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# Effect of Long-Term Chemical Fertilizer Application on Soil Chemical Properties: A Review

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**Abstract**
Chemical fertilizers like urea (N) and ammonium ($NH^{+4}$) are very important for the crop's growth and productivity. But long-term fertilizer experiments play an important role in understanding the complex interactions involving soils, plants, climate and management practices and their effects on crop productivity. It is well recognized that long term fertilizer experiments are repositories of valuable information regarding the sustainability of intensive agriculture. The LTFE serves as an important tool to understand the changes in soil properties due to intensive cropping and continuous fertilization. Continues and long-term use of chemical fertilizers and manures in soil alters the physico-chemical and biological properties of the soil. So, on this review we advised the farmers and other stack holders to use organic fertilizer and integrated soil fertility management rather continues chemical fertilizers.
**Keywords:** Chemical fertilizers**,** long term fertilizer experiment, Intensive agriculture and Soil properties
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## INTRODUCTION

Intensive agriculture can speed up soil acidification through many processes – increasing leaching, addition of fertilizers, removal of produce and build-up of soil organic matter. Many African soils which are predominantly Acrisols, Nitosols and Ferralsols, are acid due to old age (highly weathered), depletion of soil carbon and continuous cultivation (Lungu O., 1987, Sumner ME., 2001). Inorganic fertilizers may aggravate the process, particularly with application of ammonium-based fertilizers such as ammonium sulphate, ammonium nitrate and urea. Previous studies on long term (5-10 years) soil fertility in Kenya and West African moist Savannah soils have shown an increase in soil acidity of between pH 1.0 to 5.0 (Smaling and Bau., 1996, Vanlauuwe and Giller, 2006**)**. The problem of soil acidification is likely to increase with intensification of agriculture and increased fertilizer use.

Chemical fertilizers or inorganic fertilizers are manmade soil enhancers used to raise the level of nutrients found in soil. The natural nutrients found in the soil essential to plant growth, such as nitrogen, phosphorus and potassium, are manufactured synthetically from inorganic material and applied to soil in the form of chemical fertilizers. Although chemical fertilizers improve the growth of plants and increase the yields of fruits and vegetables in a relatively short period of time, there are certain disadvantages of using chemical fertilizers as opposed to organic fertilizers derived from natural sources.

Long term fertilizer experiments play an important role in understanding the complex interactions involving soils, plants, climate and management practices and their effects on crop productivity. It is well recognized that long term fertilizer experiments are repositories of valuable information regarding the sustainability of intensive agriculture. The long-term fertilizer experiments (LTFE) serve as an important tool to understand the changes in soil properties due to intensive cropping and continuous fertilization. Consistent use of chemical fertilizers and manures in soil alters the physico-chemical and biological properties of the soil **(**Hemalatha *et al,* 2013).

Soil acidification is a widespread natural phenomenon in regions with medium to high rainfall, and agricultural production systems can accelerate soil acidification processes through perturbation of the natural cycles of nitrogen (N), phosphorus (P) and sulfur (S) in soil, through removal of agricultural produce from the land, and through addition of fertilizers and soil amendments that can either acidify soil or make it more alkaline (Kennedy, 1986). Changes in soil pH may be advantageous or detrimental depending on the starting pH of the soil and the direction and speed of pH change – for example decreases in soil pH in alkaline soils may be advantageous for crop production due to benefits in terms of the availability of P and micronutrients like, Zinc (Zn). On the other hand, decreases in soil pH for a highly acidic soil may be detrimental in terms of increasing crop susceptibility to toxicity induced by increased solubility of aluminum (Al) or manganese (Mn) as soil pH falls (Wright, 1989). Therefore, this review paper mainly focused to review the effect of long-term application of chemical fertilizers on soil chemical properties.

## LITERATURE REVIEW

### Effect of Long-Term Nitrogen Fertilization on Soil Chemical Properties

Nitrogen fertilization is the most influential in terms of increasing crop production. Mineral nitrogen, in addition to increasing the content of nitrate in soil, leads to changes in soil pH and many other soil properties (Dragan

Cakmak *et a*l., 2010). The changes in soil quality are closely related to soil physical, chemical and biological fertility (Zhang *et al.* 2007, Brady and Weil 2002). There is general agreement, that of all the nutrient amendments made to soil, N fertilizer application has had and still has by far the most important effects in terms of increasing crop production. Under intensified agricultural production the soil receives ever more nitrogen (Freney, 2005; Erisman *et al.* 2005). Fertilizer nitrogen, apart from increasing the content of nitrate in soil that leads to its leaching results in changes in soil pH and many other soil properties (Porter *et al*. 1996; Brady and Weil, 2002). The long-term field experiments with N fertilization can give valuable information about how those changes occur and indicate the trends of the changes.

Nitrogen fertilizer primarily affected the soil pH resulting in an increase in acidity, the clear trend of decreasing soil pH was also observed with increasing the rate of applied N-fertilizer where the high statistical significance was observed between the control and the highest rate of N-fertilizer (Dragan Cakmak *et al*, 2010). Long-term application of N containing fertilizers (such as MAP) with acidifying effects, results in acidification of soil, thus lowering soil pH (Belay *et al.* 2002). Upon oxidation, $NH4^+$ can release $H^+$ ions a potential source of soil acidity (Magdoff *et al.* 1997). Soil pH is one of the main factors affecting solubility of trace elements and their phyto-availability (Kopec and Przetaczk- Kaczmarczyk 2006).

Permanent fertilization with N can lead to its leaching, where firstly the processes of nitrification build up nitrate ions, which are weakly associated to soil adsorptive complex (Mengel and Kirkby, 2001). On the other hand, processes of microorganism metabolism also affect the mineral N and microorganisms are included into the soil humus that is usually reflected in an increased content of SOM. However, in our study the expected increase in soil humus did not show a clear dependence on the amount of applied N. This can be explained partially by the changes in the composition of SOM, where addition of mineral N intensified immobilization of mineral N by microorganisms (Yaletdinov, 1988; Saljnikov, 2004), and by adsorption of ammonium by soil CEC and by processes of weak fixation within clay minerals (Mengel and Kirkby, 2001). Such processes can result in gradual accumulation of total nitrogen.

Increases in the content of available K and P in the fertilized treatments are expected. However, addition of the highest rates of N resulted in a somewhat decreased content of P, which is probably induced by reduced solubility of P-compounds due to increased soil acidity (Marsh *et al*. 1987). Decreased content of exchangeable Ca compared to the control clearly indicates an imbalance between its input and output. The reason for this is the leaching due to soil acidification and processes of nitrification that particularly apply to soils with a pH <7. This is also confirmed by the decreasing trend in the content of Mg in the studied surface soil, compared to the control (Mengel and Kirkby, 2001). Decreases in soil pH, followed by leaching of soil bases are also clearly seen in the constant decrease of basic cations on the soil CEC, whilst the increased content of humus resulted in an increased value of soil CEC (Yan *et al.* 2007). The significant decrease of basic cations on the soil CEC resulted in the changes of main soil properties resulting in a change in soil classification: the studied Eutric Cambisol has become a Dystric Cambisol. Changes in the content of Zn and Fe are closely connected to the decrease of soil pH, e.g. due to acidification of the medium Zn and Fe are activated and transformed into mobile forms that determine their increased content for the fertilized treatments (Mengel and Kirkby 2001). On the other hand, strong bonds of insoluble Cu with soil particles, and the higher concentration of Cu than of Zn in soil solution resulted in leaching due to soil acidification (Mc Bride 1989; Mengel and Kirkby, 2001).

**Effect of urea on Exchangeable Bases**

According to the report of Lungu and Dynoodt (2008) that urea has a significant effect of on the exchangeable bases in the soil. Both exchangeable Ca and Mg were lower at higher rates of urea application (>120 kg N $ha^{-1}$) than at zero and 60 kg N $ha^{-1}$. Exchangeable has also K significantly differed from the control only at 60 kg N $ha^{-1}$ while the values at the other rates did not differ from the control. The decrease in exchangeable bases followed the trend in soil acidification from annual applications. The amounts of exchangeable Ca and Mg in soil progressively deceased with annual applications of urea to this soil during the long-term application. The data of Lungu and Dynoodt (2008) also showed that exchangeable Ca decreased by 13% and Mg by 28% compared to the control whilst the soil pH on the treatment plots simultaneously decreased from 6.0 to 5.0. Therefore, decreased exchangeable bases are associated with soil acidification. The consistent result was gained by several authors (Smaling and Baun, 1990; Hoyt and BG, 1989; Wendt, Chase and Hossner, 1988) there result showed that decreased bases in an Alfisol were associated with soil acidification below pH 4.5.

**Effect of chemical fertilizers on Exchangeable calcium and magnesium**

A decrease in the exchangeable Ca and Mg contents of the soil was detected where ammonium sulphate had been used as the source of nitrogen. According to **(**Hemalatha *et al*, 2013**)** on influence of Long-Term Fertilization on Soil Fertility - A Review the decreasing of Ca and Mg was more during the first seven years but the decreasing rate lessened subsequently due to the reduction in yield with less removal of nutrients. In the case of FYM application, there was first a decrease followed by an increase due to slow mineralization of organic manures

(Subramanian KS, Kumaraswamy K., 1989). An increase in the Ca and Mg status of the soil was found due to the continued application of manure while the addition of N in soil tended to decrease it (Parmar and Sharma, 2002). The exchangeable Ca and Mg status of continuously fertilized acid soil increased due to the application of lime and FYM (Prasad and Singh, 1981). The long-term Integrated Nutrient Management on soil fertility status leads to increased content of both Ca and Mg due to the incorporation of FYM along with fertilizers. The FYM has a positive effect on Ca and Mg content in soil because it is having high adsorptive capacity that might have adsorbed Ca and Mg which would otherwise be leached (Bellaki *et al*, 1998). The cultivated soils with the application of fertilizer + compost + lime contained a large amount of exchangeable Ca associated with fertilization and liming (Suresh *et al*., 1999).

**Effect of urea on soil acidification**

Urea is least suspected to cause soil acidity compared to the more familiar acid-forming ammonium fertilizers such as Ammonium Sulphate (Hoyt and Drought, 1990; Khonje *et al*., 1989). The results presented by Lungu and Dynoodt (2008) provide evidence that annual long-term applications of urea led to soil acidification and the linear regression showed that with continuous urea application soil acidification started in the third cropping season, and the rate increased with the level of urea application, being highest with 180 kg N $ha^{-1}$ which was -0.04 pH units per month. In order to counteract this effect of soil acidification from urea and maintain soil productivity it is necessary to regularly apply lime.

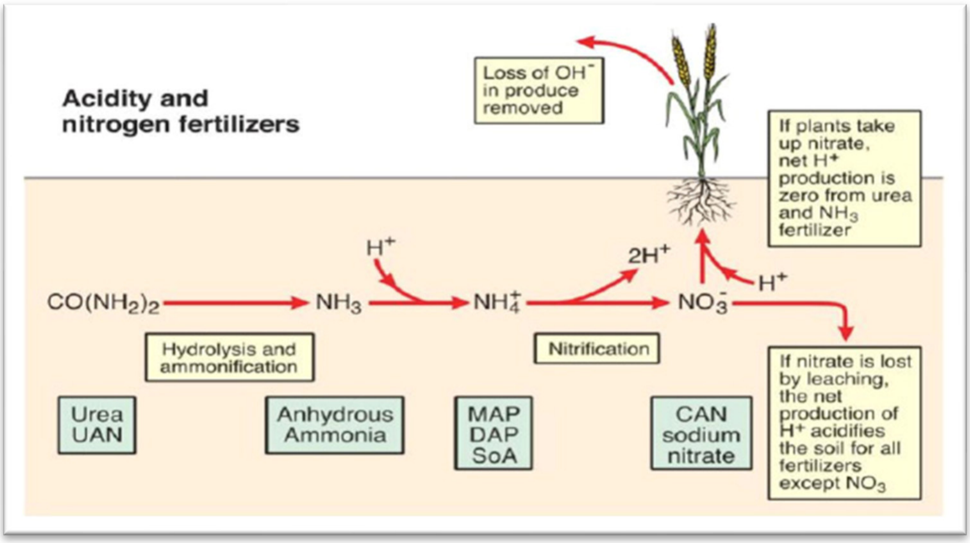


Figure 1. Soil acidity and nitrogen fertilizers (modified from (Davidson 1987)). MAP = monoammonium phosphate, DAP = diammonium phosphate, SoA = sulfate of ammonia, CAN = calcium ammonium nitrate, sodium nitrate (Mosaic Fertilizer Technology Research Centre., 2013).

 

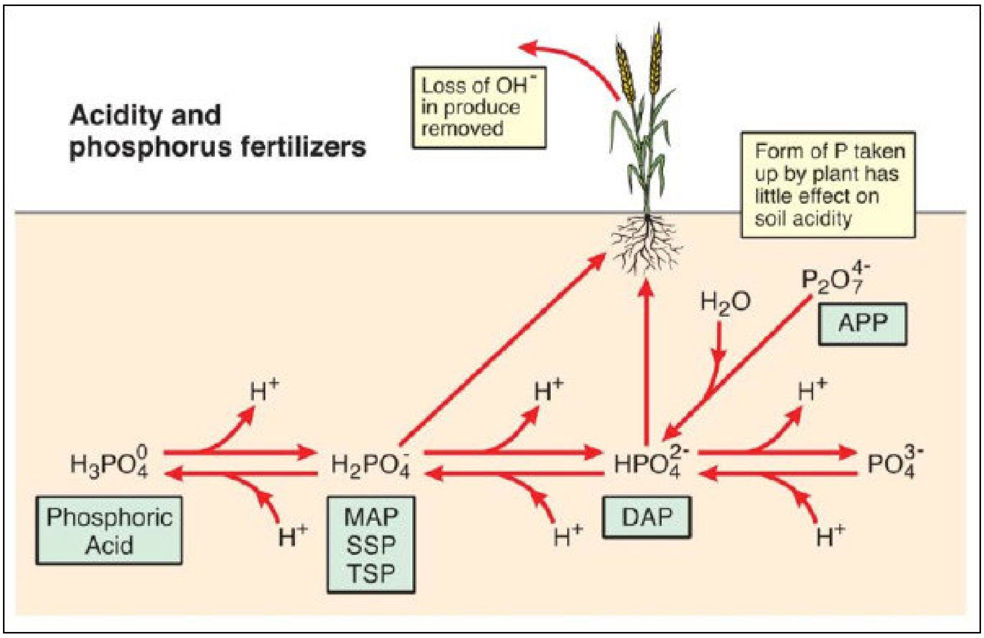


Figure 2. Soil acidity and P fertilizers. MAP = monoammonium phosphate, DAP = diammonium phosphate, SSP = single superphosphate, TSP = triple superphosphate, APP = ammonium polyphosphate (Mosaic Fertilizer Technology Research Centre., 2013)

**Soil salinity – EC**

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. Electrical conductivity is an electrolytic process that takes place principally through water-filled pores. Cations ($Ca_2^+$, $Mg_2^+$, $K^+$, $Na^+$, and $NH4^+$) and anions like $SO_4^{2-}$ , $Cl^-$, $NO_3^-$ and $HCO_3^-$ from salts dissolved in soil water carry electrical charges and conduct the electrical current. Consequently, the concentration of ions determines the EC of soils. In agriculture, EC has been used principally as a measure of soil salinity, however, in non-saline soils, EC can be an estimate of other soil properties, such as soil moisture and soil depth. EC is expressed in deciSiemens per meter (dS/m). A study in a Permanent Manurial Experiment (PME) on Aridisols showed an increase in soil EC value from 0.67 dSm-1 to 0.80 $dSm^{-1}$ due to the continued application of fertilizers for over 30 years. The increase in the EC of the soil with continued application of fertilizers was due to the addition of salts through fertilizers and solubilisation of native minerals due to the reduction in the pH of the soil (kuntal et al., 2007). Mairan *et al*., 2005; Lohan, Dev. 1998) they concluded that there was decline in values of soil EC of Vertisol with crop residue incorporation over fertilizer application in LTFE (long term fertilizer experiments) on fixed plot with sorghum-sunflower sequence.

**Effect of long-term application of N on CEC**

CEC, an abbreviation for Cation Exchange Capacity, refers to the number of negative charges available on the surface of soil particles. It gives an indication of the potential of the soil to hold plant nutrients, by estimating the capacity of the soil to retain cations, which are positively-charged substances. Therefore, the CEC of the soil directly affects the amount and frequency of fertilizer application. The CEC reductions due to prolong soil acidification include both mineral weathering, including weathering of the clay minerals themselves, and formation of none changeable hydroxy-Al complexes in the interlayer region of the clays. The process of formation of hydroxyl-Al interlayers is a recognized form of soil weathering, often termed "chloritization" because of its tendency to form aluminous chlorite as an end product (Sposito, 1989).

The extent of reversibility of the charge reduction associated with soil acidity for CEC reduction, clay mineral dissolution and chloritization are almost certainly not reversible processes within a soil environment, and certainly not reversible with aglime amendment. If the cation exchange capacity reduction is due to variable charge considerations, then the reduction may be reversible by pH amelioration and base supply with agliming, although hysteresis cannot be ruled out. Without studying the mechanism of charge reduction in this soil and the extent of the reversibility of the phenomenon, the extent to which soils have been permanently altered by common agronomic fertilization practices will be unresolved.

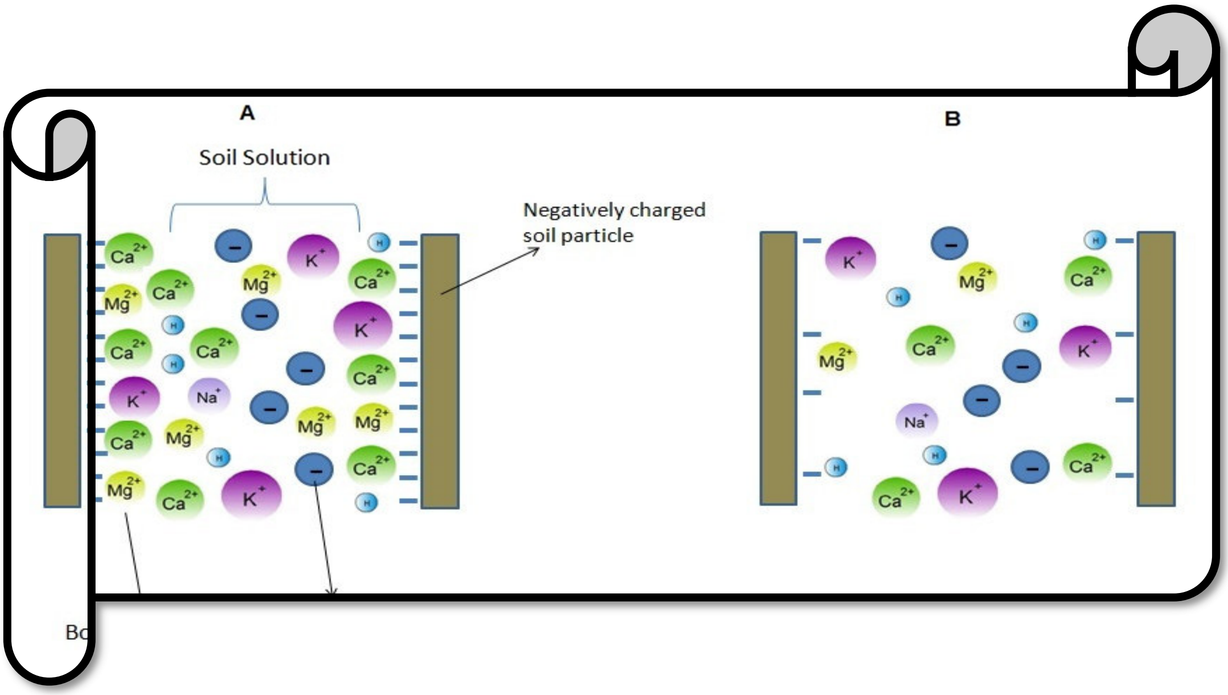


Fig.3 Soils with high CEC typically have a high clay and organic matter content. These soils are considered to be more fertile, as they can hold more plant nutrients. Sandy soils typically have a lower CEC and require more frequent fertilizer applications (Sposito, 1989).

**The Effects of Chemical Fertilizers on Soil**
**Ground Water Pollution**

The persistent use of chemical fertilizers causes the pollution of ground water sources, or leaching. Chemical fertilizers that are highly soluble get absorbed by the ground more rapidly than they are absorbed by the intended plants (Zhang *et al,* 2007; Brady and Weil 2002). Plants have the capacity to absorb only a given level of nutrition at a time leaving the rest of the fertilizer to leach. Leaching is not only hazardous to groundwater sources but also to the health of subsoil where these chemicals react with clay to create hard layers of soil known as hardpan. As a result of chemical fertilizer use the health of soil and water is jeopardized, not to mention the waste of money and nutrient deficient plants (Sposito, 1989).

**Soil Friability Effect**

The presence of a number of acids in the soil, such as hydrochloric and sulfuric acids, creates a damaging effect on soil referred to as soil friability (Mengel and Kirkby, 2001). The different acids in the soil dissolve the soil crumbs which help to hold together the rock particles. Soil crumbs result from the combination of humus, or decomposed natural material such as dead leaves, with clay. These mineral rich soil crumbs are essential to soil drainage and greatly improve air circulation in the soil. As the chemicals in the chemical fertilizers destroy soil crumbs, the result is a highly compacted soil with reduced drainage and air circulation (Wendt *et al*., 1988).

**Destruction of Micro-Organisms**

The synthetic chemicals in the chemical fertilizers adversely affect the health of naturally found soil micro-organisms by affecting the soil pH. These altered levels of acidity in the soil eliminate the micro-organisms beneficial to plant and soil health as they help to increase the plants' natural defenses against pests and diseases. These helpful micro-organisms consist of antibiotic-producing bacteria and mycorrhizal and other fungi which are found in healthy soil. The use of chemical fertilizers also jeopardizes the health of bacteria that fix the nitrogen balance in the soil. These nitrogen-fixing bacteria are responsible for converting the atmospheric oxygen into a form of nitrogen that can be used readily by plants (Yan *et al.* 2007).

**Effect inorganic fertilizers on soil fertility and productivity**

Results from the study of (Sharma *et al*., 2014) indicated that addition of FYM along with inorganic fertilizers improved soil organic carbon, CEC, bulk density, and exchangeable cations (Ca and Mg) over the treatments without FYM. Farmyard manure addition with inorganic fertilizers has resulted in moderating effect on soil pH. Balanced application of inorganic fertilizers either alone or with organics improved available N and P over their initial contents. Continuous use of imbalanced inorganic fertilizers resulted in decreased crop yields. The addition of FYM along with NP fertilizers and use of recommended dose of fertilizers resulted in good yields and thus sustained productivity in both wheat and maize crops (Sharma *et a*l., 2014). They also concluded that fertilizers play vital roles in production and productivity of any crop, but the continuous imbalanced use of chemical fertilizers adversely influences production potential. Organic manures can supply a good amount of plant nutrients, improve soil health, and contribute to crop yields substantially (Suresh S et al., 1999). Integrated nutrient management of chemical fertilizers and organic manures, therefore, is one of the viable options for sustaining soil health and crop productivity (kuntal et al., 2007). Thus, it is of great relevance to countries like India where increase in food grain production in limited available land is needed to meet the rising food grain demand of increasing population.

**Effect on Available micronutrients**

The enhancement in the DTPA- Fe due to the addition of organic substances may be ascribed to their ability to form stable water- soluble complexes preventing the reaction with other soil constituents and also increasing the Fe content by releasing it from the native reserves (Govindarajan SV, HG GopalaRao., 1978). Addition of lime along with the NPK increased the availability of micronutrients in soil, which might be due to the higher organic matter content of these soils supporting enhanced microbial activity and consequent release of organic complexing substances, which would make micronutrient cations labile (Subramanian KS, Kumaraswamy K ., 1989). According to the study of (Hemalatha *et al*, 2013) the depletion rate of DTPA- extractable micronutrients was higher in soils treated with chemical fertilizers alone as compared to the treatments that received both fertilizers and organic manures after completion of 12 cycles of rice- wheat sequence (Vyas *et al*., 2003). The DTPA - Mn content in soil showed statistically significant positive effect of all balanced fertilizer treatments (Singh *et al*., 1998). The DTPA - Zn content of N, NK and NPK treatments were observed to be higher than that of control. The DTPA - Zn level in NPK + Zn treatment was higher (2.75 mg $kg^{-1}$) due to continuous application of Zn in the soil.

## SUMMARY AND CONCLUSION

This paper showed that long-term annual application of urea resulted in soil acidification and decreases in exchangeable Ca and Mg, especially if these were already low in the soil. Soils which received various rates of acid-forming fertilizer inputs for 30 years reveals reduction of pH measured in water and strong salt, accumulation of exchangeable acidity, decrease in exchangeable $Ca^{2+}$ and $Mg^{2+}$, and reduction of CEC associated with the rate of N fertilization. Clay analysis showed that the CEC losses of 15% were not recoverable by saturating with 50-fold excess of $Ca^{2+}$ under laboratory conditions. Analysis of above-ground plant material shows that increasing N fertilization rates cause decreasing N fertilizer efficiency, leaving a larger portion of the acidity generated by nitrification in the soil. Plants sequestered between one-half and three-quarters of the alkalinity generated by N and S assimilation in the harvestable plant material, although harvesting grain only and retaining plant residue to soil would decrease the acidifying effect of fertilization. Therefore, these findings suggest that it is advisable to recommend use of agricultural lime with the use of urea fertilizer in order to maintain favorable soil reaction (pH) and soil fertility. Instead of using long term chemical fertilizer it is better using of organic fertilizer for improving and integrated soil fertility management rather continues chemical fertilizers.

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