SOIL HEALTH EVALUATION AS A RESULT OF USING GASEOUS AMMONIA AT DIFFERENT TIME PERIODS

Submitted By

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A thesis submitted in Partial Fulfillment
Of
The Requirement for the Master Degree
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APPROVAL SHEET

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ABSTRACT

Amal Abd El Gabar Mohamed Abd El Wahab:

- This study was carried out to investigate the effect of long–term application with anhydrous ammonia on physicochemical properties of soil and soil microflora and nematodes. Soil samples were collected from different localities at El-fayom Governorate. Results revealed that two soil texture of EC. All tested soil collected from different localities were slightly alkaline. High percentage of organic matter was detected at depth 15 -30 cm of all sites treated with anhydrous ammonia. The highest sodium percentage was were recorded being sandy clay soil for Hossam Nassar farm site and sandy clay loam soil for both of Rahil and Tamia localities. Soil of Rahil and Tamia localities gave the highest values noticed at Tamia site.

The highest amount of N and K was recorded in soil collected form Hossam Nassar (10 years long –term application). The total microbial count was recorded at the second depth (15 -30 Cm) than that observed at the first one. Total fungal counts recorded the highest values in soil samples collected from Rahil and Tamia treated with ammonia. Asymbiotic aerobic nitrogen fixers showed high percentage at soil treated with urea. Clear retardation of harmful Nematodes was recorded in soil treated with ammonia at different sites and at different depths.

Key Word : Anhydrous Ammonia, Physical and Chemical porpertes, Micro flora, Nematodes.

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Abbreviations

A A : Anhydrous Ammonia
ANF: Asymbiotic Aerobic Nitrogen fixers
AOB: ammonia-oxidizing bacteria
CFU: Colony Forming Unit
CTKI: Conventional till knife injection
DN : Died Nematodes
DSm^{-1}: Deci Semens /Meter
EC : Electrical Conductivity
FN: Free Nematodes
GY: Grain yield
HSLD: High speed low draft
LSD: Least Significant Difference
MPN: Most Probable Number
NDVI: Canopy normalized difference vegetative index
O M : Organic Matter
PN: Parasitic Nematodes
SD: Standard Deviation
SE: Standard Error
SP: Spring pre-plant
TF: Total Fungi
TMC:Total microbial count
TN: Total Nematodes

1-Introduction

In Egypt, the consumption of mineral fertilizers, mainly nitrogen fertilizers have tripled during the last 30 years. This increase is due to various factors including: the additional cropped area, the introduction of new high yielding varieties which need higher rates of fertilizers and increased cropping intensity that reached about 180 percent. On the other hand, global fertilizer prices rise more than 200% in 2007 as farmers applied more fertilizer to maximize production and to replenish nutrient-depleted soils.

This fact encouraged the researchers to use other forms of fertilizers, such as anhydrous ammonia, that is efficient and cost effective. Anhydrous ammonia, (NH_3) is one of the most efficient and widely used sources of nitrogen for plant growth. The advantages of ammonia relatively easy application and ready availability have led to increase its application use as a fertilizer. Ammonia is known with its sharp and pungent fumes given off by household ammonia.

The primary ammonia for agriculture use is the same substance; it is the pure ammonia compound consisting on weight basis by 82% nitrogen and 18 % hydrogen. If liquid ammonia is released in the atmosphere, it rapidly expands into a gas which is colorless although it first appears as a dense white vapor due to the absorption of heat from the atmosphere. One m^3 of liquid expands to about 859 m^3 of vapor.

Immediately after fertilization, high concentrations of ammonia temporarily inhibit soil microbes in the fertilizer retention zone. Bacteria are sensitive to ammonia and are affected by it to a greater extent than fungi. Over time, ammonia concentrations gradually decline as the ammonia adheres to soil particles or moves with water away from the application site. As ammonia concentrations decrease, soil microbes repopulate in the affected area.

The main objectives of this study was to investigate the effect of a long – term application of anhydrous ammonia as a nitrogen fertilizer on the physicochemical properties of soil at different depths. Three localities were selected for this study at El- Fayom Governorate. These localities were Hossam Nassar ,Rahil and Tamia which there soils were injected with anhydrous ammonia as a long – term application being 15,10 and 5 years respectively. The effect of a long – term application of anhydrous ammonia on the microbial load and nematodes were also elucidated.

2- Review of Literature

Soil health indicators are a composite set of measurable physical, chemical and biological attributes which relate to functional soil processes and can used be to evaluate soil health status. It is realized that the former term (soil health) gives greater emphasis on soil biodiversity and ecological functions that make soil a dynamic living resource with capacity for self-organization. **Diane *et al.*(2011). Mortland (1958)** stated that ammonia may be sorbed on colloidal systems by chemical or physical mechanisms or a combination of them. Chemical sorption by soils is expected where hydrogen ions are present with the resulting formation of ammonium ions.

The H^+ ions may arise from the soil solution or the soil phase. In the case of hydrogen ions provided by the soil solution, an ordinary chemical reaction takes place to form either a salt or ammonium hydroxide. In the case of the reaction of ammonia with hydrogen ion associated with clay minerals and organic matter, the ammonium ion is also formed but in an association with these materials.

The most common local of labile H^+ ion on clay minerals and organic matter is at cation exchange sites. Upon reaction of ammonia with these hydrogen ions; ammonium ions become the exchangeable ions. Physical sorption of ammonia by soils is nonspecific in that the presence of H^+ ions is not required. It involves lower sorption of energy than the chemical sorption and therefore is more easily reversible. ***Mortland (1966)*** explained the mechanisms by which the ammonia adsorbed on clay minerals. He stated that these mechanisms range from weak physical forces to strong chemical bonds and the formation of the ammonium ions results when hydrogen ions on the exchange complex react with ammonia. The ammonium ion may enter into fixation reaction with certain clay minerals in a manner similar to potassium fixation.

2.1. Factors affecting maximizing nitrogen availability in soil

2.1.1. Placement depth

Gros (1951) showed that the proper depth of anhydrous ammonia is 6 inches below the surface of the soil. On the other hand, **Baker *et al.* (1959)** revealed that depths of 2 to 3 inches were completely adequate for maximum retention of anhydrous ammonia at usual field application rates. Ammonia losses were reduced considerably when the application was changed from 40-inch to 16-inch spacing's and the rate applied per acre was maintained a constant. **Allison (1966)** stated that an adequate depth of anhydrous ammonia incorporation is essential for minimizing NH_3 volatilization losses. **Fenn and Kissel (1976)** mentioned that the objective of this study was to determine the influence of soil cation exchange capacity (CEC) and depth of incorporation on NH_3-N volatilization from NH_4^+-N compounds applied to calcareous soil. This study was conducted in the laboratory on soils with a wide range of CEC. An increasing CEC resulted in decreasing NH_3 losses.

Ammonium sulfate produced higher soil pH values and NH_3 losses than did NH_4NO_3.The pH of the soil decreased with increasing NH_4NO_3 application rates. With NH_4NO_3 percent NH3-N losses decreased with increasing application rate; however, with $(NH_4)_2SO_4$, percent NH_3-N losses increased as the application rates increased. Incorporation of the NH_4^+-compounds into the soil reduced NH_3 losses. Increasing depths of NH_4^+- N incorporation resulted in reduced NH_3 loss. Losses decreased as the CEC of soil increased.

The effectiveness of soil depth in reducing NH_3 loss was associated with soil water content. Decreasing the soil water increased the effectiveness of soil incorporation for reducing NH_3 losses. Two regression equations were developed to describe NH_3 losses with respect to CEC, soil pH, time, NH_4^+-N application rate and temperature. Correlation coefficients were 0.86 and 0.81 for $(NH_4)_2SO_4$ and NH_4NO_3 systems, respectively.

Murphy *et al.*(1978) indicated much greater efficiency of nitrogenous fertilizers when nitrogen was knifed into the soil compared with surface application. ***Vitosh (1982)*** reported that anhydrous ammonia (AA) is a widely used N fertilizer because of the many positive agronomic and logistical characteristics of the product. The effects of AA on the soil are generally minimal with regard to soil physical and chemical properties when compared to other N fertilizer sources. While AA can have an immediate effect on soil microbe populations, these effects are localized and not long lasting. Altering the concentration of AA in the retention zone by varying knife spacing can have an effect on ammonium persistence in the band. This effect can lead to less N losses in the soil when conditions for loss are favorable. Yield data has concluded no significant difference in grain yields at different AA band application widths.

Hagin and Tucker (1982) stated that anhydrous ammonia is stored and transported to the field under pressure in the liquid form in carbon steel containers. As the liquid is released into the soil it is vaporized to NH_3 gas. The slit may be the applicator knives must immediately close as the applicator knives are drawn through the soil in order to trap all the gas. As long as the soil is in good tillable condition with sufficient soil mulch on the surface to close the opener slit, application losses will be negligible. Depth application must be regulated accordingly, in order to prevent losses .

Sommer and Christensen (1992) reported that the losses form a dry and a wet soil were 20% and 50% of injected ammonia, respectively. From The dry soil, losses of gaseous ammonia took place within the first hours after injection, which indicates a rapid transport through cracks and voids. From the wet soil, 20% of the injected ammonia was lost more gradually between 6 hours and 6 days. This indicates that upward movement of water due to evaporation may be the main cause of ammonia losses which proceeded for longer periods. Soil bulk density and soil compaction showed that losses were insignificant from a moist soil.

Hanna *et al.*(2005) stated that anhydrous ammonia (NH_3) was injected below the soil surface during application to limit loss to the atmosphere. Application at a shallower depth may reduce tractor power or allow greater speed. Losses of NH_3 during the 1st hr. after field application were measured from a typical knife injector treatment operated at a 15 cm depth and 8 km/hr. travel speed and from a single-disc injector at shallower depths (5 and 10 cm) and a range of travel speeds (8, 12 and 16 km/hr).

NH_3 losses during application as measured with a hood over the single-disc injector were 3% to 7 % in clay loam, silty clay loam and loam soils and 21% to 52% in a coarser-textured fine sandy loam soil. Applying NH_3 with a knife injector at deeper depth resulted in losses of 1% to 2% across all soil types. NH_3 losses measured during an hour after application with stationary collection over the injected trench were 1% or less for all treatments.

2.1.2. Effects of anhydrous ammonia indication

Intrawech *et al.* (1982) investigated the influence of various N sources including anhydrous ammonia on soil physical properties. They found that such properties as hydraulic conductivity, bulk density, water-stable aggregates, compatibility and penetrometer resistance at field capacity were unaffected by fertilizer treatment. **Darusman *et al* .(1991)** observed that the comparisons of anhydrous ammonia, ammonium nitrate, urea and urea- ammonium nitrate solution in four Kansas soils at N rates 112-224 kg ha^{-1} showed no difference among N fertilizers on soil acidification. Also no effects on soil physical properties were observed after 20 years of annuals application of these N sources.

Schmitt and Rehm (1993) reported that anhydrous ammonia is often perceived as being detrimental to several physical and chemical soil properties. Results from a long-term (10yr) study comparing the effects of several N sources and a control (no N) revealed that none of the N sources were significantly different from each other or the control (no N).

This was true when measured in the plow layer (shallow) or just beneath the plow layer (deep). They also indicated that application of all the N-fertilizer sources, significantly reduced soil pH as compared to the control treatment. Because nitrification of ammonium is an acid forming reaction, the net effect will be a lowered pH.**Tisdale *et al.*(1999)** reported that several long-term studies have shown no differences among N sources included anhydrous ammonia on soil physical properties.

2.1.3. Effect on soil micro-organisms, nematodes and nitrification:

Eno *et al.* (1955) reported that the application of anhydrous ammonia to soil by conventional applicators employing knife-type injectors results in large concentrations of ammonia in a localized area. The effect of these concentrations on the soil population has been evaluated in several ways. The numbers of fungi and nematodes were reduced by all levels of ammoniacal nitrogen from 741 to 136 ppm.

Compared to untreated soil, only 0.6% of the nematodes and 4.9% of the fungi survived at 608 ppm of ammoniacal nitrogen in the soil. This level of ammoniacal nitrogen occurs regularly in the retention zone when anhydrous ammonia is applied in the field. The largest reduction in both nematodes and fungi occurred above 365 ppm. Field studies showed a drastic reduction in all nematodes in the retention zone.

Plant parasitic nematodes were greatly decreased and in many cases, certain species could not be detected during counting. Reestablishment of the nematodes was greatest among the saprophytic species and was of the same character as that following fumigation with conventional nematodes. The economic value of the reduction of plant parasitic nematodes by anhydrous ammonia, applied primarily for its nitrogen content, will require further work on a field basis. Gross elimination of nematodes is not necessary for successful crop production. Thus, it can be seen that in addition to the primary use of anhydrous ammonia as a fertilizer, the destruction of plant parasitic nematodes in the retention zone also may be of value. They also added that nitrification studies showed this process to be inhibited by concentrations of ammoniacal nitrogen above about 300 ppm. The field situation is probably one where nitrification is inhibited within the retention zone but not at the periphery and, therefore, the nitrifiers gradually reduce the concentration of ammonia centripetally until all of it is utilized. Immediately after fertilization, high concentrations of ammonia temporarily inhibit soil microbes in the fertilizer retention zone. Bacteria are sensitive to ammonia and are affected by it to a greater extent than fungi. Over time, ammonia concentrations gradually decline as the ammonia adheres to soil particles or moves with water away from the application site. As ammonia concentrations decrease, soil microbes repopulate in the affected area.

Addiscott *et al.*(1992) explained that once in the soil ammonia reacts with water to produce ammonium. Either the large localized concentrations of ammonia or the intense alkalinity has an inhibitory effect on the microbes that only wears off slowly. **Blackmer (1992)** stated that anhydrous ammonia. (The most commonly used nitrogen N fertilizers in lowa) is unique in the ways it behaves in soils, it immediately reacts with the soil to form ammonium (NH_4^+) an ion that is strongly attracted to soil particles. Because of this strong attraction, the ammonium ions are retained in high concentrations that are localized within bands formed by the fertilizer applicator. The high ammonium concentrations found in these bands is the major factor that distinguishes anhydrous ammonia from other fertilizers. High ammonium concentrations localized within bands tend to retard the fertilizers conversion to nitrate (NO_3^-). This retardation gives the anhydrous ammonia a "slow-release" characteristic. In an effort to create this slow- release effect, farmers-until recently unaware of this characteristic of anhydrous ammonia – often purchased inhibitors(compounds that "Stabilize" the fertilizer by retarding the conversion of ammonium to nitrate).Nitrate, unlike ammonium, can leach (percolate) from the root zone when excess water passes through the soil. It also can be converted to a gas (denitrified) when excess water remains in the soil.

Strong (1995). reported that within the zone of influence of anhydrous ammonia, numbers of fungi, nematodes and bacteria were reduced temporarily, serval days after application, the numbers of bacteria had increased to between 6 and 25 fold those of untreated soil. Change of the microbial population was essentially confined to the