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The Effect of Urea Fertilizer Loaded on Hydrogel Compounds Prepared from Gelatin in Increasing Nitrogen Availability and Reducing Ammonia Volatilization in Soil

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ABSTRACT
Objective: *This study aims to evaluate the effect of urea fertilizer encapsulated with hydrogel compounds prepared from gelatin on increasing nitrogen availability and reducing ammonia volatilization in soil.* ***Method:*** *A laboratory experiment was conducted using urea fertilizer coated with hydrogel composites at different encapsulation ratios of gelatin to sodium alginate (1:1, 1:2, and 2:1), designated as G1, G2, and G3, respectively. The hydrogels were crosslinked with 7% calcium chloride ($CaCl_2$) and applied to two soil types, clay loam and sandy loam, at a nitrogen rate of 1000 mg N kg $^{-1}$ soil. The samples were maintained at field capacity and incubated for 3, 6, 9, 12, 15, 20, and 30 days, during which ammonia volatilization and available nitrogen were measured.* ***Results:*** *The results demonstrated that urea encapsulated with hydrogel compounds significantly reduced ammonia volatilization and enhanced nitrogen availability compared to uncoated urea. Among the treatments, the 2:1 ratio (G3) showed superior performance in minimizing nitrogen losses and improving soil nitrogen retention.* ***Novelty:*** *This study introduces an innovative approach to nitrogen management through hydrogel-based encapsulation, highlighting its potential to improve fertilizer efficiency and mitigate environmental impacts associated with ammonia volatilization.*

INTRODUCTION

Nitrogen is one of the most important nutrients in fertilization programs, as plants need it in quantities greater than other elements. This element also contributes to the formation of chlorophyll molecules, the construction of proteins, enzymes, and cell membranes, in addition to its role in cell division and elongation. Queen New cells, It also enhances the ability of plants to withstand harsh environmental conditions [1]. Urea fertilizer is considered one of the most common sources in ready Soil nitrogen worldwide; due to what it contain of a high percent of reach to 46%, in addition to its low production costs [2]. The use of urea fertilizer as a source of nitrogen is accompanied by many problems, including the loss of large quantities of it through washing processes, as well as the volatilization process in the form of ammonia gas and oxides through the process of reverse nitrification and surface runoff when added to the soil surface. In order to get rid of this problem, research has been directed towards using for slow-release fertilizers that control the release of nutrients from them to the plant. This method is considered one of the important processes for increasing the efficiency of mineral fertilizers and reducing the loss of nutrients from the soil [3]. Where the trend was towards Studies to the use of renewable, biodegradable polymers that are available in nature and have a low economic cost, such as cellulose, which is the most abundant biopolymer on earth and is obtained from multiple sources such as cotton, wheat, and wood, as well as chitosan, which is in second place and is obtained by partial deacetylation of the group N-acetyl chitin is a major component of crustacean exoskeletons [4] . Also use gelatin with sodium alginate which dissolves in water to form gelatinous materials and Formation of calcium films, fibres and complex formations that are slow-release in agricultural applications and are biodegradable in the aquatic system at normal temperatures. Gelatin is a transparent, colorless, brittle, and biodegradable, flavorless polymeric substance obtained from animal bone collagen. It consists of nineteen amino acids and can therefore be hydrolyzed. There are many proteolytic enzymes to produce the amino acids that make it up [5]. In this research we prepared hydrogel polymer from gelatin and sodium alginate in presence of the crosslinking agent ($CaCl_2$) as a urea fertilizer loading agent to keep it from being lost and wasted, to make the urea fertilizer release process slow, and reduce ammonia volatilization and increase Nitrogen availability in soil.

RESEARCH METHOD

Packaging of urea fertilizer loaded on hydrogel polymers

A proportion of urea was weighed and 40 ml of urea solution with a concentration of 100% (50 g urea: 50 ml distilled water) was mixed with gelatin and sodium alginate in different proportions according to different combinations (1:1) G1, (1:2) G2, and (2:1)G3 (gelatin: sodium alginate) was added with continuous stirring of the solution until complete homogeneity was reached between them. The prepared solution was then slowly pumpedwitha5mLsyringeandaddeddropwiseto 10 mL of7% calcium chloride solution with continuous stirring for 30 minutes and left in the same reaction solution for 24 hours. After the hydrogel was completely formed into beads, the product was filtered, washed twice with distilled water, allowed to dry, and stored in the refrigerator at4°C. and Fig.1 represent the hydrogel beads shape.

Figure 1. The hydrogel beads

Swelling ratio study hydrogel polymer (%):

The swelling ratio of the prepared hydrogel was studied from the following equation:

$$\text{Swelling ratio (Sw)} = w_1 - w_0 / w_0 \times 100 \text{------------ (1)}$$

Where it represents w_1 wet hydrogel weight.
It represents w_0 dry weight of hydrogel (zero gel).

Swelling tests were performed at room temperature and 2 g of dried beads were kept in 5 mL distilled water for 2 hours. After the swelling period, the beads were collected, wiped gently with a paper towel, and weighed again. The dynamic weight change of the beads was termed the swelling degree (Sw) and calculated according to equation (1).

Laboratory experiment

100 g of air-dry soil was collected, sieved through a 2 mm sieve and placed in sealed plastic containers; urea was added in a steady and slow-release manner according to thecombinationofG1, G2and G3. These containers were moistened with distilled water to field capacity and incubated at laboratory temperature for different periods (3, 6, 9, 12, 15, 20 and 30). During this period, the amount of ammonia collected in 2% boric acid solution was measured using two different indicators (bromo cresol green and methyl red). The amount of volatile ammonia collected after each incubation period was calculated to estimate the following:

Total ready nitrogen (NH_4, NO_2 and NO_3)

For each experimental unit, after each incubation period,5 g of air-dried soil from the previoustreatmentwasweighed,50 ml of KCl (2M) was added, shaken for1h, filtered through filter paper 42 and 15 ml of the filtrate was placed in a steam distillationunit, towhich 0.2 g of MgO and 0.2 g of Devarda alloy(2%) with boric acid were added. Volatile ammonia was removed and titrated with hydrochloric acid at a concentration of 0.005 N to estimate total available nitrogen (NH_4), NO_2 and NO_3 in the sample [6].

RESULTS AND DISCUSSION

Figure (2) shows the effect of hydrogel compounds (fertilizer combinations) on the sorption rate: The sorption rate of G1, G2 and G3 increases with time; for G1, it can be seen that the sorption rate increases slightly until the saturation point is reached. The absorption of the hydrogels in distilled water reaches 30% after 30 minutes, 33.5% after 1 hour, 50% after 3 hours, 53% after 6 hours, and 53% after 24 hours, indicating that the saturation point has been reached and by 6 hours they can no longer absorb more water. The effect of the absorption rate of the hydrogel compound (G2) shows that in the first few hours the absorption rate increases until the saturation pointis reached. The absorption ratereaches 40% after 30 minutes, 46% after 1 hour, 68% after 3 hours, 92% after 6 hours and its stability is 92% until 24 hours after placement in water. Regarding the effect of the absorption rate of the hydrogel compound (G3), it can be seen that the increase in the absorption rate is higher than the beginning and reaches the saturation point after 3 hours. The absorption rate of the hydrogel reaches 55% after 30 minutes, 60% after 1 hour and 85% after 3 hours, indicating that the stability of the hydrogel up to24 hours after placement in water reaches full saturation after 3 hours and the water absorption rate is higher than the G1 and G2 combinations, gelatin and sodium alginate have the ability to absorb large amounts of water within their network structure without dissolving in water for long periods of time, and these results are consistent with the fact that gelatin is a protein macromolecule with a high amount of hydrophilic amino acid residues [8],[9]. Here, it was noticed that the rate of absorption of the gel polymer into water increased with time and the rate completely stabilized after a few hours in water.

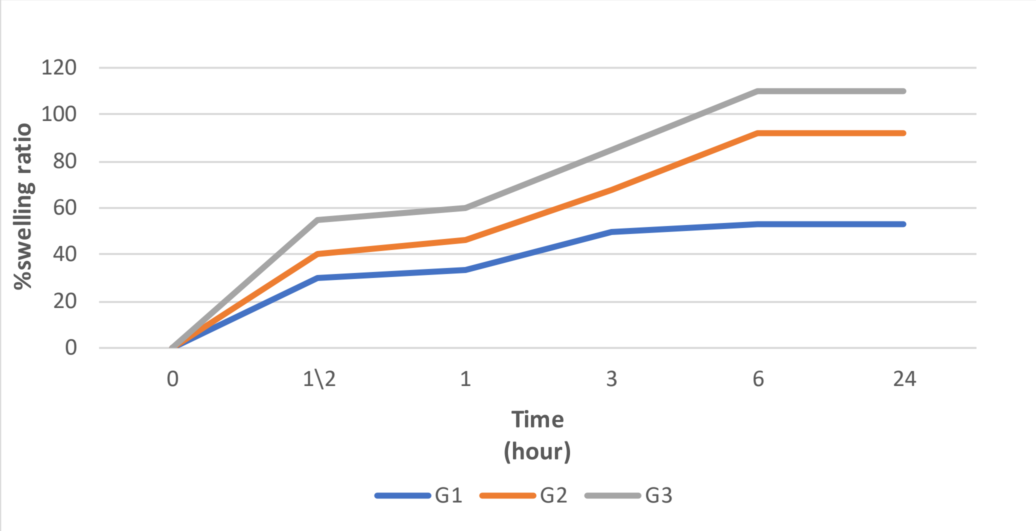


Figure 2. Absorption rate Swelling % of hydrogel G1, G2, and G3 with time

Volatility

Figure (3) shows the effect of hydrogel coated urea fertilizer combination on the volatile ammonia content of the two test soils. (01P≤). The G3 fertilizer combination produced the lowest volatile ammonia content with 10.79 and 29.7 mg NH_3-N kg-1 soil on clay and sandy loam respectively, while the comparison treatment produced the highest volatile ammonia content with 34.61 and 73.7 mg NH_3-Nkg-1 soil. 61 and 73.7 mg NH_3-N kg-1 soil on clay loam and sandy loam, the reason for the decrease in volatile ammonia content in urea fertilizer treatments is due to the inhibition of hydrolysis of urea and the nature of the combined composition of ا hydrogel in urea fertilizer packaging. Ammonia content decreased.

We noticed a reduction in the amount of volatile ammonia when urea was coated with plant extracts compared to the comparative treatment, which had the highest volatile ammonia volatilization rate [10], and found a reduction in the amount of volatile ammonia when urea was coated with HA-N chelate synthetic fertilizer [11] and we was noticed a decrease in the volatile ammonia volatilization rate when treated with the hydrogel.

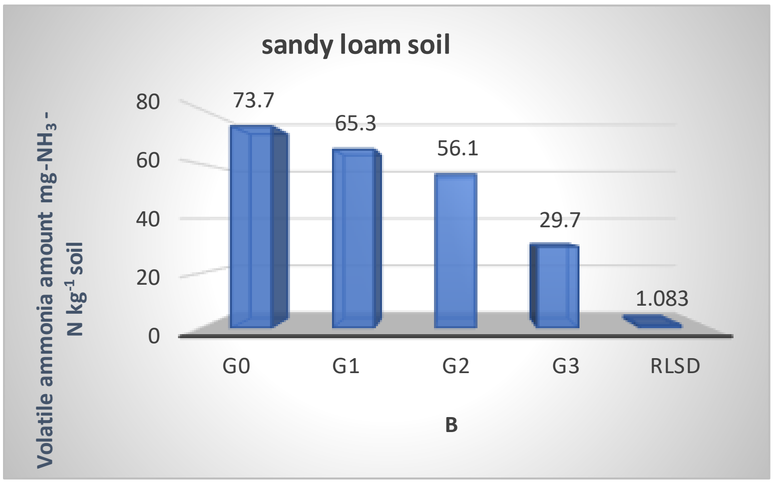
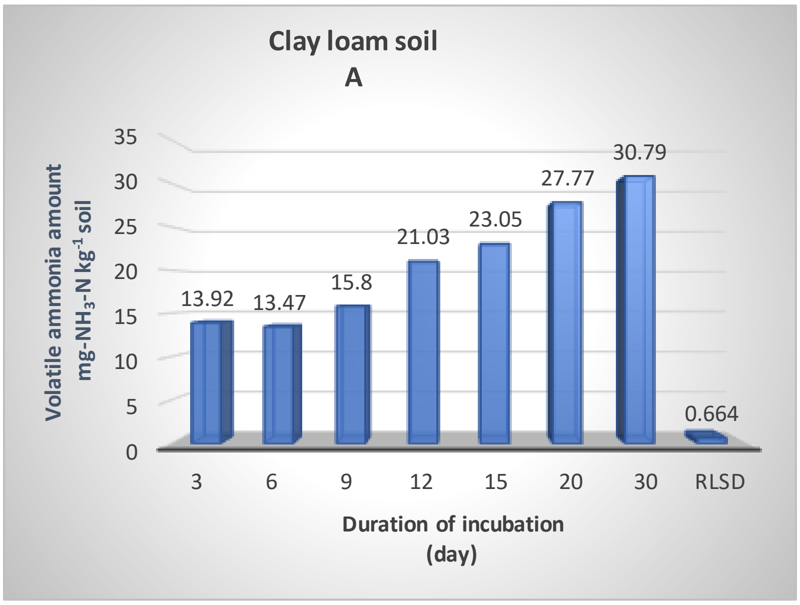


Figure 3. Effect of gelatin-coated urea fertilizer combinations on the amount of volatile ammonia for soils A- clay loam and B- sandy loam

Figure (4) The effect of incubation time on the volatile ammonia content of the two test soils was shown and significant differences were found for the mean values of 13.92, 13.47, 15.8, 21.03, 23.05, 27.77 and 30 and for each day of incubation time (3, 6, 9, 9, 12, 15, 20, 30)..79 mg.NH_3-N kg-1 soil and 39.3, 39.2, 40.3, 52.7, 62.5, 77.5 and 81.9 mg.NH_3-N kg-1 soil in sandy loam, respectively. This may be due to the gradual decomposition of the added fertilizer under the action of urease enzymes and the release of nitrogen, part of which is lost in the form of ammonia gas. This result is in agreement with the result found in references. He found significant differences in the percentage of volatile ammonia at incubation periods (3, 6, 12, 24 and 48).



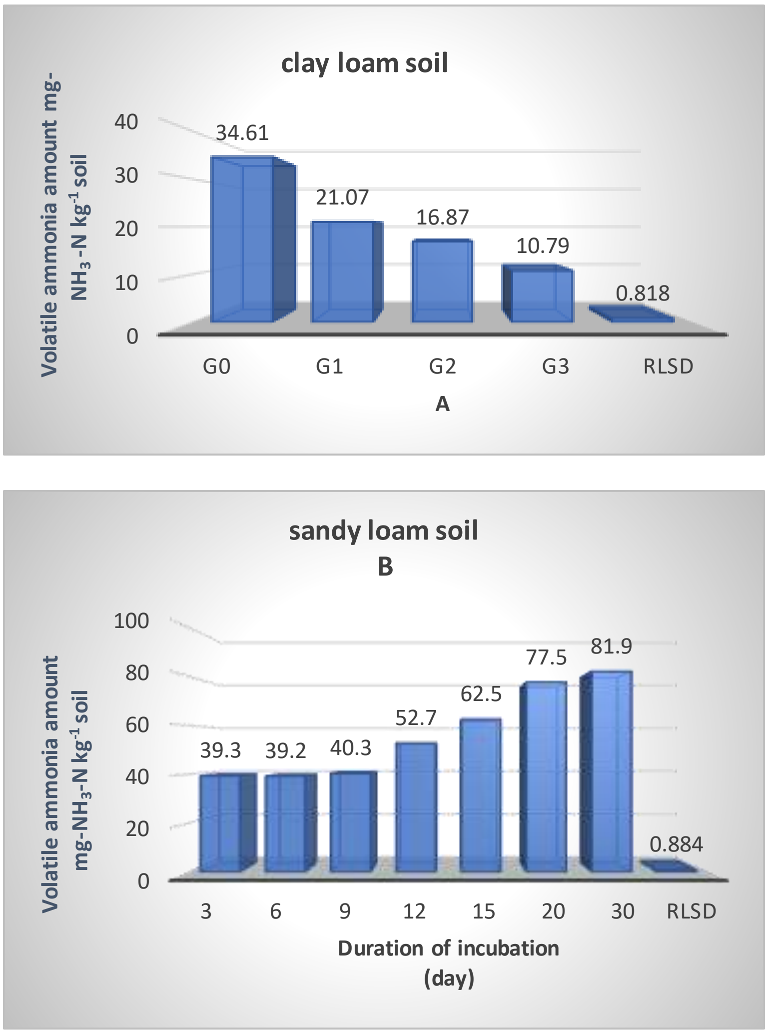
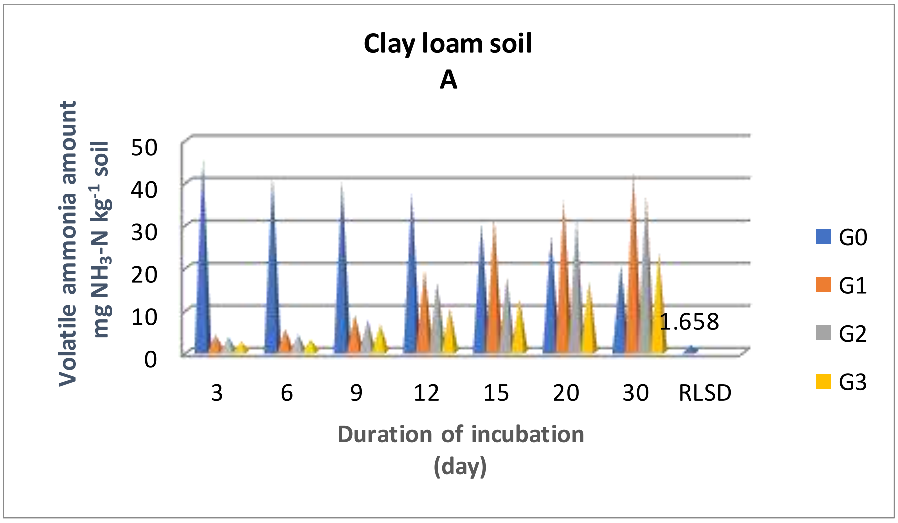


Figure 4. Effect of incubation duration on the amount of volatile ammonia for soils A-clay loam and B- sandy loam soil

Figure (5) shows the effect of the interaction between fertilizer combination and incubation time on the total volatile ammonia content of the two test soils. Focusing on the gelatin combination in the urea fertilizer applied treatments, it can be seen that there is a significant effect on the percentage of volatile ammonia content; G1, G2 and G3 have the lowest percentage of volatile ammonia after3 days of incubation time with 4.16, 3.6 and 2.45 mg NH3-N kg-, respectively, in clay loam soil.1 soil and 10.4, 6.4 and 4.5 mg NH3-N kg-1 soil in clay loam and mixed sandy soil, respectively. This is due to the ability of clay loams to retain ammonium and limit its loss in the form of ammonia gas. The volatilization rate increased with the incubation period, the highest amount of volatile ammonia was collected at 30 days of incubation, reaching 42.3, 37.06 and 23.3 mg NH_3-N kg-1 soil in clay loam soil and 128.3, 121.8 and 54.3 mg NH_3-N kg-1 soil in sandy soil, respectively, reaching the following levels. The high effectiveness of gelatin combinations in reducing volatile ammonia is due to the nature of the properties and composition of encapsulated gelatin combinations for urea fertilizers. On the other hand, the comparative application of un encapsulated urea G_0 had the highest percentage of volatile ammonia at 45.5 and 135.9 mg NH_3-N kg-1 soil (clay loam and mixed sandy loam) after 3 days of incubation period, and the volatilization rates decreased with the incubation period and at 30 days of incubation these rates were 20.4 and 23.2 mg NH3-N kg-1 soil in clay loam and sandy loam, respectively.



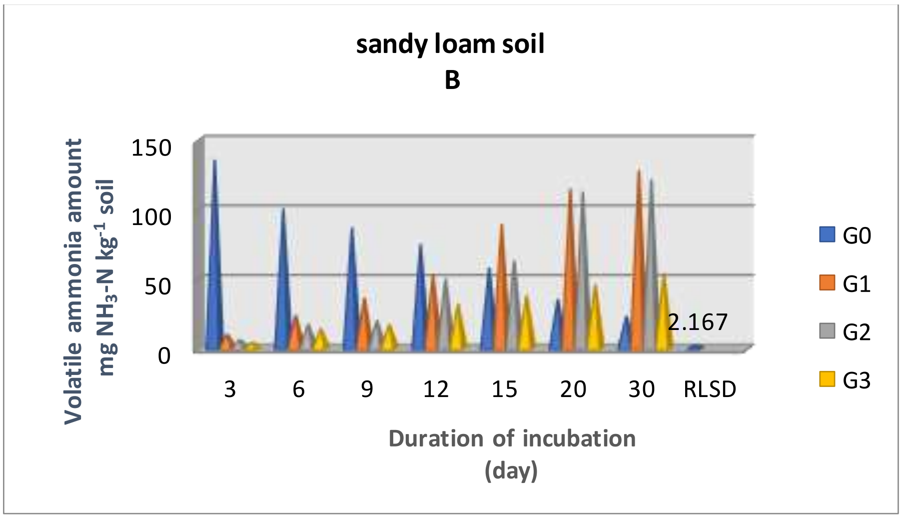


Figure 5. Effect of interaction between gelatin combinations of urea fertilizer and incubation duration on the amount of volatile ammonia for soils A- clay loam B- sandy loam soil

Available nitrogen

Figure (7) shows the effect of fertilizer combinations on the available nitrogen values of the two test soils; the G3 fertilizer combination shows a highly significant effect (0.01P≤8 and 121.2 mg N kg-1(clay loam and sandy loam soils).In contrast, the comparison treatments had the lowest available N values with 90.1 and 85.2 mg N kg-1(clay loam and sandy loam soils). The increased availability of nitrogen in the soil is due to the nature of the composition of the gelatin-coated fertilizer formulation and its ability to retain ammonium ions in the soil and not lose them through volatilization or decomposition of the fertilizer by nitrification processes, which affected the accumulation of ammonium ions in the soil and led to the increased accumulation of ammonium ions in the soil observed in the test, which increased the availability of nitrogen in the soil. This is in agreement with references; their results show that urea coating caused an increase in the amount of ammonium in the soil compared to the uncoated urea comparison treatment [12, 13, and 14].

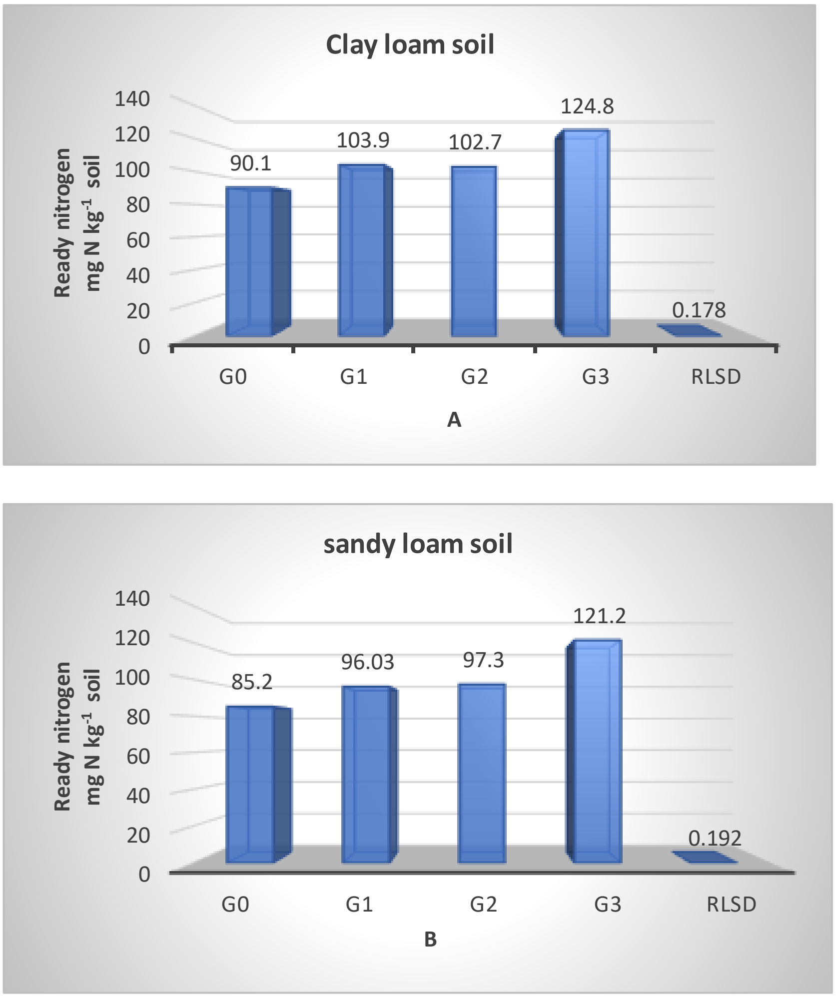


Figure 6. Effect of gelatin combinations on the available nitrogen values of soils A- clay loam B- sandy loam

Figure (7) shows the effect of incubation time on the available N in the two test soils; there were significant differences between incubation times (3, 6, 9, 12, 15, 20 and 30) reaching 135.9, 122.6, 112.3, 102.8, 98.01, 87.4and 78.8mg N kg-1 soil and clay loam. The reason for the decrease in the available nitrogen rate over time in mg N kg-1 sandy loam soil is that with longer incubation periods, the volatile ammonia rate increases and the amount of ammonium in the soil decreases and the available nitrogen rate decreases. This may be because the volatile ammonia rate increases with longer incubation times and the available nitrogen rate decreases over time [15].

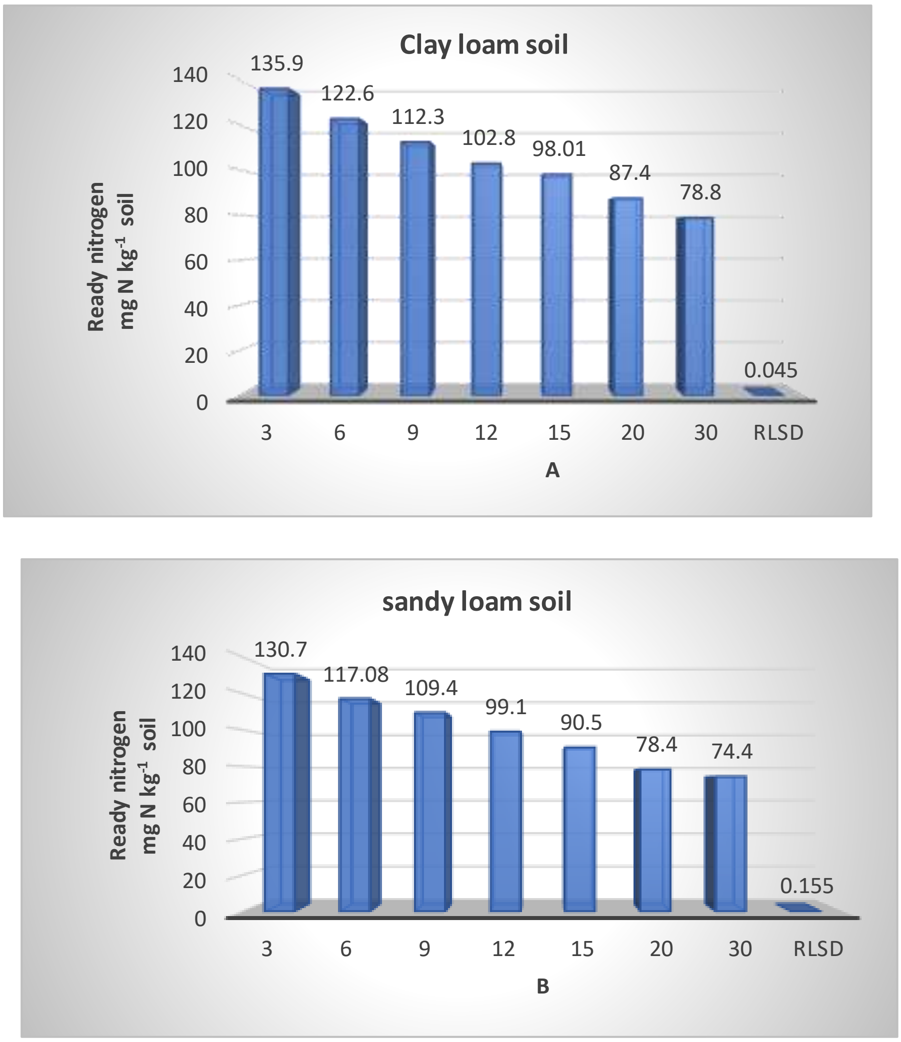
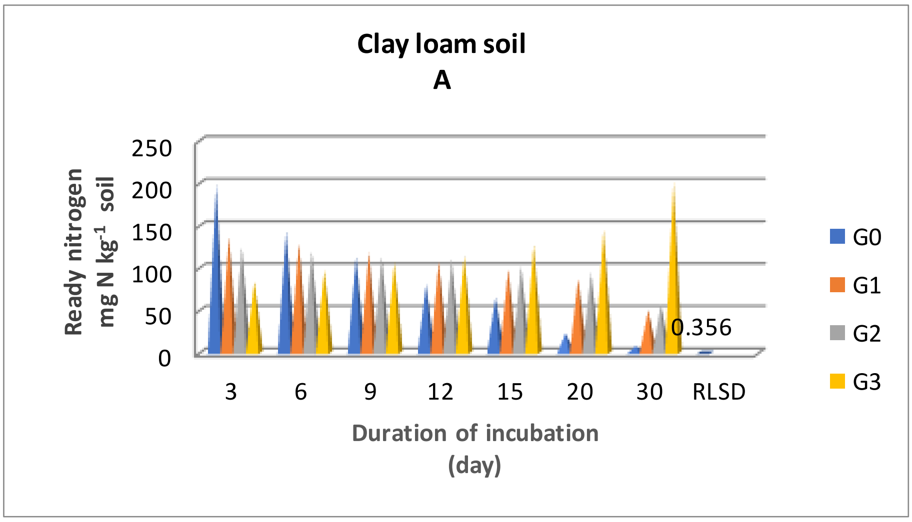


Figure 7. Effect of incubation duration on the available nitrogen values of soils A- clay loam B- sandy loam

Figure (9) shows the effect of the interaction between urea-fertilizer hydrogel combination and incubation time on the available N values of the two test soils: Treatments G0, G1 and G2 had the highest available nitrogen rates after 3 days of incubation time, reaching 198.4, 137.1 and 124.2 mg N kg-1 soil and 191.1, 128.4 and 122.3 mg N kg-1 soil, respectively. The percentage of available nitrogen decreased gradually with time and reached 7.7, 49.9 and 56.8 mg N kg-1 soil in clay loam soil and 5.2, 44.7 and 53.8 mg N kg-1 soil in sandy loam soil respectively after 30 days of incubation. The superior percentage of available nitrogen in mixed clay soils can be a ttributed to the ability of clay soils to retain ammonium ions in the soil and limit their loss in the form of ammonia gas. For nitrate the G3 combination had the lowest percentage of available nitrogen at 3 days incubation time, reaching 84.1 mg N kg-1 soil in clay loam soil and 81.1 mg N kg-1 soil in sandy loam soil. The percentage of available nitrogen increased with the incubation period, with the highest percentage of available nitrogen reaching 201.05 mg N kg-1 soil in clay loam soil and 194.06 mg N kg-1 soil in sandy loam soil at 30 days of incubation. The G3 combination was superior in increasing soil nitrogen availability over time. The reason for the superiority of the G3 combination in increasing soil nitrogen availability over time is due to the slow release of fertilizer over time (Figure7).



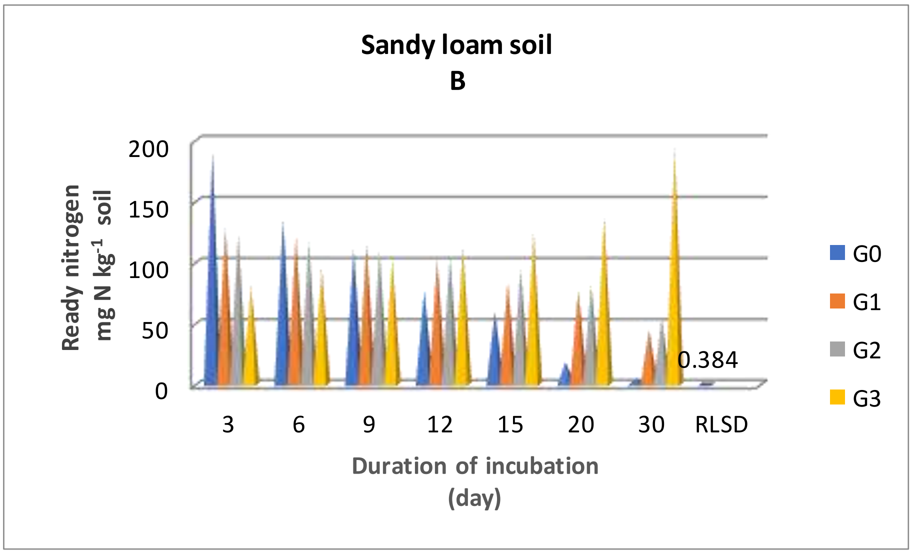


Figure 8. Effect of interaction between gelatin combinations and incubation duration on available nitrogen values for two soils: A- clay loam B- sandy loam

CONCLUSION

Fundamental Finding: This study concludes that polymeric hydrogel compounds prepared from gelatin and sodium alginate are effective in encapsulating urea fertilizer, significantly reducing ammonia volatilization and enhancing nitrogen availability in both clay loam and sandy loam soils. The G3 combination (gelatin:sodium alginate at a 2:1 ratio) demonstrated the most effective performance, with the lowest ammonia volatilization rates (10.79 and 29.7 mg-NH_3-N kg^{-1} soil) and the highest available nitrogen concentrations (124.8 and 121.2 mg N kg^{-1} soil) for clay loam and sandy loam soils, respectively. **Implication:** These findings suggest that hydrogel-based encapsulation of urea fertilizers can improve nitrogen use efficiency, reduce environmental nitrogen losses, and promote sustainable agricultural practices. **Limitation:** The study was conducted under controlled laboratory conditions, which may not fully represent field variability. Additionally, the long-term effects of hydrogel degradation on soil health were not assessed. **Future Research:** Future studies should focus on field trials to validate these results under diverse environmental conditions, assess the economic feasibility of large-scale application, and investigate the long-term impacts of hydrogel materials on soil microbiota and ecosystem health.

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