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Nitrogen Transformations as affected by some factors at cultivated soils in Saudi Arabia

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تأثير بعض العوامل على تحولات النيتروجين في الترب الزراعية بالمملكة العربية السعودية

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المملكة العربية السعودية

تمت دراسة تأثير التركيزات المختلفة من الملوحة والمادة العضوية والمحتوى الرطوبي على تحولات النيتروجين في عينات تربة رملية جمعت من المملكة العربية السعودية. تم إضافة كبريتات الأمونيوم بمعدل ٥ ملجم/جم تربة ووضعت التربة عند درجة ٢٥°م لمدة أربعة أسابيع في الحاضنة.

وجد أن عملية تحولات النتروجين تتأثر بالملوحة في كل التراكيز. إضافة المواد العضوية (قش القمح) شجع كثيراً على عملية تمثيل النيتروجين. وتلاحظ أيضاً أن تحولات النيتروجين وصلت أعلى معدل لها عند رطوبة ٧٠٪ من السعة المائية، وتتناقص مع زيادة رطوبة التربة.

Key Words: Ammonium oxidation, nitrification, organic matter, salinity, soil moisture.

ABSTRACT

The influence of serial concentration of salts (0.5, 1.0 and 1.5%), application of organic matter (0.5, 1.0 and 1.5% of wheat strat) and varying soil moisture content 50, 70 and 90%) on nitrification in sandy loam soil was studied. Ammonium sulphate (5 mg N g-1 soil) was added and the soil samples were incubated at 25°C for 4 weeks. Increased salinity delayed or inhibited nitrification. Addition of organic matter enhanced nitrification processes. The nitrification rate showed progressive increase with time at 70% water holding capacity, but as moisture increased the nitrate production decreased.

INTRODUCTION

Nitrogen is essential for life and its transformations in soil are integral parts of the overall nitrogen cycle in nature. Microbial activity in the soil is important in the cycling of nitrogen and organic matter decomposition. Nitrification in soil involves the oxidation of ammoniu, via nitrite, to nitrate (1). It is generally accepted that the dominant form of nitrification in most soils is chemoautotrophic, largely carried out by the Gram-negative bacteria *Nitrosomonas* and *Nitrobacter*. A wide variety of heterotrophic fungai have been shown to be capable of oxidizing reduced forms of nitrogen (2). Certain fungi and heterotrophic bacteria have also a role to play in nitrification, particularly in acid forest soils (3).

Minimization of losses of nitrogen is one of the important goals of good soil management. It is generally recognized that in addition to removal of nitrogenin crops, losses from soil can occurby leaching of nitrate or reduction of nitrate to nitrogen gas, and by volatilization of ammonia. Therefore, in order to conserve soil nitrogen it may be necessary to control nitrification (4). Nitrogen transformations in soil are governed by various environmental factors, including moisture, salinity and organic matter (4,5,6).

The present investigation based on a laboratory experiment which extended to four weeks, was undertaken to study the biochemical transformation of ammonium sulphate nitrogen as influenced by moisture, salinity and organic matter.

MATERIALS AND METHODS

Collection and analysis of soil samples

Thirty kilograms of cultivated soil were collected in sterile polythylene bags from the upper layer (0-20 cm) from Riyadh area, Saudi Arabia. Analyses of soil were carried out according to the methods given by Jackson (7). Soil used in this study was sandy loam soil containing 56.4% sand, 6.1% silt, 37.5% clay, 7.5% $CaCO^3$, 0.34 organic carbon, 0.045% total nitrogen, 17 ppm nitrate-nitrogen, 27 ppm ammonium-nitrogen, C/N ratio of 8.3, pH of 7.8 and total solublesalts (T.S.S.) 0.083% (Allvalues are means of triplicates).

Nitrification and Extraction of soil Nitrogen ions

All collected samples were amended with ammonium sulphate (5 mg N g-1 soil), in order to determine the effect of moisture, salinity and organic matter on the process of nitrification of ammonium. Serial concentrations of salts (0.0, 0.5, 1.0 and 1.5%) and different rates of wheat straw (0.0, 0.5, 1.0 and 1.5%) were used. The soil moisture content was kept constant at 50, 70 and 90% of the water holding capacity (WHC). The soil samples were incubated in polythene bags, closed with a small hole to allow for gas exchange. The bags were set up in triplicate and incubated at 25°C for 4 weeks.

Ammonium was extracted from soil using KCL (1.5N), nitrate and nitrate were extracted from soil distilled with water. In all cases a 1:10 soil extractant ratio was used and the slurry was shaken for 15 min (100 throws min-1). After being shaken, the soil slurries were filtered through Whatman No.1 filter paper and the concentration of nitrogen ions determined. Ammonium by the indophenol blue method (8); nitrate using an Orange 1 method (9) and nitrite colorimetrically as described by Hesse (10).

Standard statistical procedures were applied for all data in order to see the relation between nitrification and factors. Minitab-for-Windows program was used in statistical analysis for all results obtained in this investigation.

RESULTS

The changes in the levels of ammonium, nitrate and nitrite of ammonium sulphate in soil as affected by serial concentrations of salts are shown in Fig. 1a - 1c. The data showed that nitrification of ammonium sulphate was greatly decreased by increasd salinity and was completely inhibited at 1.5% salinity. Ammonium sulphate in control soil (no salinity) completely nitrified within 4 weeks leading to the maximum nitrification rate of 35 ppm of nitrate. The nitrification rate decreased from the lowest salt concentration of 0.5% to the highest concentration of 1.5% after 4 weeks of incubation. The final nitrate concentrations of the soil samples were 25 and 12 ppm after an addition of 0.5 and 1.0% respectively. While 1.5% salinity suppressed nitrification for two weeks and then slightly increased (5 ppm) at the end of the experiment. The concentration of nitrite in all soil samples was highly fluctuated and tended to increase with time.

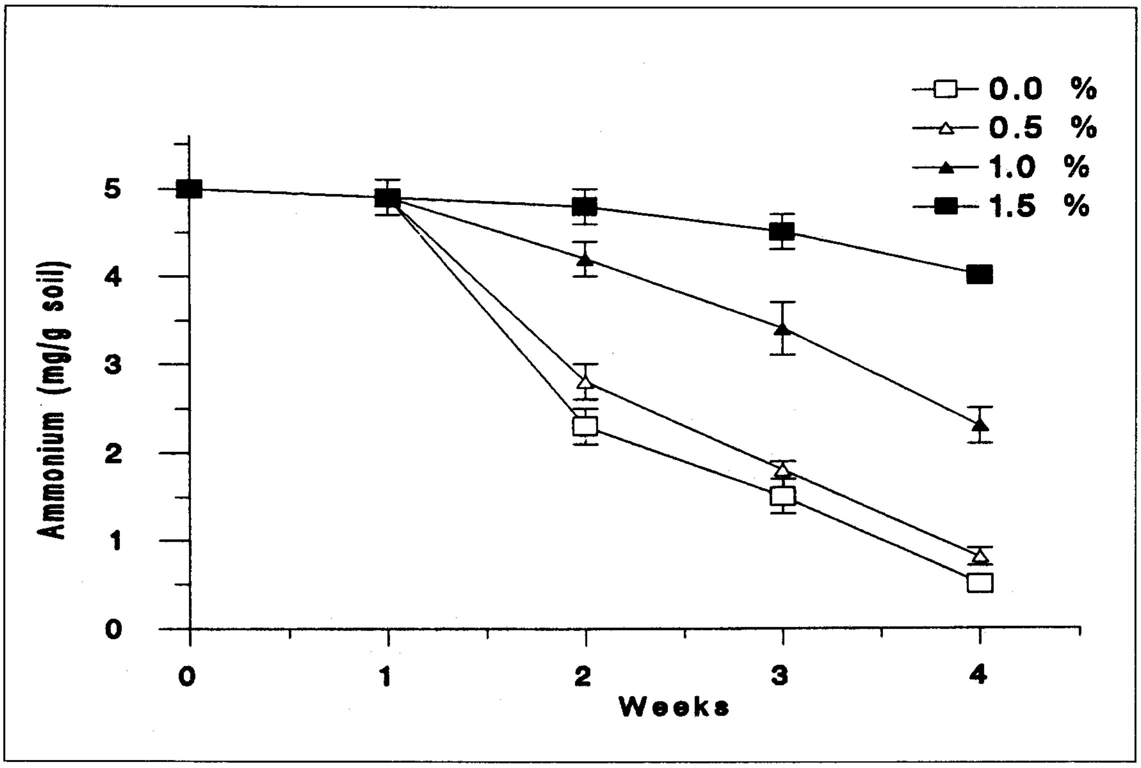

Fig. 1a. Effect of salinity of ammonium concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

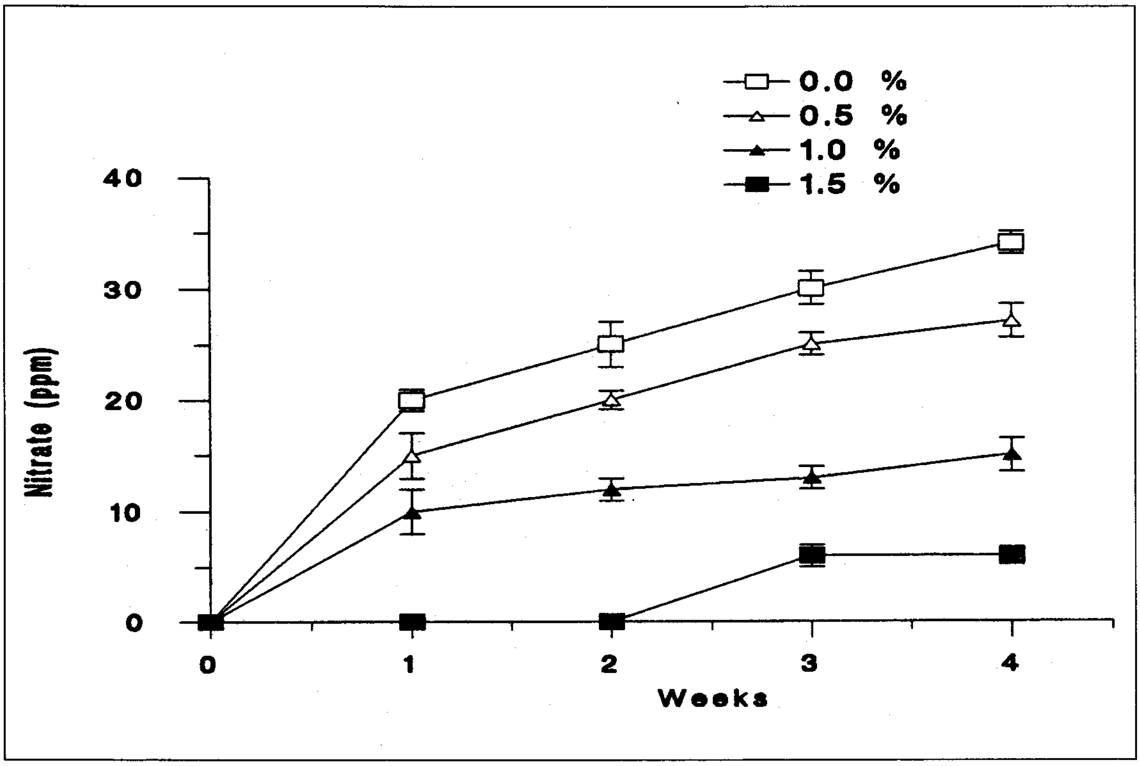

Fig. 1b. Effect of salinity of nitrate concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

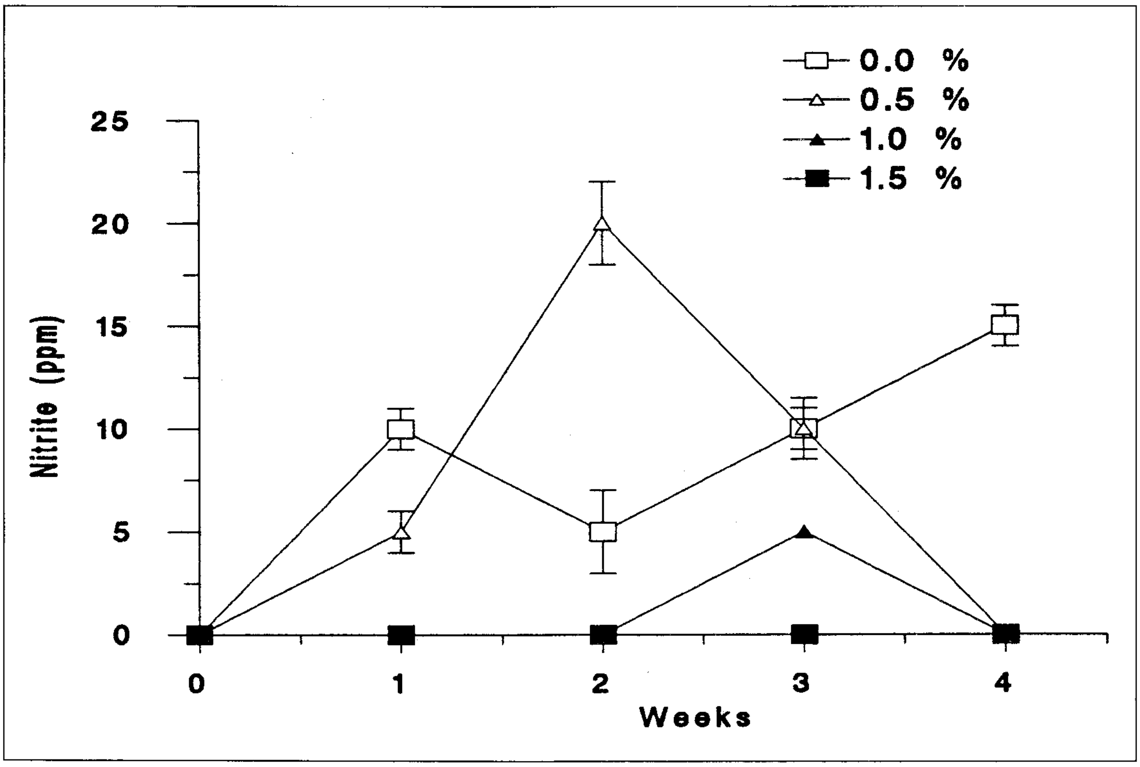

Fig. 1c. Effect of salinity of nitrite concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

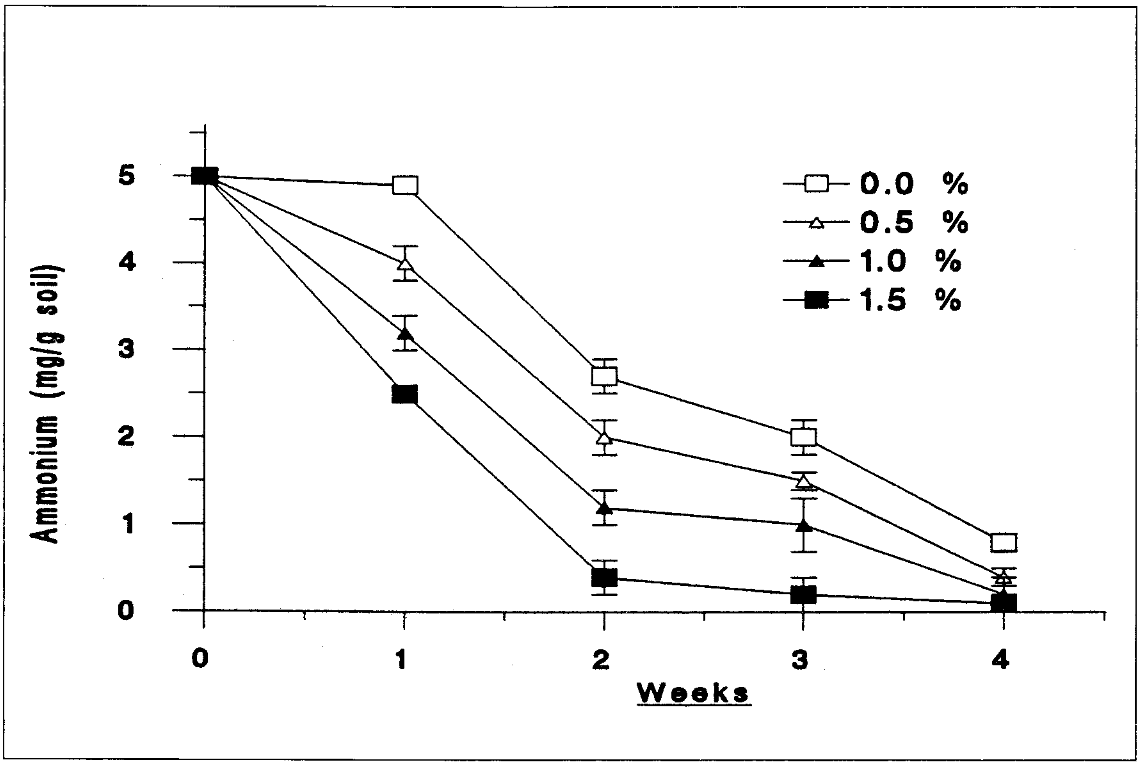

Fig. 2a. Effect of organic matter on ammonium concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

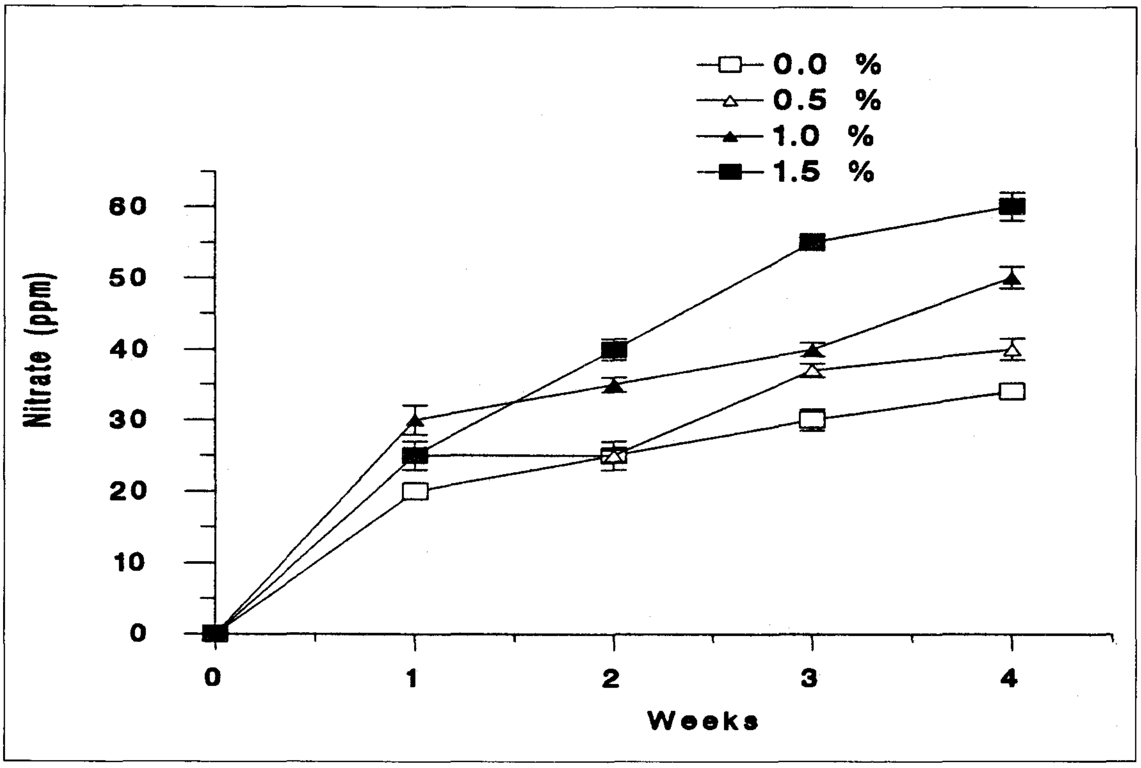

Fig. 2b.Effect of organic matter on nitrate concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

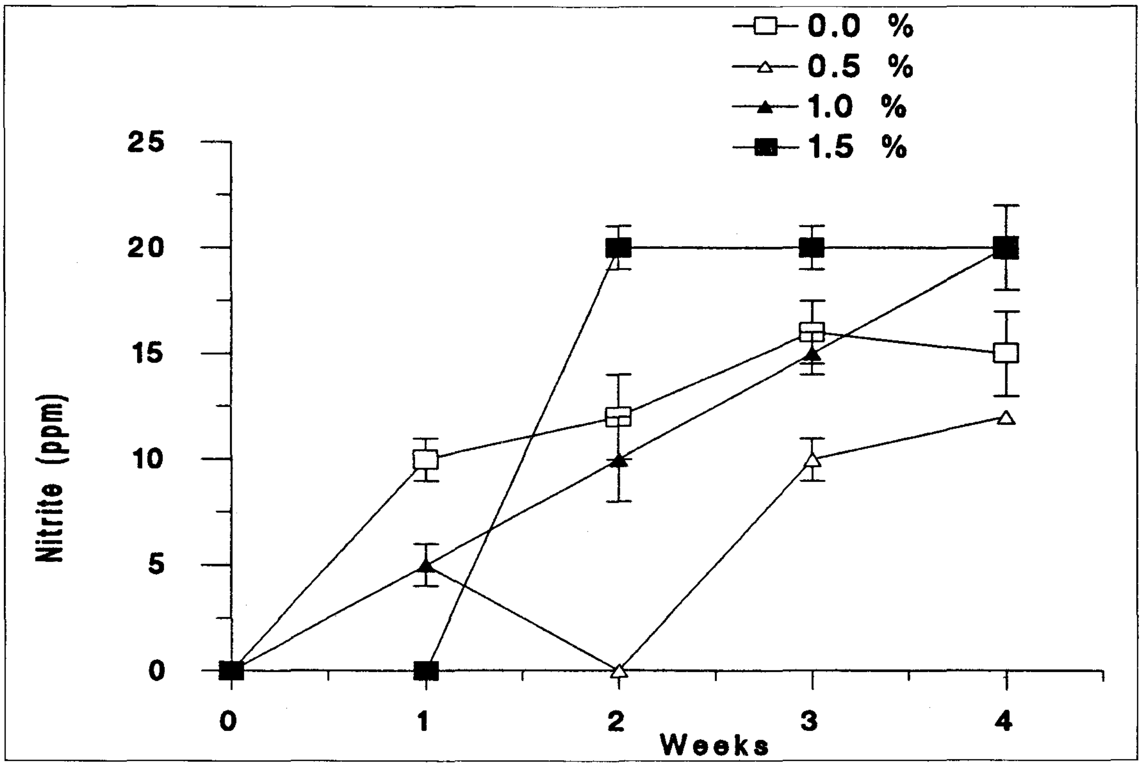

Fig. 2c. Effect of organic matter on nitrite concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

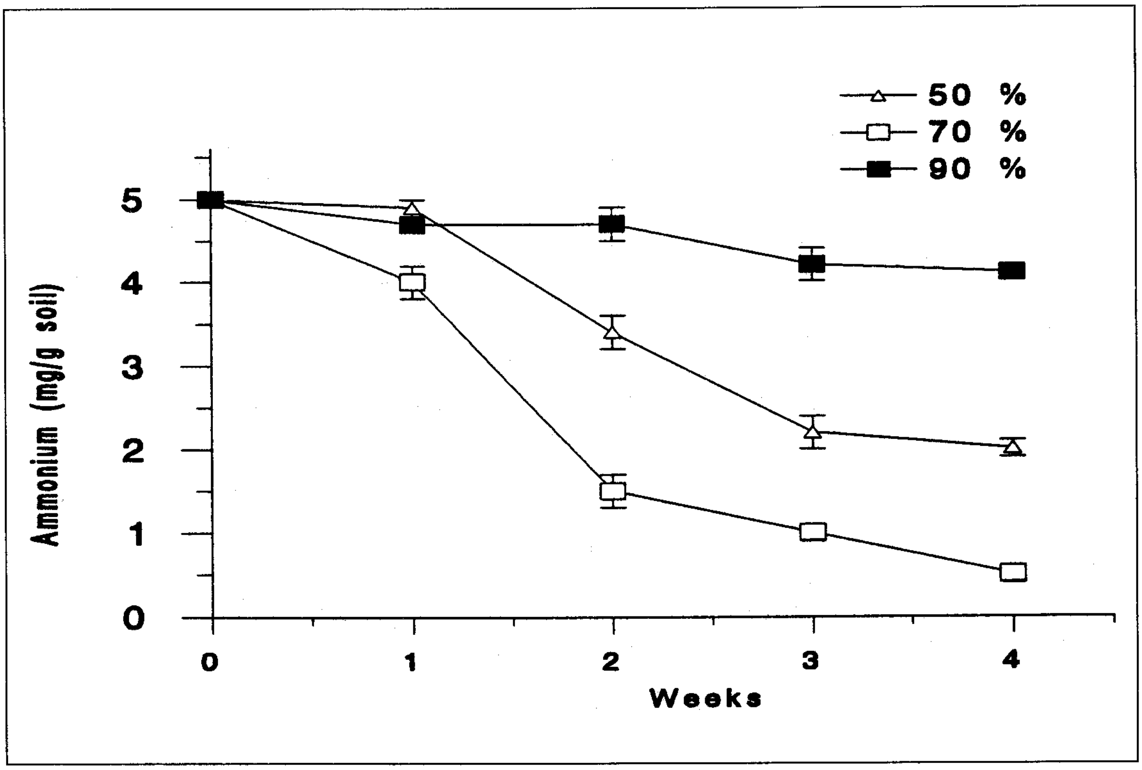

Fig. 3a. Effect of moisture content on ammonium concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

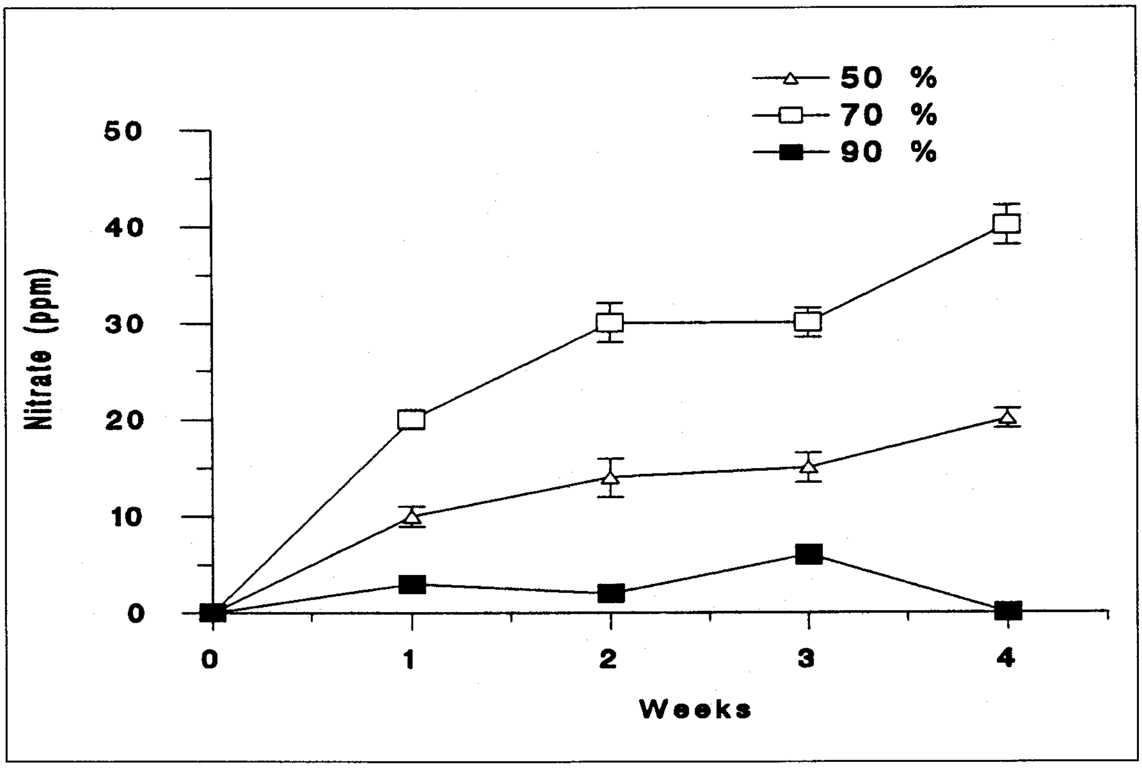

Fig. 3b. Effect of moisture content on nitrate concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

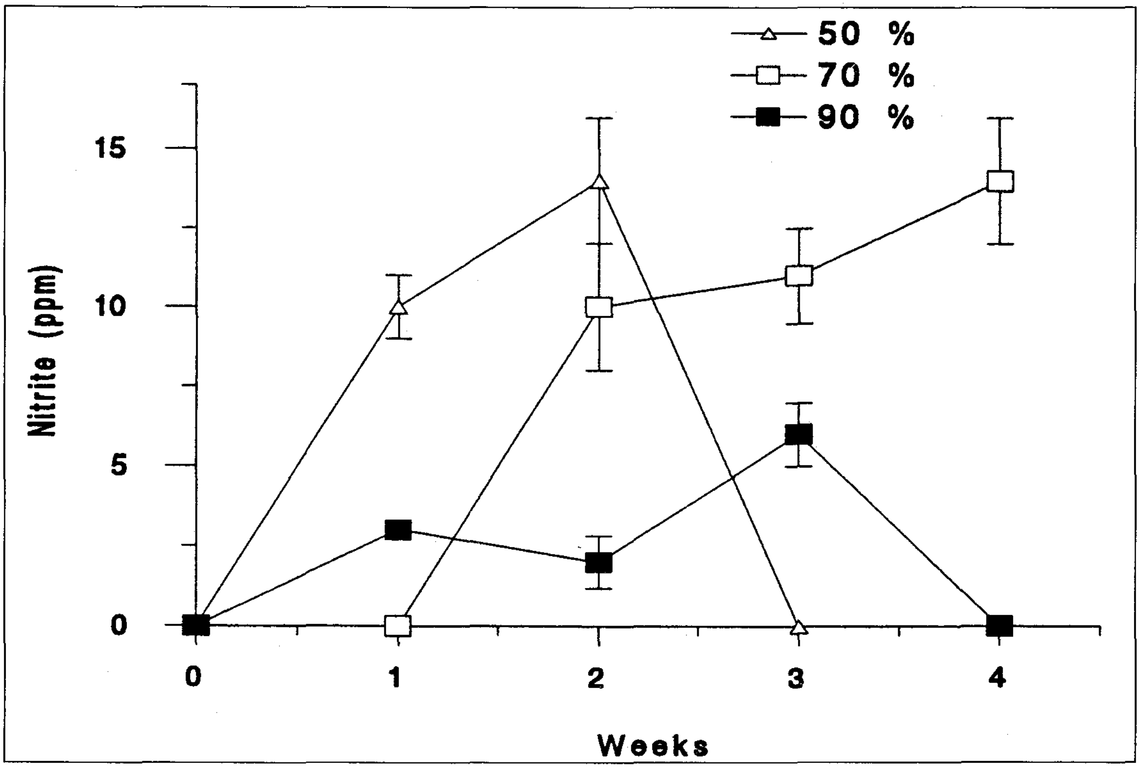

Fig. 3c. Effect of moisture content on nitrite concentration in soil samples treated with $(NH_4)_2SO_4$ at 5 mg/g. All values are mean of triplicates – S.D.

Changes in the content of the different forms of nitrogen as affected by organic matter (wheat strat) application are shown in Fig. 2a - 2c. Organic matter supplementation generally resulted a higher nitrate and nitrite concentrations. The increase in nitrate and nitrite was proportional to decrease in ammonium levels. The nitrification of ammonium sulphate was greatly increased by increased organic matter percentage and was completely nitrified within two weeks at 1.5% of organic matter, while ammonium sulpahte in control soil nitrified within 4 weeks. The maximum nitrification rate (62 ppm) was observed at the highest level of organic matter amendment (1.5%), approximately two-fold higher than the control soil. Nitrite concentration varied with time for all soil treatments. In general, as the organic matter increased the values of nitrite were higher.

Fig. 3a - 3C, illustrate changes in the content of the different forms of nitrogen as affected by moisture levels. The highest increased detected for nitrate was 40 ppm for the treatment of 70% moisture content. Both of 50 and 90% water holding capacity inhibited the nitrification of ammonium sulphate. At 50% water holding capacity nitrate progressively decreased with time, reaching 15 ppm at the end of the incubation time, but the treatment of 90% moisture concent, showed a greater decrease of nitrage and disappeared after 4 weeks.

DISCUSSION

In salts amended soils, the addition of 0.0, 0.5, 1.0 and 1.5% salt led to accumulation of 36, 25, 10 and 5 ppm nitrate respectively at the end of 4 weeks. This result indicated that addition of salts caused significant inhibition of the nitrification processes. The nitrification rate in soil samples after 4 weeks of incubation decreased with increasing concentrationof salts in the soil. As a result, the largest effect ofsalts on ammonium nitrification was observed at higher levels indicating the sensitivity ofnitrification to salt concentration. Similar results were reported earlier (6, 11, 12, 13), suggesting that nitrification occurring at higher salt concentrations may be chemical rather than biological in nature.

The results showed a small amountof nitrite in all soil samples tested with the exception in 1.0 and 1.5% salt (Fig 1c). Nitrite ion is usually considered to be intermediate and rarely exceed the concentration of nitrate. As a result, NO_2 ion was only formed transiently in trace amounts towards the end of the incubation period which was consistent with the findings of (4, 8, 11).

Application of wheat straw, as an organic carbon source, stimulated the nitrification processes. Therefore, the highest rate of ammonium oxidation recorded after the addition of maximum level of organic matter amendment.

The addition of organic matter to soils led to a marked increase in available carbon which was associated with a similar increase in numbers of both heterotrophic bacteria and fungi (11). Organic matter amendment therefore stimulated the nitrification of added ammonium. Stimulation of nitrification following organic matter amendment and the resultant increase in microbial numbers is to be expected since these are processes mediated by heterotrophic microorganisms (3).

Since nitrification is generally considered to be mediated by chemoautotrophic bacteria, it is surprising that this process was stimulated by the addition of a carbon source. Despite the fact that numbers of microorganisms do not always reflect rates of measured activity, the obvious explanation for this observed stimulation in nitrification is that it was due to the marked increase in population of heterotrophic microorganisms following organic matter amendment. Although heterotrophic microorganisms are known to be able to nitrify (14), with the possible exception of acid soils, they are thought to make only a minor contribution to nitrification rates in the environment. Although we did not determine the ability to the heterotrophic bacteria present in soil to nitrify, previous studies showed that a range of filamentous fungi and yeasts were capable of relatively rapid rates of nitrification *in vitro* (15).

The nitrification in soil is an oxidation processes catalysed by microorganisms and controlled by environmental factors including moisture and organic matter content (1, 5). The optimum rate of nitrification was detected at 70% of moisture content that permits presence of adequate oxygen supply which is necessary forthe sctictly aerobic nitrifying bacteria. Thus nitrate, form ammonium oxidation, accumulate with the lapse of incubation. Both 50 and 90% water holding capacity inhibited the ammonium oxidation rate. The highest moisture content (90% water holding capacity) limited oxygen diffusion in soil and hence suppressed nitrificationon one hand and encouraged deintrification and nitrate reduction on the other. Thus, nitrate was used by faculative anaerobes as the terminal electron acceptor instead of oxygen under anaerobic conditions. The rate of nitrification was highest at 70% water holding capacity due to growth and proliferation of aerobic and faculatively anaerobic microorganisms when adequate moisture and oxygen supply were present under suitable temperature (1,5).

In conclusion, the addition of organic matter enhanced nitrification processes. Nitrate concentration increased as the amount of organic matter increased. While increased salinity delayed or inhibited nitrification. The minimum oxidation of ammonium sulphate added was recorded at 1.5% of salts. The nitrification rate showed progressive increase with time at 70% water holding capacity, but as moisture content increased the nitrate production decreased.

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