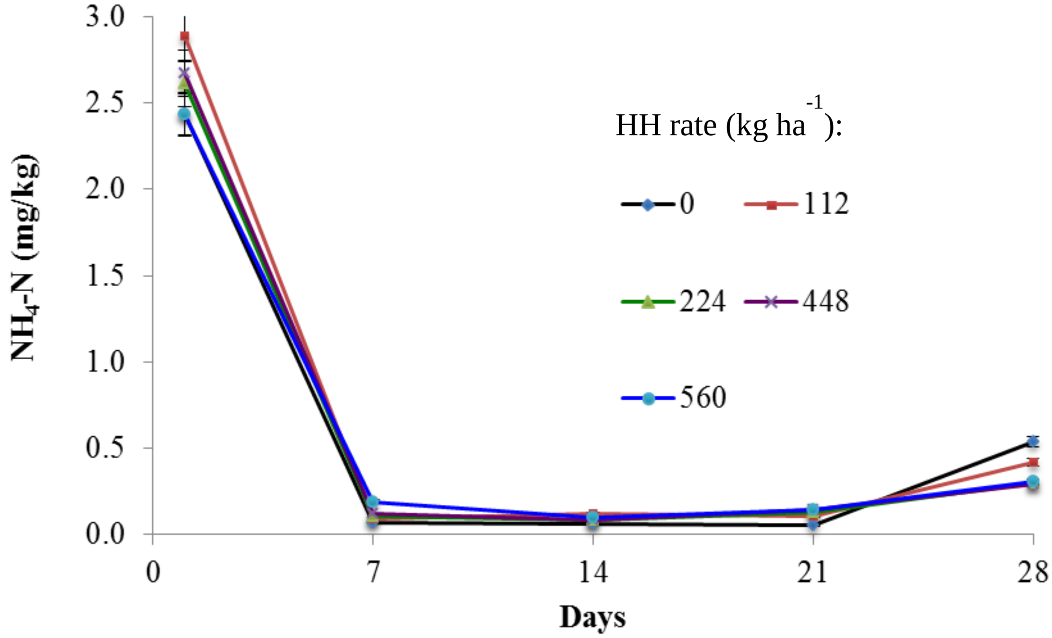

Figure 2-6. Effect of organic amendment on KCl-extractable NH$_4$-N in Alfisol

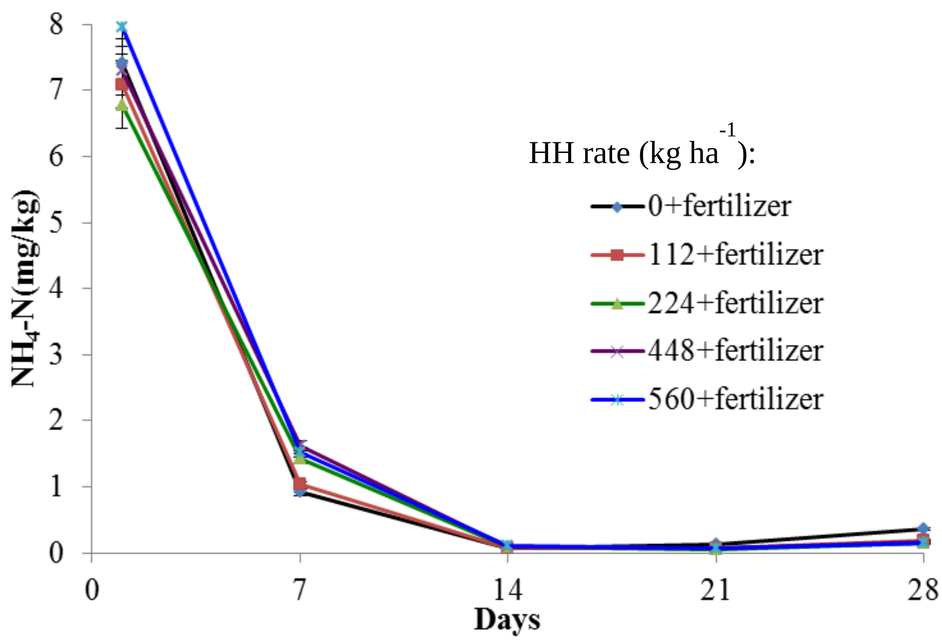

Figure 2-7. Effect of organic amendment and fertilizer on KCl-extractable NH$_4$-N in Spodosol

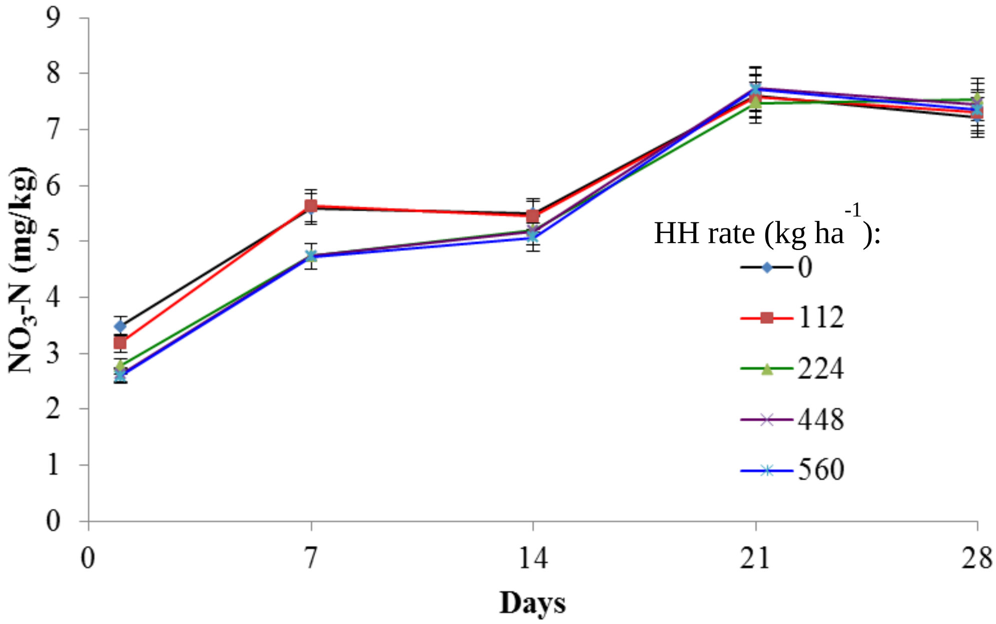

Figure 2-8. Effect of organic amendment on KCl-extractable NO_3-N in Alfisol

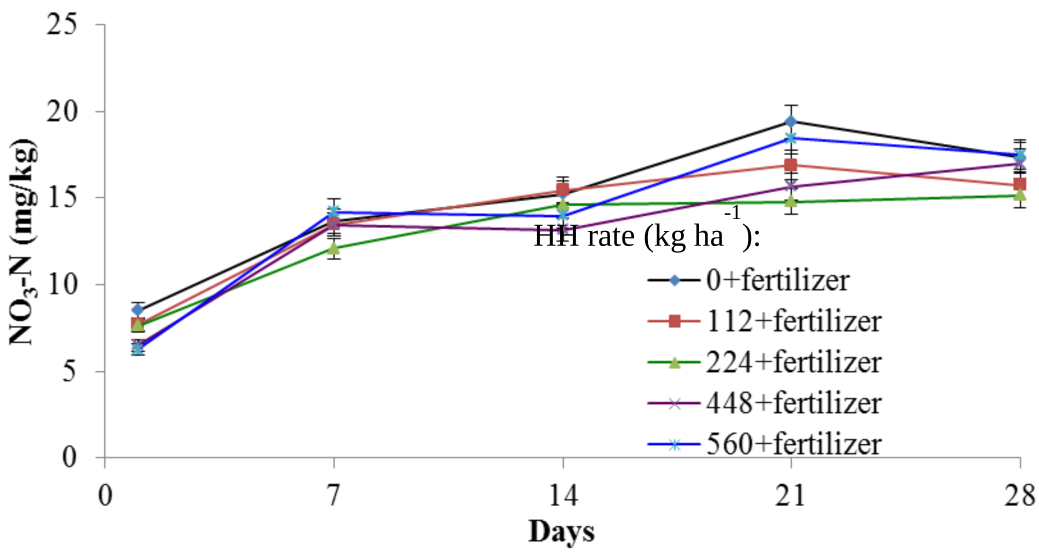

Figure 2-9. Effect of organic amendment and fertilizer on KCl-extractable NO_3-N in Spodosol soil.

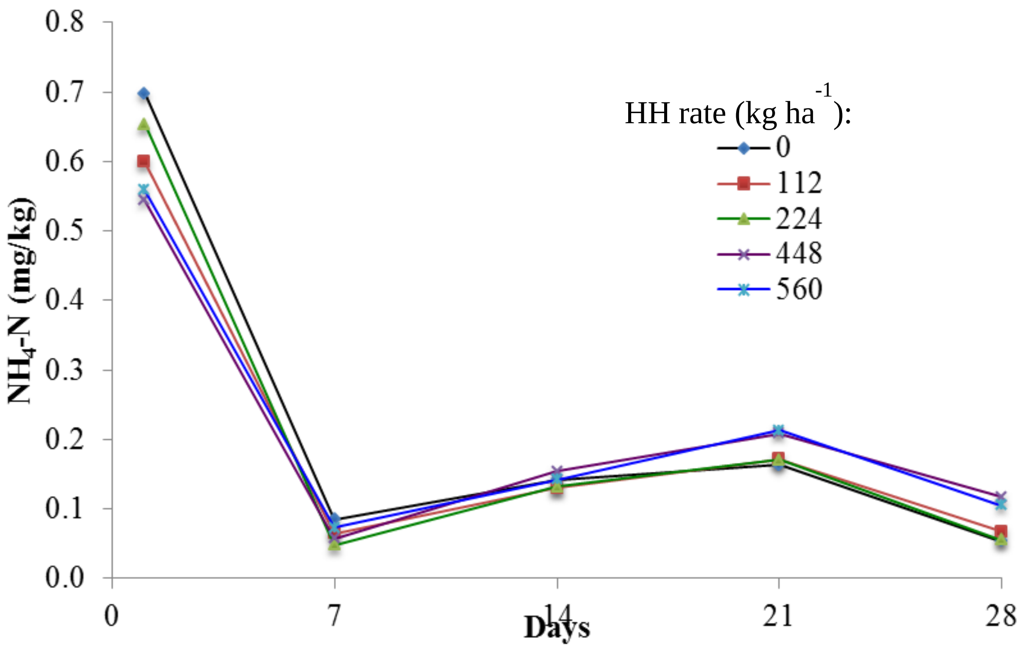

Figure 2-10. Effect of organic amendment on KCl-extractable NH_4-N in Spodosol

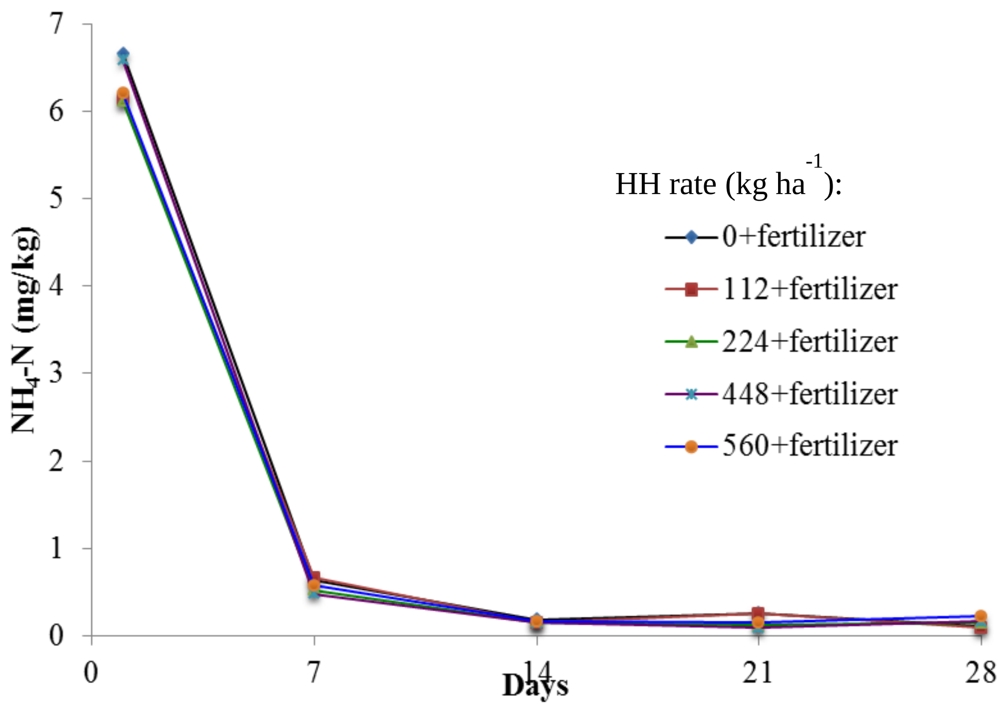

Figure 2-11. Effect of organic amendment and fertilizer on KCl-extractable NH_4-N in Spodosol

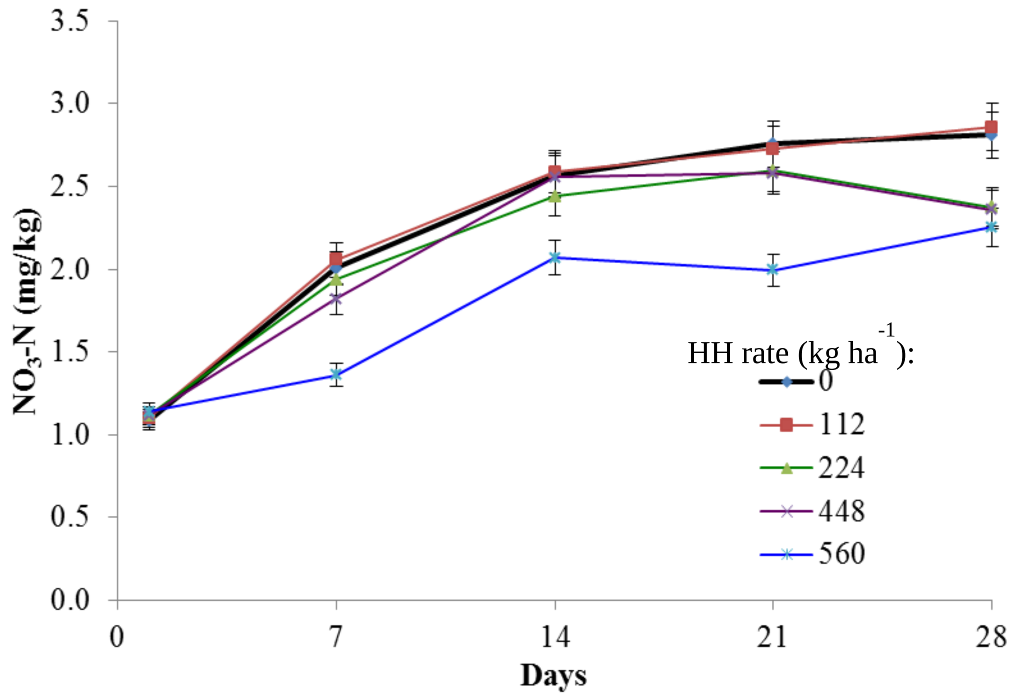

Figure 2-12. Effect of organic amendment on KCl-extractable NO_3-N in Spodosol

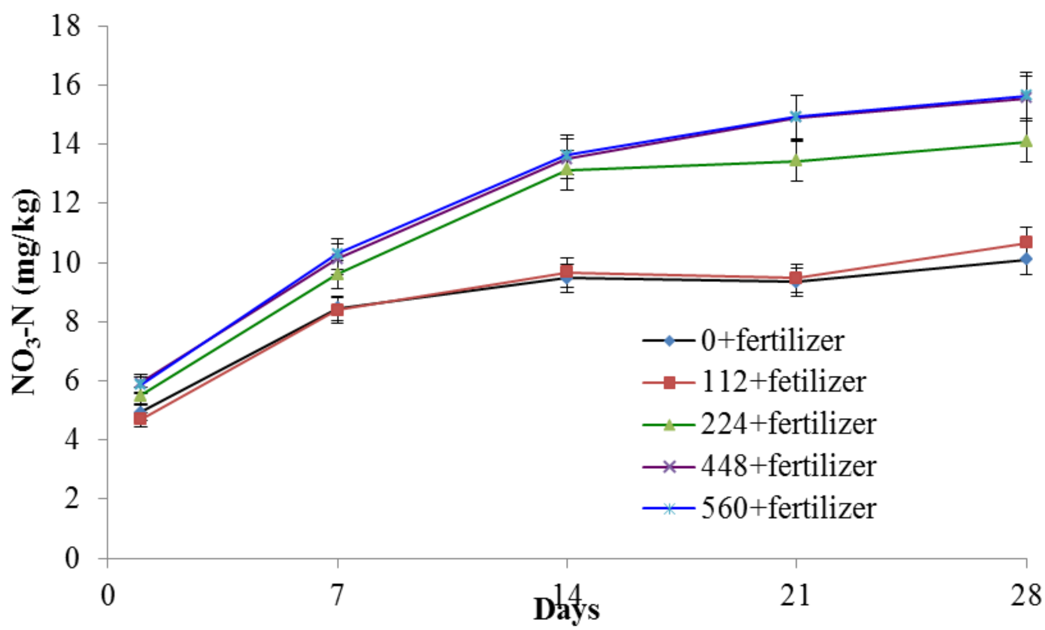

Figure 2-13. Effect of organic amendment and fertilizer on KCl-extractable NO_3-N in Spodosol

Table 2-1. General properties of the two soils and Hydra-Hume

Properties/ Soil type	**Alfisol (Sandy,siliceous,hyperthermic,Arenic Glossaqualf)**	**Spodosol (Sandy,siliceous, Hyperthermic, Alfic Alaquods)**
Cropping history	Citrus	Citrus
Soil texture (g/kg)	Sand 908, Silt 42.8, clay 9.6	Sand 902,silt 53,clay 45
pH (H_20)	7.8	6.8
Electrical conductivity (µS/cm)	150.9	61.59
Organic C (g/kg)	1.03	2.68
Total N (g/kg)	0.05	0.2
C/N ratio	22.05	13.58

Table 2-2. General properties of the Hydra-Hume

Properties	pH	EC	N%	C%	C/N ratio
Hydra-Hume	2.83	2977	1.31	54.98	42.13

Table 2-3. Statistical analysis of KCl extractable NH_4-N in Alfisol

		KCl extractable NH_4-N (mg kg^{-1}) in Alfisol									
		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	112	224	448	560	0	112	224	448	560
Sampling time (Day)	0	2.43	2.41	2.44	2.3	2.43	7.41	7.09	6.77	7.3	7.95
	7	0.06 b	0.08b	0.10a b	0.11a b	0.19 a	0.91 b	1.03a b	1.42 a	1.62 a	1.51 a
	14	0.1	0.1	0.06	0.1	0.09	0.07	0.08	0.08	0.09	0.1
	21	0.05 b	0.11a b	0.13a	0.14a	0.14 a	0.13	0.05	0.04	0.07	0.06
	28	0.53 a	0..42 b	0.30c	0.30c	0.29 c	0.36 a	0.38a	0.14 b	0.16 b	0.14 b

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 2-4. Statistical analysis of KCl extractable NO_3-N in Alfisol

		KCl extractable NO_3-N in Alfisol									
		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	112	224	448	560	0	112	224	448	560
Sampling time (Day)	0	3.47	3.18	2.76	2.61	2.58	8.07 ab	8.35a	7.72 ab	7.72 ab	6.70 b
	7	5.58 a	5.63 a	4.73 b	4.73 b	4.73 b	13.66 a	14.00 a	12.09 b	13.47 a	14.21 a
	14	5.49	5.44	5.19	5.18	5.06	16.18	18.75	19.36	13.18	16.69
	21	7.61	7.57	7.47	7.73	7.07	18.75 a	16.89 ab	14.77 b	16.63 ab	17.69 ab
	28	7.21	7.29	6.53	7.44	7.34	16.90	15.74	15.17	17.01	17.51

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 2-5. Statistical analysis of KCl extractable NO_3-N in Spodosol

KCl extractable NO_3-N in Spodosol											
		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	112	224	448	560	0	112	224	448	560
Sampling time (Day)	0	1.08	1.09	1.11	1.23	1.13	4.92 ab	4.68 b	5.20 ab	5.92a	5.85a
	7	2.00 ab	2.05 a	1.93 ab	1.75 ab	1.29 b	8.44b	8.38b	9.59a	10.11 a	10.29 a
	14	2.56 ab	2.68 a	2.43 ab	2.31 ab	2.00 b	9.48b	9.75b	13.98 a	15.51 a	13.63 a
	21	2.75 a	2.72 a	2.59 a	2.43 ab	1.93 b	12.76 ab	9.47b	13.43 ab	14.96 a	14.92 a
	28	2.81 a	2.85 a	2.37 b	2.35 b	2.25 c	9.8b	10.11 b	14.09 a	15.54 a	15.65 a

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

CHAPTER 3
ORGANIC AMENDMENT EFFECTS ON NITROGEN LEACHING

Introduction

Nitrogen (N) is a nutrient often associated with accelerated eutrophication of surface waters. It is estimated that each year, more than 1,000,000 kg N is transported to the St. Lucie Estuary (SLE) (St. Lucie River Issue Team Interim Report, 1998) and the resultant increased nutrient loads have been suspected to cause declining water quality and decreased grass coverage of the SLE and Indian River Lagoon (IRL). In South Florida, high temperature and the sandy nature of soils provide favorable conditions for rapid mineralization of organic materials. As soils in this area have a coarse texture (sand content often >90%) and a relative low nutrient retention capacity, citrus trees cultivated on these soils receive high rates of fertilizer application, which could increase the potential risk of nitrate pollution to groundwater (He et al., 1999). Martin et al. (1994) reported that light-textured soils and intensive production of crops under irrigated conditions could lead to considerable nitrate losses by leaching.

Soil amendments can improve soil quality by neutralizing soil acidity and increasing soil's holding capacity for nutrients and moisture and is, therefore, a very promising approach to reduce loads of nutrients and metals in surface runoff. Environmental management of N from organic amendment requires an understanding of the factors and processes that influence the extent and rate of conversion of organic N to forms plant available N or loss to the environment (He et al., 2000).

In Chapter 2, it mentioned that the influence of soil texture on N mineralization is related to clay content (Breland and Hansen, 1996). Small pore spaces protect organic matter from microbial attack whereas large pores facilitate N mineralization. Moreover, other soil characteristics, such as heavy metal content and salinity, may also affect organic material decomposition and N mineralization.

For soil quality, microbial biomass is an important indicator (Elliott et al., 1996). Organic C from the organic material may enhance the growth of microorganism, thus increasing microbial biomass. In Florida, many soils are extremely sandy with low adsorption capacity for ions; therefore, microbial biomass can be a sensitive indicator to the change of N dynamics in soils.

The major objectives of this study were to 1) investigate the effect of organic amendment on N leaching in soils, 2) evaluate the effect of organic amendment on N availability in soil and 3) assess potential environmental risk of heavy metals from the soil amended with Hydra-Hume.

Materials and Methods

The tested organic amendment is Hydra-Hume, provided by Helena chemical Company, a commercial product showing potential for improving citrus growth in South Florida. However, its effectiveness for reducing fertilizer N loss is not well documented.

The soils used in this leaching study were collected from a representative commercial citrus grove (citrus) and a vegetable farm (vegetable). One is Alfisol and the other is Spodosol, representing two major soil types for citrus and vegetable production in the Indian River area. The relevant properties of the tested soils are listed in Table 2-1.

The organic amendment was ground to pass a 1-mm sieve before it was mixed into the soil. Organic amendment was applied at the rates: 0, 22.4, 44.8, 89.6, 112 kg ha^{-1} soil, respectively. Fertilizer was applied at a rate of 168 N kg ha^{-1} (N-P_2O_5-K_2O=12-4-15). The soil samples receiving no organic amendment or inorganic fertilizer were used as the control. Plexiglas leaching columns (30.5cm long, 6.6cm inner diameter), with several 5mm diameter holes at the bottom were used (Fig. 1). About 1.5 kg soil was packed into each column to the bulk density of approximately 1.45 mg cm^{-3} with amendment mixed in the top of the soil column. There are three replications for each treatment. The soil columns were saturated with deionized water for three days to allow soil compact naturally and equilibrium of chemical and biological reactions prior to leaching. Leaching was conducted at 1, 3, 7, 14, 28, 42 day, 302 ml of deionized water being leached for each column per leaching event, which is based on half year's rainfall in South Florida. The deionized water was applied using a peristaltic pump and the leachates were then collected from each leaching event and analyzed for pH, electrical conductivity (EC), NH_4-N, NO_3-N and metals. At the end of leaching, the soils were removed from the column and subsamples were taken after through mixture, air-dried, and measured for pH, EC, available N, Mehlich III extractable metals and microbial biomass.

Leachate pH and EC were measured using a pH/ion/conductivity meter (pH. Conductivity Meter, Model 220, Denver Instrument, Denver, Co). Available N (NH_4-N, NO_3-N) was analyzed using a N/P Discrete Autoanalyzer (EasyChem, Systea Scientific LLC, Oak Brook, IL). Available metals were determined using an inductively coupled plasma optical emission spectrometry (ICP-OES, Ultima, JY Horiba, Edison, NJ).

Electrical conductivity and pH of soils after leaching were measured in slurry with deionized water at a soil: water ratio of 1:1 and 1:2, respectively, using a pH/ion/conductivity meter. Available N (NH_4-N, NO_3-N) was determined by shaking a 2.5 g air-dried sample in 25 ml 2M KCl for 1h and the concentrations of NH_4-N and NO_3-N in the filtrate were analyzed with a N/P Discrete Autoanalyzer. Available metals were determined by extracting the samples with Mehlich III solution (Mehlich, 1984), and measuring the metal concentrations using the ICPAES, following EPA method 200.7 (EPA, 1998).

Results and Discussion

Effects of Organic Amendment on Soil pH and EC

Incorporation with chemical fertilizer decreased leachate pH for both soils, result from the nitrification of added NH_4-N (Fig. 3-2). Organic amendment generally increased leachate pH of the Spodosol for the first three leaching events, as compared with the control (Fig. 3-2), whereas the difference diminished and all leachate pH tended to approach 7.4 with increasing leaching events. The decrease in leachate pH by soil amendment with increasing leaching events was attributed to organic acids released from the decomposition of the organic matter during the leaching process (Fig. 3-2). In addition, Ca and Mg from the organic amendment can replace H^+ on the soil exchange complex, and thus decreasing soil leachate pH. However, relatively stable leachate pH with leaching times was observed in the Alfisol because of its calcareous nature. With increasing organic amendment rates, pH of Spodosol increased, whereas that of Alfisol slightly decreased after six leaching events (Fig. 3-3), probably due to their different mechanisms affecting soil pH.

Low EC values (<500 μS/cm) of leachates from Spodosol were measured due to its low holding capacity and low salts (Fig. 3-4). The EC of leachates from Alfisol was higher as compared to the Spodosol, indicating higher salts contained in the Alfisol (Fig. 3-5). However, there's no apparent difference between the control and treatments with organic amendment only. Application of chemical fertilizer increased leachate EC in both soils (Figs. 3-4 and 3-5). Obviously, fertilizer contributed to EC or salt concentration in the amended soils. In the first two leaching events, leachate from both soils amended with Hydra-Hume and fertilizer had lower EC than the controls, implying that less mineral ions was leached from the soils amended with fertilizer and organic amendment. This behavior probably resulted from the retention of salts by the organic materials, which agreed with the results obtained in the incubation experiments in which processes of nitrate immobilization were observed.

Effect on N Leaching and Soil N Pool

The volume of leached water was very similar and independent of the treatments. However, the concentration of nitrate in the leachate varied depending on the treatments. Application of organic amendment tended to increase NH_4-N concentration in leachates, indicating that mineralization of organic material in the amendment may have contributed to soil NH_4-N, which is subjected to leaching. Leachate NH_4-N concentrations decreased drastically in both soils in the first four leaching events and reached almost zero after the sixth leaching event (Figs. 3-6, 3-10). The decreased concentration of NH_4-N in leachates with time or leaching events may be related to depletion of NH_4-N because of nitrification to NO_3-N and microbial incorporation into organic fractions. Lower NH_4-N concentrations were observed in leachate from the Alfisol than the Spodosol, probably due to lower available N and organic matter in the former than in the latter (Table 2-1). Similarly, the total amount of NH_4-N recovered in leachates was much less for the Alfisol than the Spodosol, while same trend and conclusion can be drawn from Alfisol.

Nitrate leaching from soils amended with organic material depends on the nature of material, the applied dose, the time of application, the quantity of water applied as well as the type of soil (Burgos et al., 2006). Compared with the control, application of organic amendments drastically decreased NO_3-N concentration in leachates in the first leaching event (Fig. 3-8). The mechanisms of NO_3-N leaching reduction by organic amendment is likely related to the enhanced microbial transformation of NO_3-N into organic N such as microbial biomass N, with the increased input of organic C. Leachate NO_3-N concentrations decreased rapidly with increasing leaching events and were below 10 mg L^{-1} regardless of treatments. Since most of

NO_3-N in the soils was leached in the first two leaching events, application of organic amendment appeared to be effective in reducing NO_3-N in sandy soils (Fig. 3-8). A significant difference in the total amount of NO_3-N from the six leaching events occurred between the control and the treatments amended with Hydra-Hume, when the application rate of Hydra-Hume reached 44.8 or above (Table 3-1). When fertilizer was incorporated, NO_3-N contents increased at the beginning, but decreased in the subsequent leaching events, particularly for the soil amended with Hydra-Hume, as compared with the control, indicating the potential of organic material in reducing NO_3-N leaching in soils (Fig. 3-9). An application rate of 44.8 kg ha^{-1} or above is required for Hydra-Hume to accomplish a significant reduction in NO_3-N leaching from the soils (Table 3-2). In addition, total mineral N (NO_3-N and NH_4-N) was calculated to understand the N pool in the amended soils. No significant difference in total amount of mineral N was observed between the control and treatments amended with Hydra-Hume only, whereas a significant reduction of total mineral N in leachate was obtained for the fertilized soils when the application rate of Hydra-Hume reached 44.8 kg ha^{-1} in the Spodosol and 22.4 kg ha^{-1} in the Alfisol.

In general, organic amendment was effective in reducing N leaching in sandy soils when it was applied at 44.8 kg ha^{-1} in Spodosol and 22.4 kg ha^{-1} in Alfisol with fertilizer. Significant reduction in total NO_3-N amount was observed when organic amendment was applied only at the application rate of 44.8 kg ha^{-1} or above. Moreover, leachates from the Alfisol had a lower NO_3-N concentration than from the Spodosol (Tables 3-4 and 3-5).

Potential Effects on Heavy Metals

Trace metals, such as Cu, Cd, Co, Cr, Ni and Pb, are usually present at very low concentrations in soils, but are toxic to plants and soil microorganisms if at a high concentration. Controlling the input of toxicants is crucial for sustainable agriculture. Therefore, a critical evaluation for concentrations and potential toxicants in organic amendment was carried and statistical analyses were calculated between control and the treatments. The amounts of extractable heavy metals (Cd, Co, Cr, Ni, Pb, Zn) were not affected by the amendment, mainly because of their extremely low concentrations (Tables 3-3, 3-6). The application of organic amendment does not increase bioavailability of heavy metals in soil or transport of these elements from soil to the environment.

Characterization of Leached Soil

With increasing organic amendment rates, pH of Spodosol amended with Hydra-Hume alone decreased slightly, but increased slightly for the fertilized soil (Fig. 3-14). However, the changes were small (within 0.2 pH units), indicating that this organic material has a limited influence on soil pH.

Compared with leachates, soil EC after the leaching was much lower (<200 μS cm^{-1}), although it had different trends with or without fertilizer (Fig. 3-15). The difference between treatments narrowed gradually with increasing leaching events (Figs. 3-14 and 3-15).

No significant difference in trace metals occurred between treatments, indicating that there was a minimal influence on the transport of heavy metals from the organic material or fertilizer to the environment.

Conclusion

In this chapter, column leaching was conducted to examine the effects of Hydra-Hume on the transformation dynamics and leaching potential of mineral N in the Alfisol and Spodosol. The obtained results indicate that significant reduction in total NO_3-N amount can be obtained when Hydra-Hume applied alone in both of the soils, but a minimal application rate of 44.8 kg ha^{-1} is required. If fertilizer is incorporated with organic amendment, significant reduction of total NO_3-N amount and total mineral N amount can be achieved at a minimal application rate of

44.8 kg ha^{-1} for the Spodosol and 22.4 kg ha^{-1} for the Alfisol soil. The influence of organic amendment on the leaching of heavy metals from the soils appears to be insignificant.

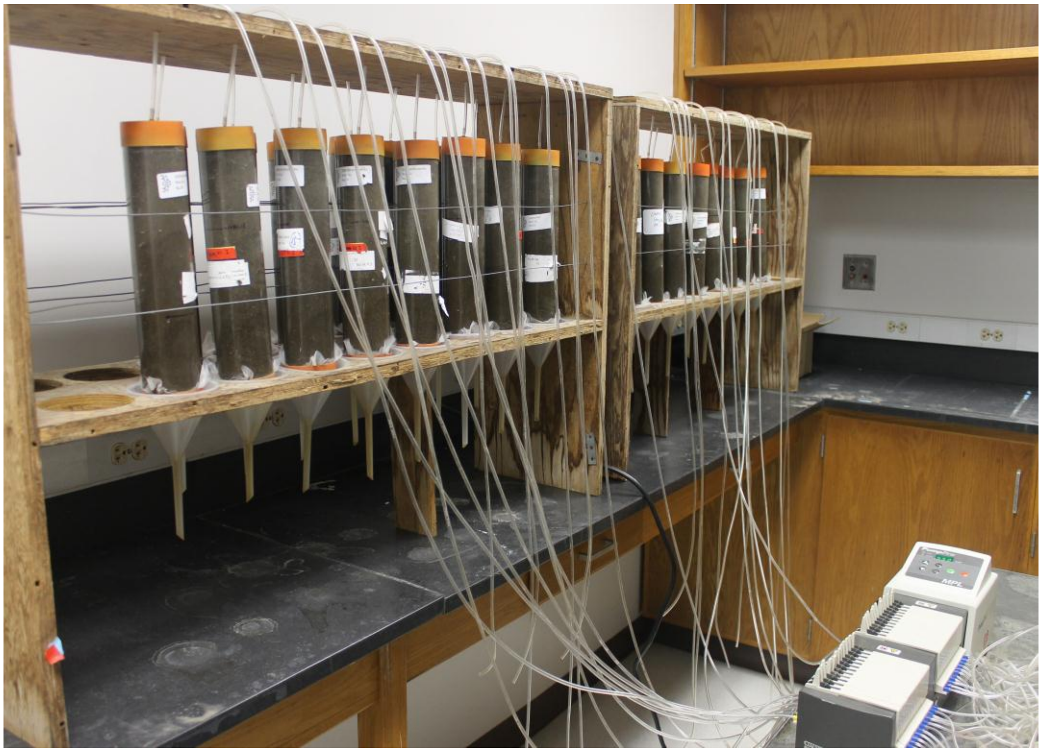

Figure 3-1. Column leaching setup

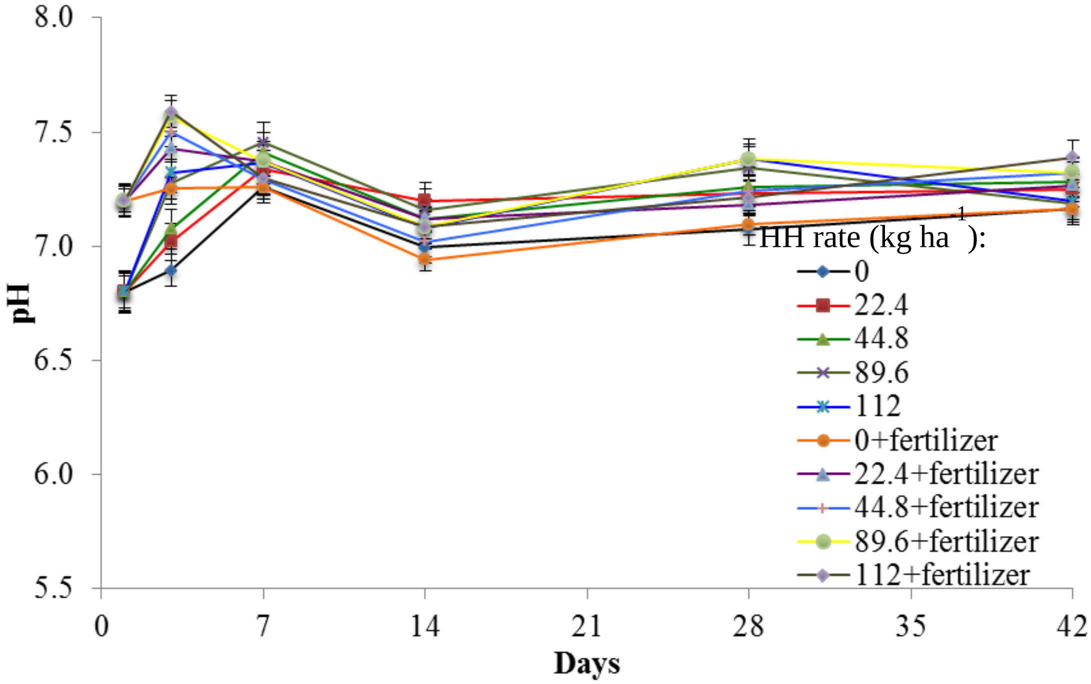

Figure 3-2. pH of leachate form Spodosol amended with fertilizer and different rates of Hydra-Hume

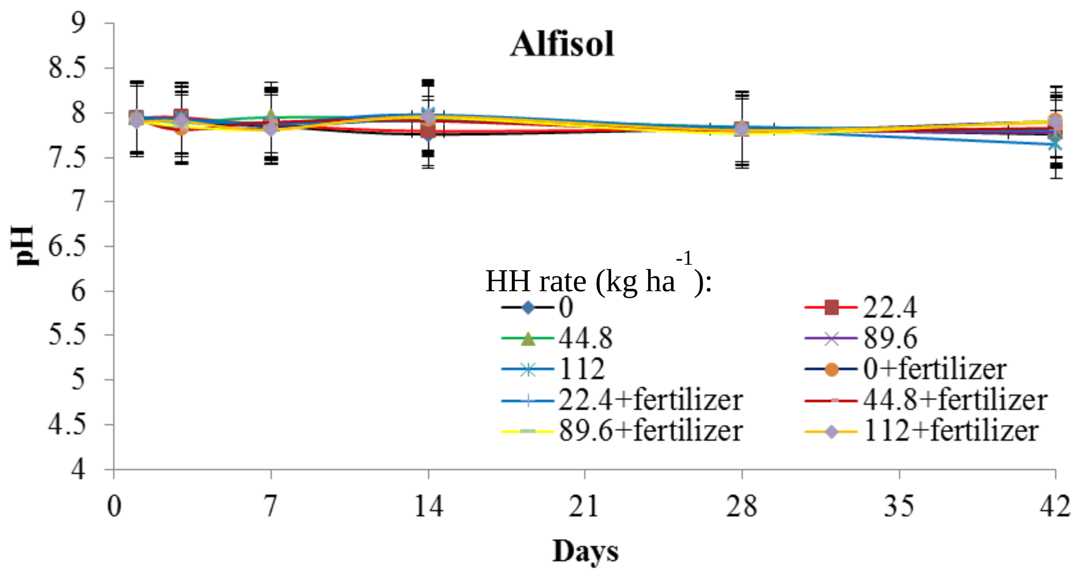

Figure 3-3. pH of leachate form Alfisol amended with fertilizer and different rates of Hydra-Hume

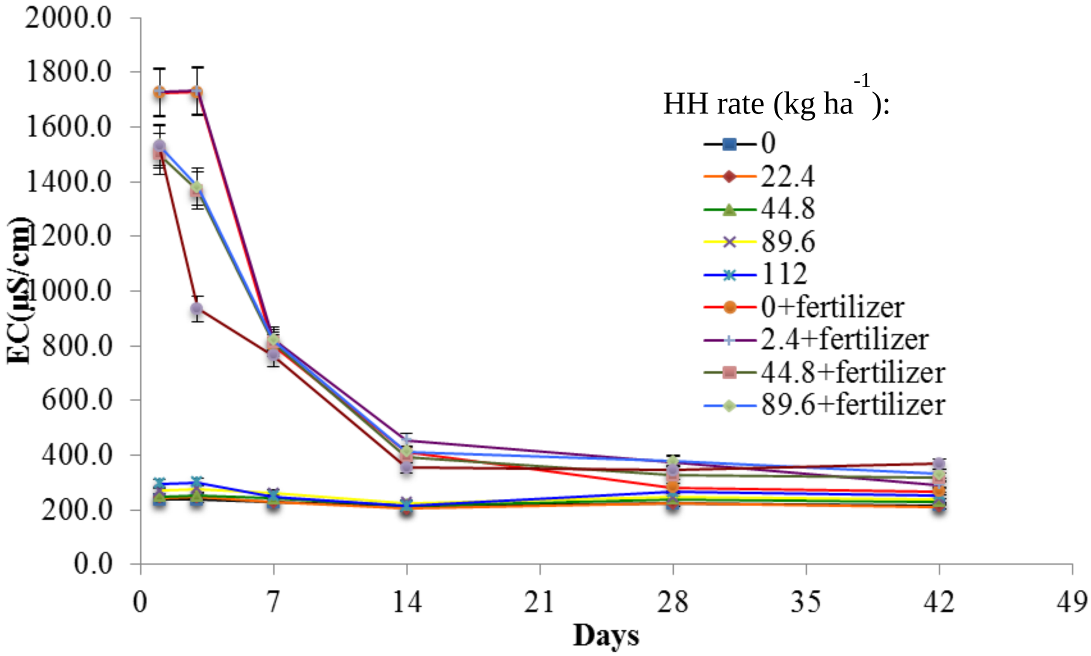

Figure 3-4. Leachate EC form Spodosol in relation to fertilizer and different rates of Hydra-Hume

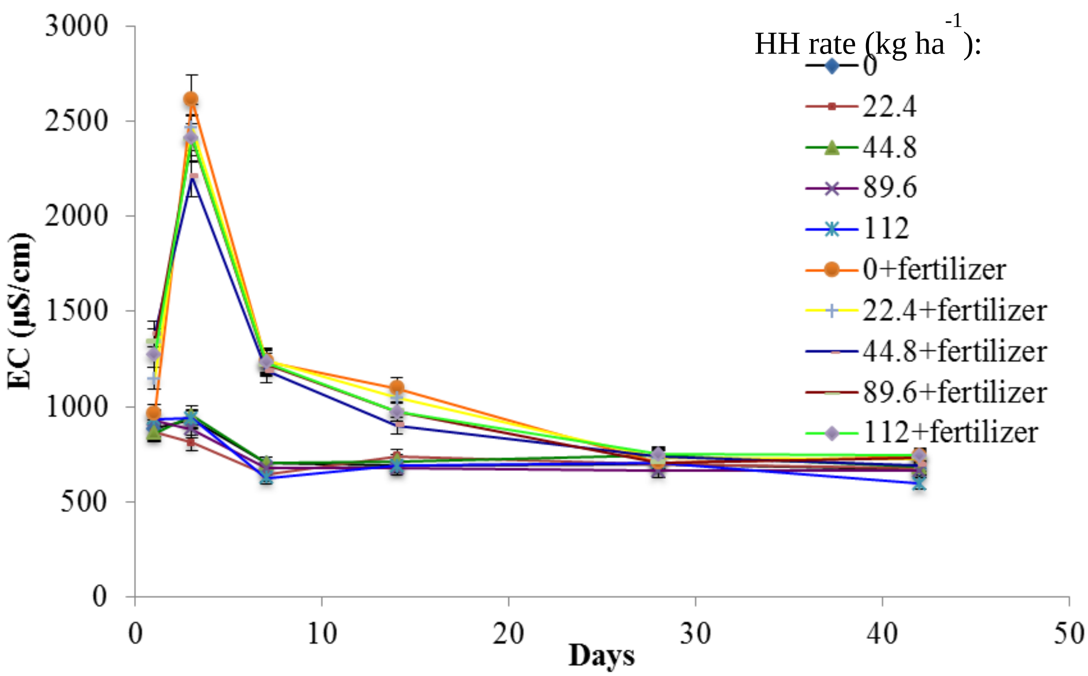

Figure 3-5. Leachate EC form Alfisol in relation to fertilizer and different rates of Hydra-Hume

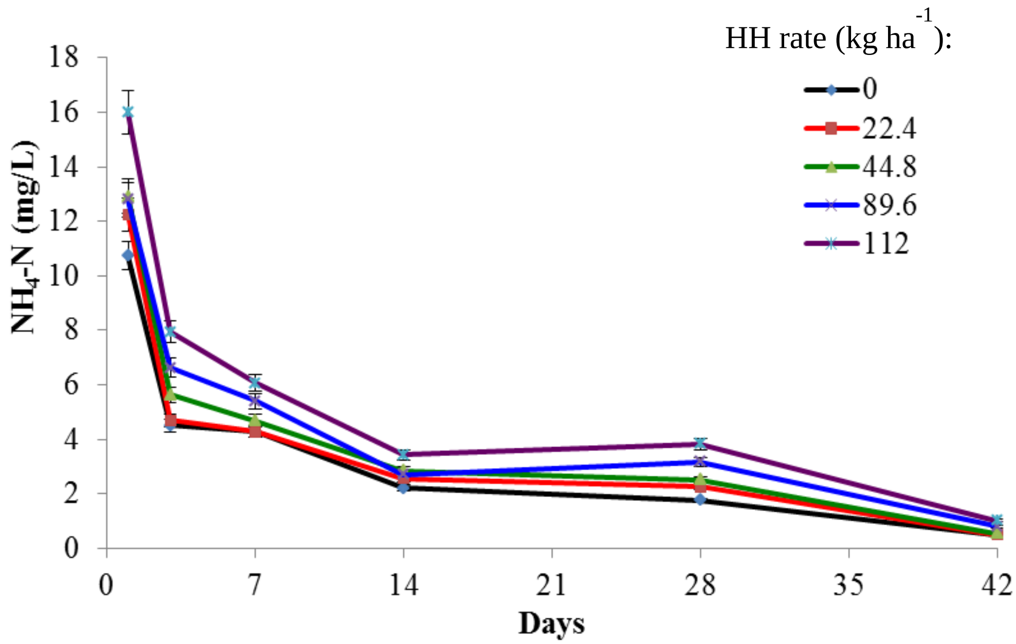

Figure 3-6. Leachate NH_4-N concentration from Spodosol in relation to different rates of Hydra-Hume alone

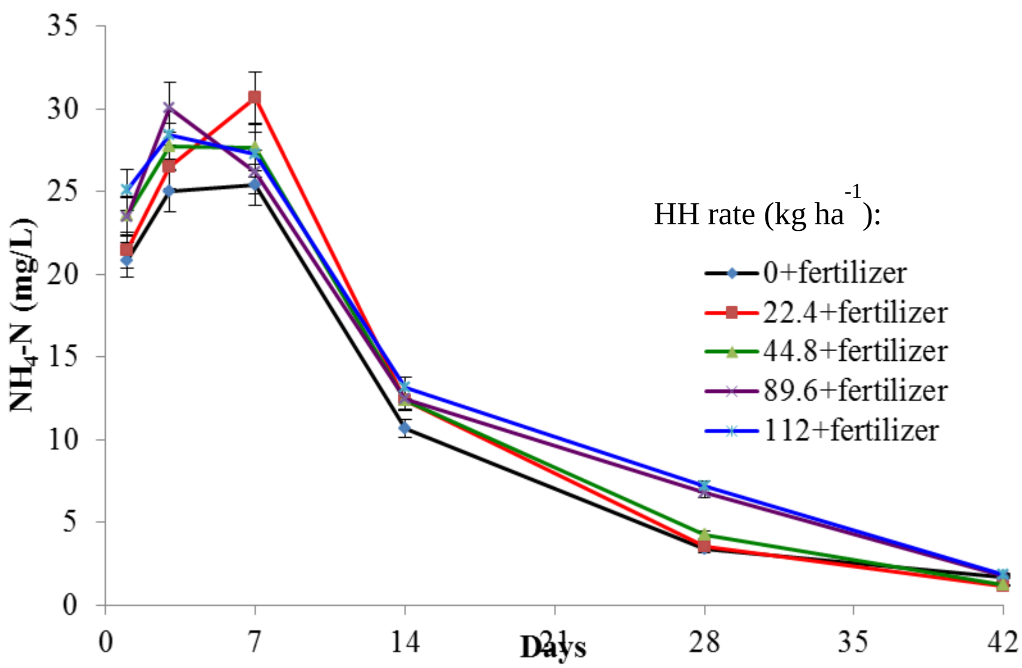

Figure 3-7. Leachate NH_4-N concentration from Spodosol in relation to fertilizer and different rates of Hydra-Hume

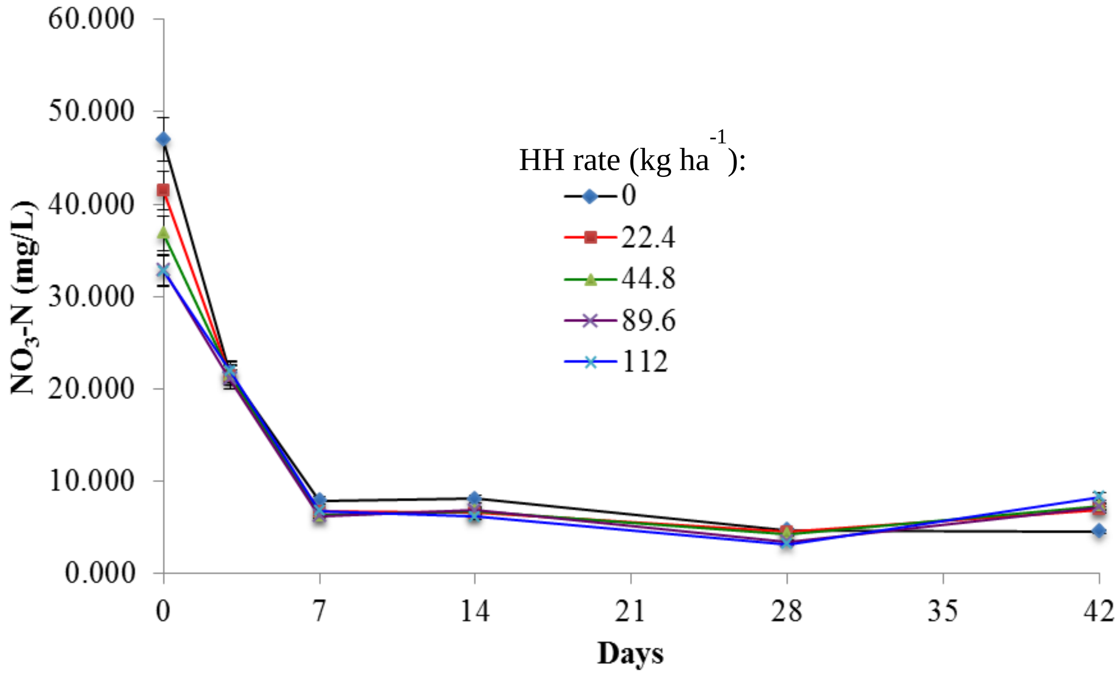

Figure 3-8. Leachate NO_3-N concentration from Spodosol in relation to different rates of Hydra-Hume alone

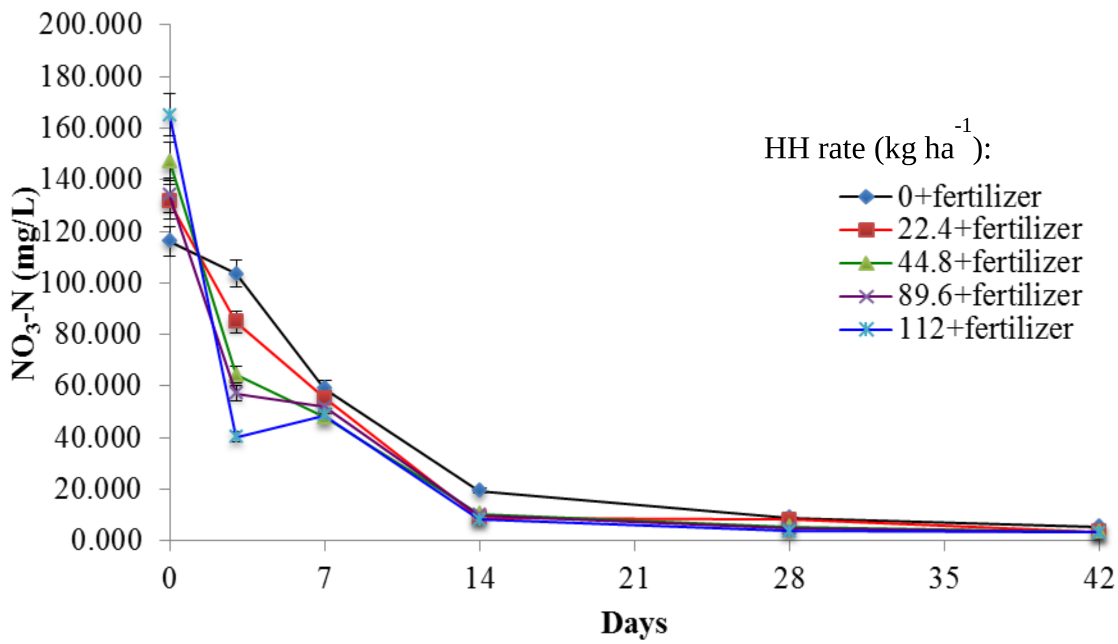

Figure 3-9. Leachate NO_3-N concentration from Spodosol in relation to fertilizer and different rates of Hydra-Hume

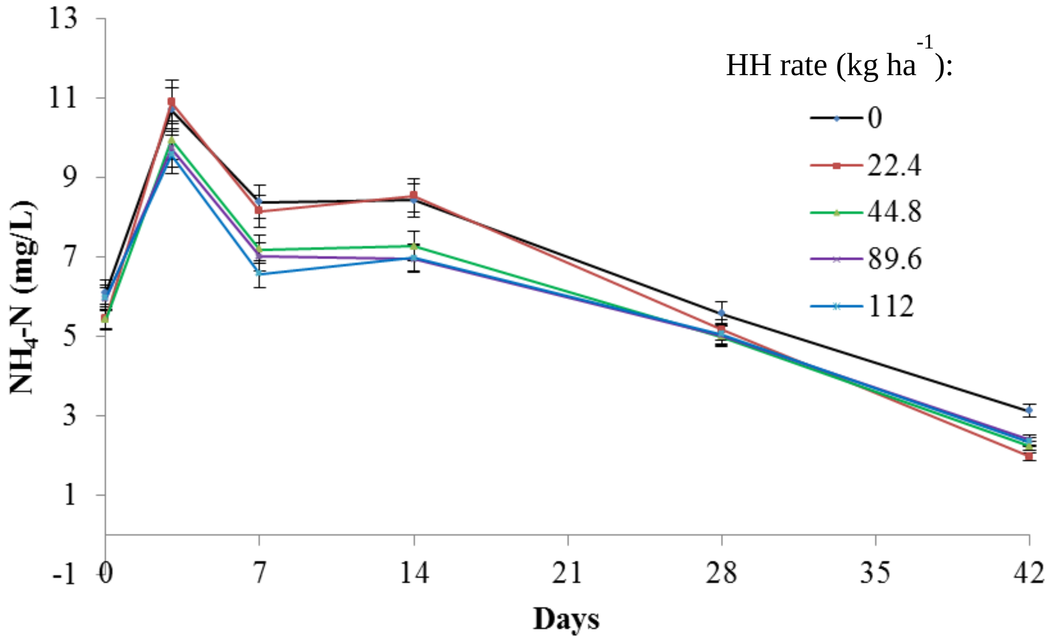

Figure 3-10. Leachate NH_4-N concentration from Alfisol in relation to different rates of Hydra-Hume alone

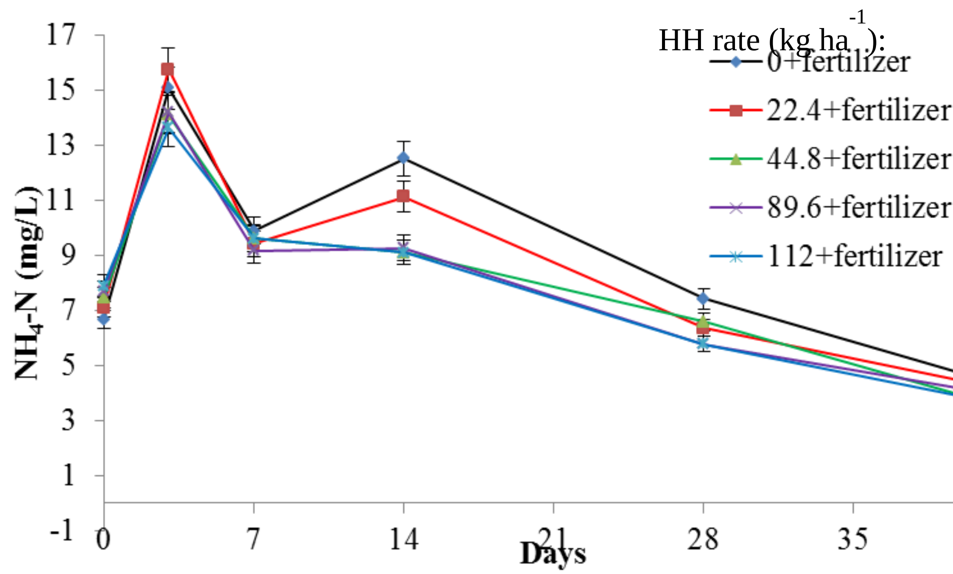

Figure 3-11. Leachate NH_4-N concentration from Alfisol in relation to fertilizer and different rates of Hydar-Hume

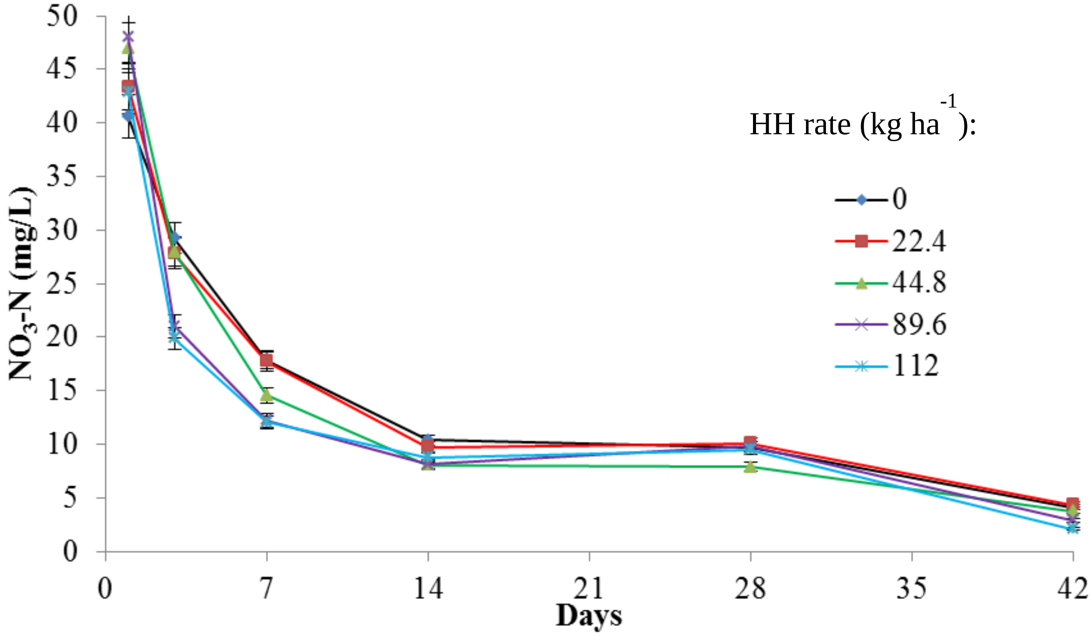

Figure 3-12. Leachate NO_3-N concentration from Alfisol in relation to different rates of Hydra-Hume alone

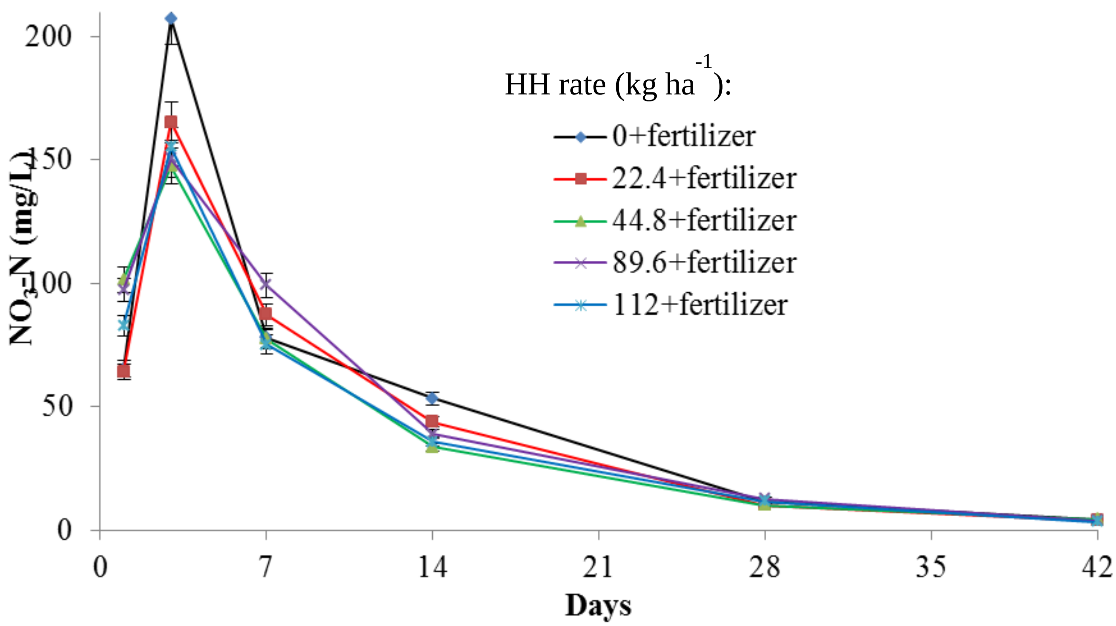

Figure 3-13. Leachate NO_3-N concentration from Alfisol in relation to fertilizer and different rates of Hydra-Hume

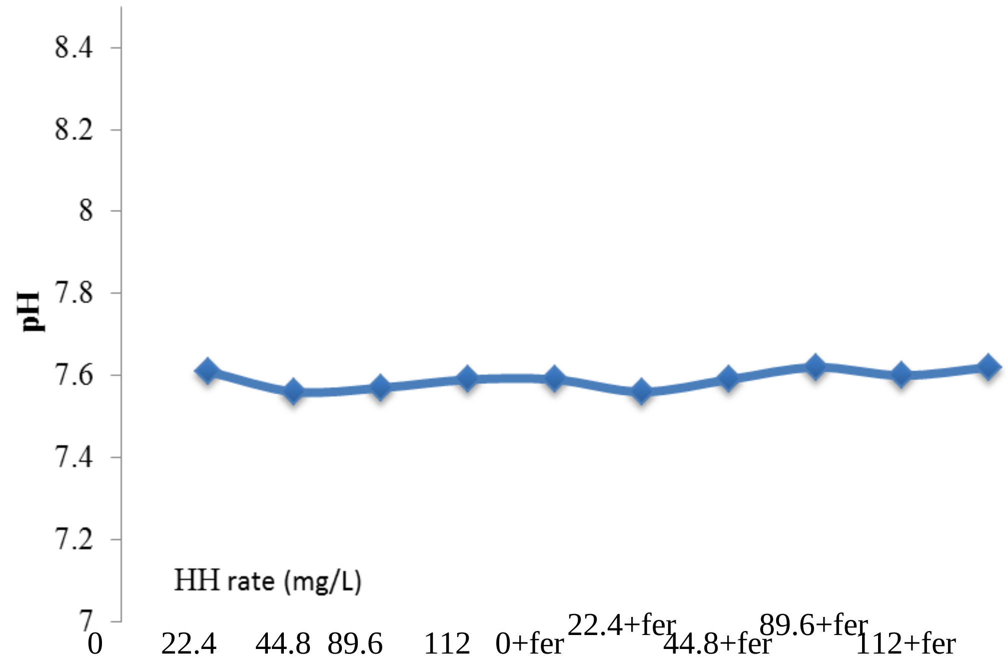

Figure 3-14. Soil pH after leaching in relation to fertilizer and different rates of Hydra-Hume

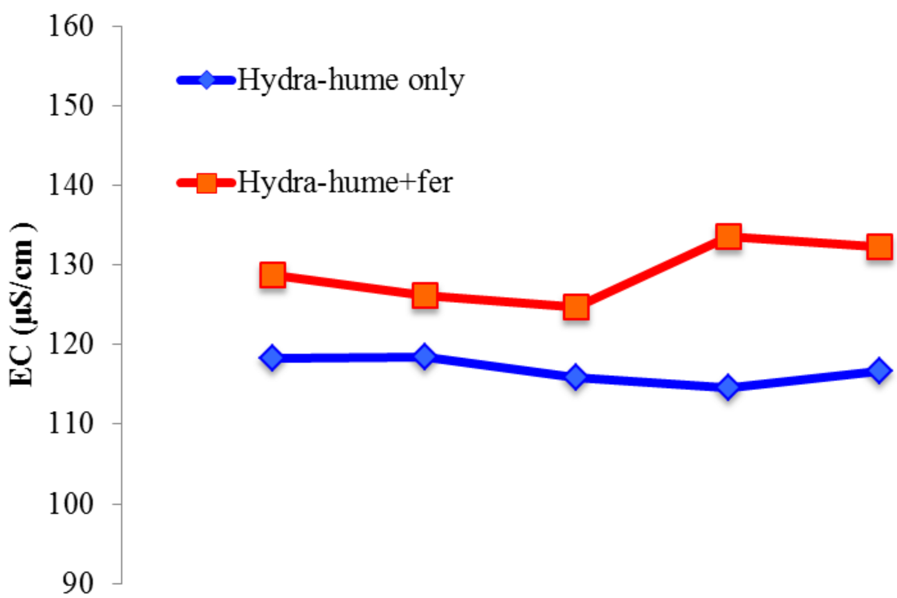

Figure 3-15. Soil EC after leaching in relation to fertilizer and different rates of Hydra-Hume

Table 3-1. Statistical analysis of NO_3-N concentration and total amount of NO_3-N in leachate from Spodosol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Leaching time (day)	0	12.42ab	14.84a	12.49ab	10.19b	11.26ab	36.00d	40.71c	45.60b	41.84c	51.20a
	3	6.74	6.64	6.68	6.52	6.8	32.06a	30.63a	19.97b	17.73b	13.13c
	7	2.46a	2.05b	1.95b	1.94b	2.12b	15.84	14.6	13.53	16.08	15.76
	14	2.52	2.05	2.06	2.13	1.91	7.39a	2.81b	3.24b	3.13b	2.59b
	28	1.45a	1.39a	1.33a	1.07b	0.99b	2.76a	2.52a	1.72b	1.51b	1.16b
	42	1.52	1.88	2.56	2.23	2.57	1.70a	0.98b	1.06b	1.01b	1.01b
Amount of NO_3-N (mg)		27.14a	28.89a	27.1ab	24.113b	25.683b	95.77a	92.03a	85.15b	81.32b	84.46b

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 3-2. Statistical analysis of NH_4-N concentration and total mineral N in leachate from Spodosol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Leaching time (day)	0	3.32b	3.80ab	4.00ab	3.96ab	4.95a	6.46b	6.64ab	7.29ab	7.28ab	7.78a
	3	1.39c	1.45bc	1.74abc	2.05a	1.90ab	7.75b	8.21ab	8.59ab	9.32a	8.80ab
	7	1.32b	1.32b	1.44b	1.66ab	1.87a	7.87d	9.51a	8.57b	8.11cd	8.44bc
	14	0.68c	0.79bc	0.88bc	0.83ab	1.05a	3.32b	3.83a	3.87ab	3.86a	4.09a
	28	0.54b	0.69ab	0.77ab	0.97ab	1.18a	1.18c	1.13bc	1.32ab	2.11a	2.22a
	42	0.15	0.12	0.21	0.16	0.31	0.52	0.37b	0.37b	0.55a	0.57a
Total mineral N		34.56a	37.09a	36.16a	33.78a	36.97a	122.8a	121.7a	115.2b	112.5b	116.7ab

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 3-3. Statistical analysis of heavy metals in leachate from Spodosol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Heavy metal (mg kg^{-1})	Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Co	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pb	0.10	0.09	0.10	0.13	0.13	0.15	0.15	0.13	0.13	0.14

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 3-4. Statistical analysis of NO_3-N and total amount of NO_3-N in leachate from Alfisol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Leaching time (day)	0	12.16	13.6	14.1	14.3	11.79	19.59	19.28	21.48	29.71	24.85
	3	8.77	8.34	8.58	6.30	5.96	62.17	46.09	50.96	42.93	46.56
	7	5.36	5.06	5.03	4.09	3.77	23.41	29.26	21.52	30.64	20.75
	14	3.11	2.92	2.26	2.43	2.86	16.00	13.16	10.08	13.62	16.68
	28	3.13	3.02	2.19	2.93	2.83	3.46	3.05	3.06	3.77	3.77
	42	1.32	1.30	1.26	0.88	0.69	1.05	1.15	1.15	1.15	1.05
Amount of NO_3-N (mg)		112.0 b	113.1 a	109.2 c	102.0 d	95.2 e	419.7 a	402.9c	375.0 d	374.6 b	364.5 e

*Means followed by different letters within the same row indicate significance level at P<0.05 by the Duncan multi-range test.

Table 3-5. Statistical analysis of NH_4-N concentration and total mineral N in leachate from Alfisol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Leaching time (day)	0	6.11	5.46	5.42	5.94	5.98	6.65b	7.10ab	7.44a	7.68a	7.89a
	3	10.71a	10.89a	9.94b	9.74b	9.57b	15.07a	15.75a	14.19b	14.19b	13.63b
	7	8.38a	8.15a	7.18b	7.00b	6.55b	9.9	9.42	9.61	9.16	9.60
	14	8.43a	8.55a	7.27b	6.95b	6.98b	12.52	11.11	9.11	9.26	9.10
	28	5.58	5.17	5.00	5.02	5.06	7.41	6.36	6.58	5.77	5.77
	42	3.12	1.98	2.24	2.40	2.35	4.28	4.12	3.48	3.88	3.58
Total mineral N		154.3a	153.4b	147.1c	139.1d	131.7e	474.5a	428.9c	427.1b	425.0d	414.1e

*Means followed by different letters within the same row indicate significance level at $P<0.05$ by the Duncan multi-range test.

Table 3-6. Statistical analyses of heavy metals in leachate from Alfisol

		Without fertilizer					With fertilizer				
HH rate (kg ha^{-1})		0	22.4	44.8	89.6	112	0	22.4	44.8	89.6	112
Heavy metal (mg kg^{-1})	Cd	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Co	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Ni	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pb	0.06	0.06	0.06	0.06	0.08	0.09	0.09	0.07	0.07	0.08

CHAPTER 4
SUMMARY, CONCLUSIONS AND PERSPECTIVE

Summary and Conclusions

Nitrogen (N) is an essential nutrient for plant growth and crop production. N deficiency may hinder and stunt plant growth, and therefore decrease crop yield. Large amounts of fertilizer N was applied into soils to obtain the maximum crop yield. If application of fertilizer exceeds the gap between crop uptake needs and the supply from the external sources, excessive N may be brought into the environment and contributed to environmental pollutions, such as water eutrophication, nitrogen deposition, *etc*. Different from C cycle, elemental N (N_2) cannot be utilized by plants and microbial organisms directly, which means N becomes biologically active when it is fixed or bound, such as incorporating into ammonium (NH_4^+) and nitrate (NO_3^-). However, most of the N in terrestrial systems is largely bound to organic matter and mineral materials that protect it from loss but make it unavailable to the plants. A mineralization process may be observed to convert N from organic forms into plant-available forms, when fertilizer was added to soil. Therefore, to maintain a balance between N supply and crop demand without excess or deficiency is the main obligation of N management.

For citrus yield and quality, N plays a very import role. However, the low use efficiency of fertilizer (usually from 30%-50%) with current practices not only represents a significant cost to the grower but also contributes to environmental pollution, such as water eutrophication of St. Lucie River and ecological degradation of Everglades National Park in Florida. Soils in the major citrus and vegetable production area in Florida are composed largely of sand (sand content >90%) and have a low nutrient retention capacity. High summer temperatures and rainfall in Florida provide favorable conditions for rapid leaching loss of N from fertilizers, which may pose adverse impact to the environment. Agricultural practices were applied to increase N use efficiency and reduce inorganic fertilizer-N use, such as cover crops, crop rotation, organic amendment, *etc*. Among these agricultural practices, soil amendment of humic substances may improve N use efficiency by crops by stimulating transformation of available N (NO_3-N and NH_4-N) into less mobile forms, such as microbial biomass and organic N pool.

One of the main objectives therefore of this study was to quantify the effect of Hydra-Hume, as an organic amendment, on N transformation dynamics in both original and fertilized soil. Two representative soils (Alfisol and Spodosol) in South Florida were selected to test. The N dynamics in soil was affected by the C/N ratio of Hydra-Hume as well as the original C/N ratio of the soil itself. Hydra-Hume, which had the C/N ratio around 42.13, induced a net immobilization process when applied alone in both soil types. For Alfisol soil, the immobilization process only occurred in the first two weeks with an application 224 kg ha^{-1} or higher. However, fertilizer contains large amounts of mineral ion, which is an N reserve for microbial biomass. When fertilizer was incorporated with the treatments, different N dynamic trends were observed in the two soils, probably due to the difference of C/N ratio in soils. The N dynamics in Alfisol soil, which had the C/N ratio around 22, induced net immobilization, while in Spodosol, a net mineralization curve occured.

The other objective was to examine the effects of Hydra-Hume on leaching potential of mineral N in Alfisol and Spodosol soils. Significant reduction in total NO_3-N amount could be observed when Hydra-Hume applied alone in both of the soils, but at an application rate of 44.8 kg ha^{-1}. If fertilizer was incorporated with the treatments, both of significant reduction of total NO_3-N and total mineral N amounts occurred, but a minimal application rate of 44.8 kg ha^{-1} is required to accomplish significant results in Spodosol soil and 22.4 kg ha^{-1} in Alfisol soil. In addition, no apparent influence on the leaching of heavy metals from the organic amended soil was measured.

In general, for both soils, the applied rate of Hydra-hume do not appear to pose an environmental risks with respect to the amounts of nitrate leaching and the concentration of heavy metals in leachate. Analysis of the leachate data confirmed that Hydra-Hume had the potential in reducing mineral N leaching, but certain application rates need to be required if significant difference was needed.

Perspective

This study provided some new information to soil and environmental science in the following aspects: (1) N transformation dynamics was affected by the properties of both organic material and the soil. (2) The application of Hydra-Hume showed the potential in reducing mineral N leaching in both Alfisol and Spodosol. (3) No apparenet influence was observed on the leaching of heavy metals from organic material and fertilizer. However, future research is still needed to address concerns with attention to the following aspects.

All the experiments were conducted in the labtory; therefore, field trials are needed to confirm the effects of Hydra-Hume on reducing NO_3-N leaching in the real circumstances. Moreover, potential contributions of irrigation to the N dynamics NO3-N leaching need to be considered. The types of irrigation as well as the amounts of irrigation play an important role in affecting NO_3-N leaching.

However, the effects of plants growth need to be taken into consideration. Ecosystem is an integral unit, which soil, water and plants interact with each other. Plants compete with microbes to take up mineral N, and during this process, plants take part in N transformation dynamics in soils. Therefore, the influence of plants is a key factor in N management.

LIST OF REFERENCES

Al-Redhaiman, K.N., 2000. Nitrate accumulation in plants and hazards to man and livestock: A review. J. King Saud University 12: 143-156.

Appel, T., Mengel, K., 1990. Importance of organic nitrogen fractions in sandy soils, obtained by electro-ultrafiltration or CaCl2 extraction, for nitrogen mineralization and nitrogen uptake of rape. Biology and Fertility of Soils 10 (2): 97-101

Ayongwa, G.C., Stomph, T.J., Kuyper, T.W., 2011. Host-parasite dynamics of Sorghum bicolor and Striga hermonthica- the influence of soil Organic matter amendments of different C/N ratio. Crop Protection 30:1613-1622

Azam, F., Malik, K. A., Hussain, F., 1986. Microbial biomass and mineralization-immobilization of nitrogen in some agricultural soils. Biology and Fertility of Soils. 2:157-163

Azim, M.E., Little, D.C., Bron, J.E., 2008. Microbial protein production in activated suspension tanks manipulating C: N ratio in feed and the implications for fish culture. Bioresource Technology 99:3590-3599

Bhogal, A., Rochford, A. D., Sylvester-Bradley, R., 2000. Net changes in soil and crop nitrogen in relation to the per- formance of winter wheat given wide-ranging annual nitrogen applications at Ropsley, UK. J Agric Sci 135: 139–149

Bouwman, A.F.,1996. Direct emission of nitrous oxide from agricultural soils. Nutrient Cycling in Agreoecosystems 46:53-70

Boverg, J., 2009. Litter decomposing fungi in boreal forests. phD thesis, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Breland, T. A., Hansen, S., 1996. Nitrogen mineralization and microbial biomass as affected by soil compaction. Soil Biology and Biochemistry. 28: 655-663

Burgos, P., Madejon, E., Cabrera, F. 2006. Nitrogen mineralization and nitrate leaching of a sany soil amended with different organic wastes. Waste Management &Reserch. 24: 174-182

Butterfly, C., Baldock, J., Tang, C., 2010. Chemical mechanisms of soil pH change by agricultural residues. World Congress of Soil Science, Soil Solutions for a Changing World. 1-6 August 2010, Brisbane, Australia. Published on DVD

Cabrera, M. L., Kissel, D.E., Vigil, M. F., 2005. Nitrogen mineralization from organic residues: research opportunities. Journal of Environmental Quality 34: 75-79

Calvert, S.E., 2004. Beware intercepts: interpreting compositional ratios in multi-component sediments and sedimentary rocks. Ogranic Geochemistry 35: 981-987

Cassman, K.G., Dobermann, A. R., Walters, D.T., 2002. Agroecosystems, Nitrogen-use Efficiency, and Nitrogen Management. Royal Swedish Academy of Sciences 31(2): 132-140

Conley, D. J., Paerl, H. W., Howarth, R. W., Boesch, D. F., Seitzinger, S. P., Havens, K. E., Lancelot, C., Likens, G. E., 2009. Controlling eutrophication: nitrogen and phosphorus. Science 323:1014-1015

Dalal, R.C., Allen, D.E., Wang, W.J., Reeves, S., Gibson, I., 2011. Organic carbon and total nitrogen stocks in a Vertisol following 40 years of no-tillage, crop residue retention and nitrogen fertilization. Soil and Tillage Research 112: 133–139.

Dawson, C.J.and Hilton. J., 2011. Fertilizer availability in a resource-limited world: production and recycling of nitrogen and phosphorus. Food Policy36 (1): S14-S22

DeBano, L. F. Conrad, C. E., 1976. Nutrients lost in debris and runoff water from a burned chaparral watershed. In: Proceedings of the Third Federal Inter-Agency Sedimentation Conference. 3-27

Diekow, J., Mielniczuk, J., Knicker, H., Bayer, C., Dick, D.P., Kögel-Knabner, I., 2005. Soil C and N stocks as affected by cropping systems and nitrogen fertilization in a southern Brazil Acrisol managed under no-tillage for 17 years. Soil and Tillage Research 81: 87–95

Ding, W., Meng, L., Cai, Z., Han, F., 2007. Effects of long-term amendment of organic manure and nitrogen fertilizer on nitrous oxide emission in a sandy loam soil. Journal of Environmental Sciences 19:185-193

Dobbie, K. E. and Smith, K. A., 2003. Impact of different forms of N fertilizer on N^2 emissions from intensive grassland. Nutrient Cycling in Agroecosystems 67:37-46.

Dobermann A., Cassman K.G., 2002. Plant nutrient manage- ment for enhanced productivity in intensive grain produc- tion systems of the United States and Asia, Plant Soil 247: 153–175

Drinkwater L.E., Snapp S.S., 2007. Nutrients in Agroecosystems: rethinking the management paradigm, Advanced Agronomy. 92: 163–186

Eickhout B., Bouwman A.F., van Zeijts H., 2006. The role of nitrogen in world food production and environmental sustain- ability, Agriculture, Ecosystem &Environment 116: 4–14

Erisman, J.W., Sutton, M.A., Galloway, J., Klimont, Z., Winiwarter, W., 2008. How a century of ammonia synthesis changed the world. Nature Geoscience 1: 636-639.

Fageria, N.K., Baligar, V.C., 2005. Enhancing Nitrogen Use Efficiency in Crop Plants. Advances in Agronomy88: 97-185

Flower, K.C., Cordingley, N., Ward, P.R., Weeks, C., 2011. Nitrogen, weed management and economics with cover crops in conservation agriculture in a Mediterranean climate. Field Crops Rearch. 132:63-75

Foley, B.J., and L.R. Cooperband., 2002. Paper mill residuals and compost effects on soil physical properties in an irrigated vegetable rotation. Journal of Environment Quality 31:2086-2095.

Food and Agriculture Organization of The United Nations, 1984. Fertilizer and Plant Nutrition Guide, FAO Fertilizer and Plant Nutrition Bulletin No. 9, FAO, Rome.

Franzluebbers, A.J., Stuedemann, J.A., Schomberg, H.H., Wilkinson, S.R., 2000. Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. Soil Biology and Biochemistry 32: 469–478.

Gaju, O., Allard, V., Martre, P., Snape, J.W., Heumez, E., LeGouis, J., Moreau, D., Bogard, M., Griffiths, S., Orford, S., Hubbart, S., Foulkes, M.J., 2011. Field Crops Research 123(2):139-152.

Galantini, J.A., Senesi, N., Brunetti, G., Rosell, R., 2004. Influence of texture on organic matter distribution and quality and nitrogen and sulfur status in semiarid Pampean grassland soils of Argentina. Geoderma 123: 143–152.

Glendining, M. J., Powlson, D. S., Poulton, P. R., Bradbury, N. J., Palazzo, D., Li, X., 1996. The effects of long-term applications of inorganic nitrogen fertilizer on soil nitrogen in the Broadbalk Wheat Experiment. Journal of Agricutural Science. 127:347–363.

Goudriaan J., Groot J.J.R., Uithol P.W.J., 2001. Productivity of Agro-ecosystems in: Terrestrial Global Productivity (Roy J., Ed), Academic, San Diego, 310–313

Goulding K., Jarvis S., Whitmore A., 2008. Optimizing nutrient management for farm systems, Philosophical Transactions of the Royal Society B: Biological Sciences 363: 667–680

Griffin, D.M., 1972. Ecology of soil fungi. Chapman and Hall ltd, London, UK

Groenigen, K.J., Six, J., Harris, D., C, C.K., 2007. Elevated CO_2 does not favor a fungal decomposition pathway. Soil Biology & Biochemistry 39: 2058–2069

Hauck, R.D., 1990. Agronomic and public aspects of soil nitrogen research, Soil Use Management. 6: 66–70

He, Z.L., Alva, A. K., Calvert, D. V., Li, Y. C., Banks, D. J., 1999. Effects of nitrogen fertilization of grapefruit trees on soil acidification and nutrient availability in a Riviera fine sand. Plant soil 206:11-19

He, Z.L., Alva, A. K., Calvert, D.V., Li, Y. C., Stoffella, P. J., Banks, d. J., 2000. Nitrogen mineralization and transformation from composts and biosolids during field incubation in a sany soil. Soil Science.165: 161-169

Henao, J., Baanante, C., 2001. Nutrient Depletion in the Agricultural Soils of Africa, 2020 Vision, Brief 62, International Food Policy Research Institute, Washington, DC

Henriksen, T.M., Breland, T.A., 1999. Nitrogen availability effects on carbon mineralization, fungal and bacterial growth, and enzyme activities during decomposition of wheat straw in soil. Soil Biology & Biochemistry 31: 1121–1134

Hirel B, Le Gouis J, Ney B, Gallais A., The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. Journal of Experimental Botany.58: 2369-2387

Hirel, T. T., Lea, P. J., Dubois, F., 2011. Improving nitrogen use efficiency in crops for sustainable agriculture. Sustainability 3:1452

Hons, F.M., 2005. Rotation, tillage, and nitrogen rate effects on cotton growth and yield. In Conservation Tillage Conference 2005 Cotton Presentations, Houston, TX. 13–14 Jan. 2005. Cotton Incorporated, Cary, NC.

Houghton J.T., Ding Y.M., Griggs D.J., Noguer M., van der linden P.J., Dai X.et al., 2001. Climate Change 2001: The Scientific Basis. Cambridge University Press, Cambridge. UK.

Huang, G.F., Wong, J.W.C., We, Q.T., Nagar, B.B., 2004. Effect of C: N on composting of pig manure with sawdust. Waste Manage. 24: 805–813

Huang, Y., Zou, J., Zheng, X., Wang, Y., Xu, X., 2004. Nitrous oxide emissions as influenced by amendment of plant residues with different C: N ratios. Soil Biology Biochemistry 36:973-981.

Hue, N.V., Silva, J. A., 2000. Organic soil amendments for sustainable Agriculture: organic sources of nitrogen, phosphorus, and potassium. In: Plant Nutrient Mangement in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture (Silva, J.A. Ed). College of Tropical Agriculture and Human Resources, University of Hawaii at Manoa. 133-144

Hussain, G., Al-Jaloud, A.A., Karimulla, S., 1996. Agricultural Water Management 30(2): 175-184.

IPCC (Intergovernmental Panel on Climate Change), 2001. Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Institute for Global Environmental Strategies, Kanagawa, Japan.

James, J. J., Drenovsky, R.E., Monaco, T.A., Rinella, M.J., 2011. Managing soil nitrogen to restore annual grass-infested plant communities: effective strategy or incomplete framework? Ecological Applications 21(2): 490–502

Janssen, B.H., 1996. Nitrogen mineralization in relation to C/N ratio and decomposability of organic materials. Plant and Soil 181:39-45

Jansson, S. L., Persson, J., "Mineralization and immobilization of soil nitrogen", Nitrogen in: Agricultural Soils (Stevenson, F.J., Ed.), Monograph 22, ASA, Madison, WI (1982) 229–252

Jenkinson D.S., Ladd, J.N., 1981. Microbial biomass in soil. In: Paul EA, JN Ladd (eds) Soil biochemistry, vol 5. Marcel Dekker, New

Jenkinson, D.S., 1990. Leaks in the nitrogen cycle, in: Fertilization and the Environment (Merckx, R., Ed.), Leuven University Press, Leuven 35–49

Johnson, J.W., Welch, L.F., Kurtz, L.T., 1975. Environmental implications of N fixation by soybeans. J. Environ. Qual. 4: 303-306

Ju, X. T., Kou, C. L., Christie, P., Dou, Z. X., Zhang, F. S., 2007. Changes in the soil environment from excessive application of fertilizers and manures to two contrasting intensive cropping systems on the North China Plain. Environmental Pollution 145: 497-506

Ju, X.T., Wan, Y.J., Kou, C.L., Zhang, F.S., 2005. Nitrate accumulation in agricultural soils and groundwater of the North China Plain. In: Li (Ed.), Plant Nutrition for Food Security, Human Health and Environmental Pro- tection. Tsinghua University Press, Beijing, 1056-1057

Jua, X.T., Koua, C. L., Christiea, P., Dou, Z. X., Zhang, F.S., 2007. Environmental pollution 145(2): 497–506.

Keerthisinghe, D.G., 2003. "Plant nutrition: challenges and tasks ahead", Agriculture Conference: Global Food Security and the Role of Sustainable Fertilization, IFA/FAO, Rome

Kirkby, C.A., Kirkegaard, J.A., Richardson, A.E., Wade, L.J., Blanchard, C., Batten, G., 2011. Stable soil organic matter: A comparison of C: N: P: S ratios in Australian and other world soils. Geoderma 163: 197-208.

Kumar, M., Ou Yan L., Lin J.G., 2010. Co-composting of green waste and food waste at low C/N ratio. Waste Manage. 30: 602-609.

Lal, R., 2001. World cropland as a source or sink for atmospheric carbon, Adv. Agron. 71:146–191.

Lewis, J.A.and Papavizas, G.C., 1974. Effect of volatiles from decomposing plant tissues on pigmentation, growth, and survival of Rhizoctonia Solani. Soil Science 118: 156-163

Liang, B., Yang, X., He, X., Zhou, J., 2011. Effects of 17-year fertilization on soil microbial biomass C and N and soluble organic C and N in loessial soil during maize growth. Biology and Fertility of Soils 47: 121–128

Loes, A.K. and Ogaard, A.F., 2001. Long-term changes in extractable soil phosphorus (P) in organic dairy farming systems. Plant and Soil, 237 (2): 321-32.

Madrid, F., Lopez, R., Cabrera, F., Murillo, J. M., 2001. Nitrogen mineralization for assessing the correct agricultural use of MSW compost. In: Bioprocessing of solid waste and slude. Vol. 1(2) www.Orbit-online.Net/journal/archive/01-02/0102_06print.html

Mahvi, A. H., Nouri, J., Babaei, A.A., Nabizadeh, R., 2005. Agricultural activities impact on groundwater nitrate pollution. International journal of Environmental Science and Technology 2(1): 41-47.

Martens, R., 1995. Current methods for measuring microbial biomass C in soil: Potentials and limitations. Biology and Fertility of Soils 19:87-99

Martin, E. C., Loudon, T. L., Ritchie, J. T., Werner, A., 1994. Use of drainage lysimeters to evaluate nitrogen and irrigation management strategies to minimize nitrate leaching in maize production. Transactions of the American Society of Agricultural Engineers 37: 79-83

Matson, P.A., 1998. Integration of environmental, agronomic and economic aspects of fertilizer management, Science 280:112–115

Matthews, J.A., 1992 The ecology of recently deglaciated terrain: a geoecological approach to glacier forelands and primary succession. Cambridge University Press

Michel, F.C., Forney, L.J., Huang, A.J.F., Drew, S., Czuprendski, M., Lindeberg, J.D., Reddy, C.A., 1996. Effects of turning frequency, leaves to grass mix ratio and windrow vs. pile configuration on the composting of yard trimmings. Compost Science & Utilization 4: 126–143

Mosier, A.R., Kroeze, C., 1998. A new approach to estimate emissions of nitrous oxide from agriculture and its implications for the global N_2O budget. IGBP Newsletter 34, 8 – 13. http://www.igbp.kva.se/cgi-bin/php/frameset.php

Oglesby, R. T. and Edmondson, W. T., 1966. Control of Eutrophication. Journal Water Pollution Control Federation 38: 1452-1460.

Ogunwande, G.A., Osunade, K.O., Adekalu, K.O., Ogunjimi, L.A.O., 2008. Nitrogen loss in chicken litter compost as affected by carbon to nitrogen ratio and turning frequency. Bioresour Technology. 99: 7495–7503.

Ouedraogo, E., Mando, A., Stroosnijder, L., 2006. Effects of tillage, organic resources and nitrogen fertilizer on soil carbon dynamics and crop nitrogen uptake in semi-arid West Africa. Soil and Tillage Research 91: 57–67.

Pederson, G. A., Brink, G. E., Fair T. E., 2002. Nutrient Uptake in Plant Parts of Sixteen Forages Fertilized with Poultry Litter: Nitrogen, Phosphorus, Potassium, Copper, and Zinc. Agronomy Journal 94:895-904.

Powlson, D.S., 1998. A European network of long-term sites for studies on soil organic matter, Soil & Tillage Research. 47: 263–274.

Puget, P., Lal, R., 2005. Soil organic carbon and nitrogen in a Mollisol in central Ohio as affected by tillage and land use. Soil and Tillage Research 80: 201–213.

Rasmussen P.E., Goulding K.W.T., Brown J.R., Grace P.R., Janzen H.H., Körschens M., 1998. Long-term agroecosys- tems experiments: assessing agricultural sustainability and global change, Science 282: 893–896

Raun, W. R. and Johnson, G.V.,1999 Improving nitrogen use efficiency for cereal production. Agronomy Journal 91: 357-363

Raun, W.R., Johnson, G.V., Phillips, S.B., Westerman, R.L., 1998. Effect of long-term N fertilization on soil organic C and total N in continuous wheat under conventional tillage in Oklahoma. Soil and Tillage Research 47: 323–330.

Reddy, K.N., M.A. Locke, C.H. Koger, R.M. Zablotowicz, and L.J. Krutz., 2006. Cotton and corn rotation under reduced tillage management: Impacts on soil properties, weed control, yield and net return. Weed Sci. 54:768–774.

Ribaudo, M., Delgado, J., Hansen, L., Livingston, M., Mosheim, R., Williamson, J., 2011. Nitrogen in Agricultural Systems: Implications for Conservation Policy. USDA. Economic Research Report NO. 127

Rose, C.W., Dalal, R.C., 1988. Erosion and runoff of nitrogen. In: Advances in Nitrogen Cycling in Agricultural Ecosystems (Wilson, J. R. Ed), CAB International, Wallingford, England, 212–235.

Rousk, J., 2009. On the Ecology of Saprotrophic Fungi and Bacteria in Soil: Biotic and Abiotic Control of Growth Rates. ph.D. Thesis, Lund University.

Sanchez, L., Diez, J. A., Polo, A., Roman, R., 1997. Effect of timing of application of municipal solid wastecompost on N availability for crops in central Spain. Biology and Fertility of Soils. 25: 136-141

Scherr, S. J, Yadav, S., 1996. Lande degradation in the developing world: implications for food, agriculture, and the environment to 2020.

Scott, N. A., Cole, C. V., Elliot, E. T., Huffman, S. A., 1996. Soil textural control on decomposition and soil organic matter duamics. Soil Science Society of America Journal 60: 1102-1109

Sharifi, M., Zebarth, B. J., Burton, D. L., Grant, C. A., Porter. G. A., 2006. Organic Amendment History and Crop Rotation Effects on Soil Nitrogen Mineralization Potential and Soil Nitrogen Supply in a Potato Cropping System. Agronomy Journal 100:1562–1572

Sieling, K., Brase, T., Svib, V., 2006. Residual effects of different N fertilizer treatments on growth, N uptake and yield of oil- seed rape, wheat and barley. European Journal of Agronomy 25:40–48

Singh, J. S., Pandey, V. C. Singh, D. P., 2011. Efficient soil microorganisms: A new dimension for sustainable agriculture and environmental development. Agriculture, Ecosystems and Environment 140: 339–353

Singh, J.S., Pandey, V.C., Singh, D.P., Singh, R.P., 2010. Influence of pyrite and farmyard manure on population dynamics of soil methanotroph and rice yield in saline rain-fed paddy field. Agriculture, Ecosystems & Environment 139: 74–79

Sotta, E.D., Corre, M. D., Veldkamp, E., 2007. Differing N status and N retention processes of soils under old-growth lowland forest in Eastern Amazonia, Caxiuana, Brazail. Soil Biology & Biochemistry 40:740-740

Spiertz, J. H. J. 2009. Nitrogen, Sustainable, Agirculture and Food Security: A Review. Agronomy for Sustainable Development 635-651

Steffen, K.L.; M.S. Dann, J.K. Harper, S.J. Fleischer, S.S. Mkhize, D.W. Grenoble, A.A. MacNab, K. Fager, and J.M. Russo. 1995. Evaluation of the initial season for implementation of four tomato production systems. Journal of the American Society for Horticultural Science120 (2):148-156.

Stockdale E.A., Gaunt J.L., Vos J. 1997. Soil–plant nitrogen dynamics: what concepts are required. European Journal of Agronomy 7: 145–159.

Thiet, R.K., Frey, S.D., Six, J., 2006. Do growth yield efficiencies differ between soil microbial communities differing in fungal: bacterial ratios? Reality check and methodological issues. Soil Biology & Biochemitry 38: 837–844

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R., Polasky, S., 2002. Agricultural sustainability and intensive production practices. Nature 418: 671–677

Timsina, J., Singh, U., Badaruddin, M., Meisner, C., Amin, M.R., 2001. Field Crops Research 72(2): 143-161.

Umar, A.S.; Iqbal, M., 2007. Nitrate accumulation in plants, factors affecting the process, and human health implications. A review. Agronomy for Sustainable Development 27: 45-57.

United Nations Environment Program. Reactive Nitrogen in the Environment, 2007. ISBN: 978 92 807 2783 8

U.S. Department of Agriculture, Natural Resources Conservation Service (USDA, NRCS), 2006. Natural Resources Conservation Service Conservation Practice Standard: Nutrient Management. National Handbook of Conservation Practice.

Vitousek, P. M., J. R. Gosz, C. G. Grier, J. M. Melillo, and W. A. Reiners., 1982. A comparative analysis of potential nitrification and nitrate mobility in forest ecosystems. Ecological Monographs. 52:155-177

Walter E. Baethgen, C.Bruce Christianson, Adriana G.Lamothe., 1995. Nitrogen fertilizer effects on growth, grain yield, and yield components of malting barley. Field Crops Research 43: 87-99

Webb, P.G. and Biggs, R.H., 1988 Effects of humate amended soils on the growth of citrus. Proceedings of Florida State Horticultural Society. 101:23-25

Whitehead, D.C., Goulden, K.M., Hartley, R.D., 1986. Fractions of nitrogen, sulfur, phosphorus, calcium and magnesium in the herbage of perennial ryegrass as influenced by fertilizer nitrogen. Animal Feed Science and Technology14 (3-4): 231-242.

Wiesler, F., Behrens, T., and Horst, W.T., 2001. The role of nitrogen-efficient cultivars in sustainable agriculture. Scientific World Journal. 1: 61-69

Wortmann, C., 2006. Agricultural Nitrogen Management for Water Quality in the Midwest. USDA.

Xu, J.M., Tang, C., Chen, Z.L., 2006. Chemical composition controls residue decomposition in soils differing in initial pH. Soil Biology & Biochemistry 38, 544-552

Yamashita, T., Feiner, H., Bettina, J., Helfrich, M., Ludwig, B., 2006. Organic matter in density fractions of water-stable aggregates in silty soils: effect of land use. Soil Biology & Biochemistry 38: 3222–3234

Yuan, L., D. J. Bao, Y. Jin, Y.H. Yang and J.G. Huang., 2010. Influence of fertilizers on nitrogen mineralization and utilization in the rhizosphere of wheat. Plant Soil 343:187–193.

Zheng, Y., Ding, Y., Wang, Q., Li, G., Wu, H., Yuan, Q., Wang, H., Wang, S. 2007. Agricultural Sciences in China 6(7): 842-848.

Zhu, N., 2006. Composting of high moisture content swine manure with corncob in a pilot-scale aerated static bin system. Bioresource Technology. 97: 1870–1875.

BIOGRAPHICAL SKETCH

Wen Gu was born in Jinan, China. She received a B.S. in environmental engineering from Ocean University of China, in 2010. She took an internship in Shandong Academy of Environmental Science and took part in the environmental impact assessment program for Chengbei wastewater treatment plant in Shandong Province, China. She began her master's study in the Soil and Water Science Department, University of Florida, in 2010 and received her degree in 2012. Since 2010, she has worked as research assistant at the University of Florida's Soil and Water Science Laboratory (SWSL) at the Indian River Research and Education Center in Ft. Pierce. She conducted research on the nitrogen management in sandy soils, especially for reducing nitrogen loss by applying organic amendments. She is a member of the American Society of Agronomy - Crop Science Society of America - Soil Science Society of America (ASA-CSSA-SSSA) and Gamma Sigma Delta.