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Influence of Nano-Zinc Oxide Coated Urea Fertilizer on Ammonia Volatilization Loss and Inorganic Nitrogen Content in Loamy Sand Soil

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ABSTRACT

A laboratory incubation experiment in a closed dynamic air flow system was conducted for 30 days to estimate the volatilization loss of NH_3-N from 0, 1, 2 and 3% Nano-ZnO coated urea treated soil. The volatilized NH_3-N from the soil chambers was collected and titrated every 48 hours. Another incubation experiment was carried out to study the effect of coating urea with Nano-ZnO on the inorganic nitrogen (NH_4-N and NO_3-N) content in the treated soils at 2, 4, 8, 14 and 21 days of incubation period. The two experiments were arranged in a completely randomized design with three replications. The results of the first experiment indicated that coating urea fertilizer with Nano-ZnO reduced the total loss of NH_3-N from 22.82 % of applied N in the soil treated with uncoated urea (0 % coating) to 13.03% for the highest coating level (3%) with a reduction in NH_3-N loss by 42.90%.The results of second incubation experiment showed that the average of NH_4-N content increased from 86.52 mg Kg^{-1} for 0% Nano-Zn coated urea to 131.04 mg Kg^{-1} in the soil treated with 3% Nano-Zn coated urea, and the ratio of extractable NO_3-N average to the extractable NH_4-N average was 1: 1.06, 1: 1.17, 1: 1.50 and 1: 1.75 in the soil treated with 0, 1, 2 and 3% Nano-Zn coated urea, respectively. Also, the average of total inorganic N content increased from 168.19 mg Kg^{-1} in the soil treated with uncoated urea (0% coating) to 205.70 mg Kg^{-1} in soil treated with highest coating level (3%).Therefore, using the Nano-Zn coated urea fertilizer improves nitrogen use efficiency and reduce ammonia loss from urea fertilizer applied to loamy sand soil.

Keywords: coated urea, nano-zinc oxide, nanoparticles, ammonia volatilization, nitrification

INTRODUCTION

Nitrogen (N) element is responsible for energy synthesis and transfer as well as amino acids, proteins, vitamins and chlorophyll molecules formation, improving dry matter and crop yield of plants (Uchida, 2000; Ekbic *et al*., 2010; Xia *et al*., 2011). Plants need nitrogen in larger amounts comparing with other nutients (Marschner, 2005). Urea fertilizer contains high nitrogen percentage (46 % N), it is a cheap and very common source of nitrogen used in the agriculture over the world (Saima *et al*., 2016). The surface application of urea fertilizer accelerates the rapid urea hydrolysis rate by urease enzyme in soils to ammonium carbonate $(NH_4)_2CO_3$ and later to NH_3, CO_2, and H_2O (Havlin *et al*., 1999). Ammonia (NH_3) loss from urea by volatilization may reaches 60% of the applied N varies with soil type and temperature (Sommer *et al*., 2004), and close to 80% losses of N applied in some soils (Alberto, 2014), which decrease the urea fertilizer use efficiency and nitrogen recovery in soil (Kiran *et al*., 2010). The ammonium formed through urea hydrolysis may be oxidized to nitrate through nitrification process by *Nitrosomonas* and *Nitrobacter* bacteria. Nitrates could be lost by leaching or reduced to nitrites and then to nitrous oxide gas (N_2O) by denitrifying bacteria, which are lost into atmospheric air (Mohanty *et al*., 2009).

Coating urea granules with some chemical, biological and nanomaterials to produce a controlled release fertilizer is considered one of promising techniques needed to alleviate negative environmental problems, low nitrogen fertilizer use efficiency and to save human health (Zhao *et al*., 2013 & Dimkpa *et al*., 2020). These coating materials can affect on the urea hydrolysis and nitrification processes rate. Heavy metals are among these coating materials.

Tabatabai (1977) demonstrated that trace elements such as copper (Cu), zinc (Zn), cadmium (Cd) and lead (Pb) caused an inhibition range of 51%-94% , 23%-31% , 49%-67%, 2%-55% in urease activity and therefore inhibit urea hydrolysis and loss process. Chaperon and Suave (2007) and Nascimento *et al.* (2013) found that Zinc and copper have negative effect on the urease and dehydrogenase enzymes of N cycling bacteria), with the potential to reduce NH_3 volatilization from urea in coated fertilizer formulations. Also, Khariri *et al.* (2016) indicated that Cu-coated urea and Zn-coated urea reduced NH_3 volatilization by 28.00–19.44 %, and N_2O emission by 17.57, 21.62 % respectively compared to uncoated urea treatment, which provide a positive impact on the environment. Adoty *et al.* (2016) demonstrated that 2% zinc sulfate coated urea minimized the cumulative ammonia loss by (9.88 - 39.55 %) in different soils compared to conventional urea fertilizer. The inhibition of urease by heavy metal ions is due to their reaction with a sulfhydryl group in the active center of the enzyme by a reaction analogous to the formation of insoluble metal sulfides which were reported to be the strongest inhibitors. The heavy metal ions were found to inhibit urease in the following decreasing order: $Hg^{2+} > Cu^{2+} > Zn^{2+} > Cd^{2+} > Ni^{2+} > Pb^{2+} > Co^{2+} > Fe^{3+} > As^{3+}$ (Zaborska *et al.*, 2004). Yang *et al.* (2006) showed that urease was much more sensitive to heavy metal than the other soil enzymes. Kundu *et al.* (2016) recorded a decrease in N_2O emission by 44.95% from 2% Nano-ZnO (<100 nm) coated urea after 33 days compared with uncoated urea although surface coating in general reduces the release of N from urea fertilizer, the effect could be stronger with nano-scale coatings. Also, Jadon *et al.* (2018) found a reduction

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in NO_3-N leaching by 35.1% due to application of 2% Nano-ZnO-coated urea relative to the control. Nano ZnO particles have antimicrobial properties may be due to its smaller size and high surface reactivity might provide higher surface interaction and penetration of ZnO nanoparticles into the bacterial cells. The Nano-ZnO particles might destruct the bacterial cell integrity by direct contact of ZnO nanoparticles with cell walls (Zhang *et al*., 2007, Espitia *et al*., 2012; Singh and Nanda, 2013) that decreases the rates of urea hydrolysis and nitrification processes. Dimkpa *et al*. (2020) indicated that coating urea with 1% Nano-scale ZnO (18 nm) powder resulted in 4% higher uptake of N by wheat plants, 19% more residual soil N, and 66% higher grain yield, compared to uncoated urea.

This study aimed to evaluate the influence of various nano zinc oxide coated urea levels on NH_3-N loss from urea-N fertilizer applied to loamy sand soil and the inorganic nitrogen (NH_4-N and NO_3-N) content in the studied soil.

MATERIALS AND METHODS

1. Soil:

The used soil was brought from the farm of Agriculture Faculty, Sohag University, Sohag. The soil was air-dried and sieved to pass through 2-mm sieve and some soil physical and chemical properties were measured (Table 1) as the following: Mechanical analysis of the soil samples was determined using the pipette method (Richards, 1954). Soil pH was measured in a soil : water (1: 2.5) suspension using a pH meter with a glass electrode (pH 211, Microprocessor pH meter, HANNA Instruments) (Jackson, 1973). The electrical conductivity of the soil was estimated in the soil saturated paste extract using an electrical conductivity meter (Orion model 150) according to Hesse (1998), the soluble cations and anions were determined in this extract according to Jackson (1973). The soil CEC was determined using 1 M ammonium acetate solution (pH= 7.0) (Chapman and Pratt, 1961). The total calcium carbonate ($CaCO_3$) in soil was estimated using a volumetric calcimeter (Jackson, 1973). Soil organic matter was determined using the Walkley-Black method (Jackson, 1973), total N content of the soil was determined using micro-kjeldahl method (Jackson, 1973).

Table 1. Some physical and chemical properties of the soil used in the experiment.

property	Unit	Value
Sand		83.12
Silt	%	6.33
Clay		10.55
Texture grade	-	Loamy sand
pH (1:2.5)	-	7.51
EC_e	$dS\ m^{-1}$	2.14
OM		0.25
Total $CaCO_3$		4.40
SP	%	33.00
FC		17.60
CEC	$Cmol^{+}\ Kg^{-1}$	11.92
Total N	$mg\ Kg^{-1}$	168
Solube cations:		
Ca^{+2}		5.10
Mg^{+2}		2.00
Na^{+}	$mmol\ L^{-1}$	7.20
K^{+}		1.10
Soluble anions:		
HCO^{-}_{3}		5.30
Cl^{-}		13.00
SO^{-2}_{4}		1.00

*** Each value in this Table is the mean of 3 replicates.**

2. Preparation of coated urea:

Nano-ZnO powder (39 nm - Strem Chemicals, INC., USA) was used for coating urea fertilizer. The X-ray diffraction (XRD) analysis of Nano-ZnO powder was carried out to determine the particle size of nano-ZnO powder (Fig. 1) using a Bruker D8 Advance X-ray diffraction equipment, Department of Physics, Faculty of Science, Sohag University.

One hundred grams of urea (46% N) was moistened with spraying a very small amount (1ml) of arabic gum solution (10%). The granules were homogeneously covered with one gram of Nano-Zinc oxid (nZnO) powder to produce 1% Nano-ZnO coated urea (UCZn1), the same method used to produce 2% and 3% Nano-ZnO coated urea (UCZn2 ,UCZn3) using 2 and 3 grams of Nano-ZnO powder, respectively. All prepared Nano-ZnO coated urea allowed to dry for three hours. The dry, coated urea was stored in glass containers.

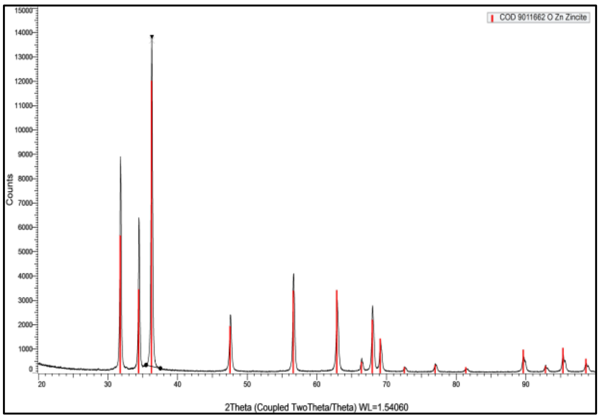

Fig. 1. X-ray diffraction (XRD) pattern of Nano-ZnO powder.

3. Ammonia volatilization loss experiment:

A laboratory incubation experiment was carried out to investigate the effect of coating urea fertilizer with Nano-ZnO on ammonia (NH_3) loss from urea amended loamy sand soil under room temperature using a close-dynamic air flow system described by Gameh (1987). This system consists of an exchange chambers with 400 cm^3 in volume, 6.5 cm in diameter and 14 cm in height glass bottles containing 500 g soil sample and a trap chamber with a 250 ml Bochner flasks containing 25 ml of 2% boric acid mixed with bromo-cresol green and methyl red indicators, which were both stoppered and fit with an inlet/outlet. The inlet of the chamber was connected to an air compressor which pumped the air to pass through diluted H_2SO_4 (0.05 M) container to scrub any ammonia in the incoming air then to distilled water container to produce filtered and humidified air which was distributed through a manifold into soil chambers connected to the system. The outlet was connected by tubes to the trap containing boric acid solution to trap NH_3 gas. Boric acid flasks periodically replaced every 48 hours (2 days intervals) and titrated using 0.01 N H_2SO_4 for 30 days of incubation. Five hundred grams of air dried soil were placed in each glass bottle and then moistened to the field capacity level. Urea fertilizer (46 % N) was added to the soil surface at level of 230 mg N Kg^{-1} through various treatments. Then, the bottles were immediately closed, and connected to the system. All treatments were arranged in a complete randomized design (CRD) with three replications and the treatments evaluated were as follows:

UCU : 0% Nano-ZnO coated urea (or uncoated urea) + soil
CUZn1 : 1% Nano-ZnO coated urea + soil
CUZn2 : 2% Nano-ZnO coated urea + soil
CUZn3 : 3% Nano-ZnO coated urea + soil

The collected NH_3-N was calculated daily and the cumulative loss was estimated as a percentage of the applied urea-N to soil.

4. Inorganic nitrogen changes experiment:

An incubation experiment was carried out to study the effect of Nano-ZnO coated Urea on the mineralization of applied urea-N over time. The treatments previously described were used. A 930 cm^3 Plastic box filled with 500 grams of soil was used for each treatment. The treatments were replicated three times and nitrogen level of 230 mg Kg^{-1} soil was used also. The soil moisture content was maintained at field capacity. The treatments were incubated for 21 days. Soil samples were taken from each box at 2, 4, 8, 14, 21 days after incubation to extract the inorganic nitrogen forms (NH_4^+-N and NO_3^--N) with 2 M KCl solution. The NH_4^+-N and NO_3^--N concentrations were determined in the supernatant using the modified micro Kjeldahl method (Jackson, 1973).

5. Statistical Analysis

The data statistically exposed to analysis of variance (ANOVA) using the GLM procedure in SAS software (SAS ver. 9.2, SAS Institute, 2008). The LSD at 5% significance level was calculated according to Peterson (1985) to compare the means of the studied treatments.

RESULTS AND DISCUSSION

1. Ammonia volatilization loss experiment:

The daily ammonia (NH_3-N) loss was calculated as a percentage of the applied urea-N to the soil. Clear differences were shown between the studied treatments. The highest daily NH_3-N loss (%) was shown between the 4th and the 6th day of incubation beginning and the loss was 2.53, 2.24 and 1.92% of the applied urea-N for CUZn1, CUZn2 and CUZn3, respectively compared to 3.18 % of the applied-N for uncoated (UCU) treatment (Fig. 2). Then, the daily NH_3 loss gradually decreased until the end of the incubation period for all treatments.

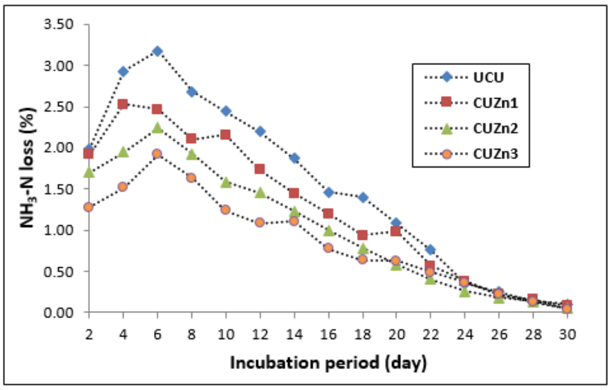

Fig. 2. Daily NH_3-N loss (%) from the soil treated with 0, 1, 2 and 3% Nano-ZnO coated urea (UCU, CUZn1, CUZn2 and CUZn3), respectively.

Fig. 3 shows the cumulative NH_3-N loss (%) recorded for the duration of the incubation. The total NH_3-N loss (%) significantly decreased from 22.82% for the uncoated urea (UCU) treatment to 18.86, 15.46 and 13.03% of the total applied urea-N for CUZn1, CUZn2 and CUZn3, respectively at the end of incubation time (30 days) (Table 2), with a reduction in loss by 17.35, 32.25, and 42.90% comparing with uncoated urea (UCU) (Table 2). It is obvious that coating urea with Nano-ZnO reduced the NH_3-N loss from this soil and this reduction increases as the coating level of Nano-ZnO increases. This reduction in the volatilization loss of NH_3 may be due to the inhibitory effect of Nano-ZnO for the soil microbes and urease which delay or slow down the urea hydrolysis and decrease the NH_3-N loss. These results coincide with the findings by Espitia *et al.* (2012) and Singh and Nanda (2013).

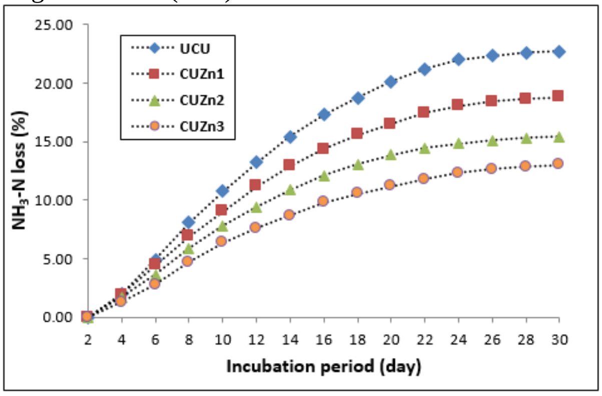

Fig. 3. Cumulative NH_3-N volatilization (%) from the soil treated with 0, 1, 2 and 3% Nano-ZnO coated urea (UCU, CUZn1, UCZn2 and CUZn3), respectively.

Table 2. The total and reduction of NH_3-N loss (%) from soil treated with Nano-ZnO coated urea after 30 days of incubation.

*Treatment	Total NH_3-N loss (%)	Reduction % in NH_3-N loss as compared with UCU
UCU	22.82A	0.00
CUZn1	18.86B	17.35
CUZn2	15.46C	32.25
CUZn3	13.03D	42.90
L.S.D 5%	1.80	-

Values with the same letter are not significantly different from each other at 5% significance level.

*** UCU = soil treated with uncoated urea, where CUZn1, CUZn2 and CUZn3 treatments = soil treated with 1, 2 and 3% Nano-ZnO coated urea, respectively.**

2.Inorganic soil nitrogen changes experiment:

a.Extractable Ammonium:

Results in Table 3 showed a gradual decrease in ammonium (NH_4-N) content of soil after the 4th day and till the end of incubation experiment time for all treatments; the overall average of NH_4-N concentration was 144.78, 188.53, 109.08, 65.68 and 31.50 mg Kg^{-1} at day 2, 4, 8, 14 and 21, respectively. Results showed also an increase in the extractable NH_4-N concentration with application of Nano-ZnO coated urea to the soil. The average of extractable NH_4-N concentration increased from 86.52 mg Kg^{-1} in the soil treated with uncoated urea (UCU) to 98.28, 115.83 and 131.04 mg Kg^{-1} in the soil treated with 1, 2 and 3% Nano-ZnO coated urea, respectively (Table 3). The extractable NH_4-N from soil treated with urea alone was 126.00, 163.80, 75.60, 42.00 and 25.20 mg Kg^{-1} at 2, 4, 8, 14 and 21 day, respectively, while the values were 163.33, 210.00, 149.33, 90.53 and 42.00 mg Kg^{-1} in the same order when the soil treated with the 3% Nano-ZnO coated urea (CUZn3) (Table 3). It is noticeable that the extractable NH_4-N values were significantly higher for CUZn1, CUZn2 and CUZn3 treatments when compared to uncoated urea (UCU) at all of incubation days (Table 3).

Table 3. The effect of Nano-ZnO coated urea fertilizer application on the ammonium (NH_4-N) content in the soil over time.

*Treatments	NH_4-N (mg kg^{-1}) Incubation time (days)					Average
	2	4	8	14	21	
UCU	126.00A	163.80A	75.60A	42.00A	25.20A	86.52
CUZn1	138.60B	186.20B	91.00B	50.40AB	25.20A	98.28
CUZn2	151.20C	194.13C	120.40C	79.80C	33.60B	115.83
CUZn3	163.33D	210.00D	149.33D	90.53D	42.00C	131.04
Average	144.78	188.53	109.08	65.68	31.50	
L.S.D 5%	4.24	5.80	7.63	8.55	5.19	

Each value represents an average of three replications. Values with the same letter are not significantly different from each other at 5% significance level.

*** UCU = soil treated with uncoated urea, where CUZn1, CUZn2 and CUZn3 treatments = soil treated with 1, 2 and 3% Nano-ZnO coated urea, respectively.**

b. Extractable Nitrate:

The concentration of extractable nitrate (NO_3-N) from the soil treated with urea is presented in Table (4). Nitrate content increased gradually and slowly with time for all treatments. The overall average concentration of NO_3-N was 38.03, 54.95, 75.49, 103.25 and 125. 53 mg Kg^{-1} at days 2, 4, 8, 14 and 21, respectively (Table 4). The decrease in the NH_4-N concentration in the soil is paralleled to the increase in the NO_3-N concentration (Tables 3 and 4).The extractable NO_3-N values were higher in the uncoated urea treated soil (UCU) than all the nano-Zn coated urea treated soils till the 8th day of incubation period. Then the NO_3-N content increased till the end of the incubation time in the coated urea treated soils comparing with the uncoated urea treated soil (Table 4).

Table 4. The effect of Nano-ZnO coated urea fertilizer application on the nitrate (NO_3-N) content in the soil over time.

*Treatments	NO_3-N (mg kg^{-1}) Incubation time (days)					Average
	2	4	8	14	21	
UCU	50.4A	63.00A	84.00A	95.20A	115.73A	81.70
CUZn1	42.00B	67.20AB	80.27AB	109.20B	122.27AC	84.20
CUZn2	34.53C	50.40B	74.67C	92.40AC	134.40B	77.28
CUZn3	25.20D	39.20C	63.00C	116.20D	129.73C	74.70
Average	38.03	54.95	75.49	103.25	125.53	
L.S.D 5%	5.90	5.82	4.50	7.23	8.08	

Each value represents an average of three replications.

Values with the same letter are not significantly different from each other at 5% significance level.

*** UCU = soil treated with uncoated urea, where CUZn1, CUZn2 and CUZn3 treatments = soil treated with 1, 2 and 3% Nano-ZnO coated urea, respectively.**

c. NO_3-N / NH_4-N Ratio:

The ratio of extractable NO_3-N average to the extractable NH_4-N average from the studied soil over the incubation period was 1: 1.06 in the uncoated urea treated soil (UCU), and 1: 1.17, 1: 1.50 and 1: 1.75 when 1, 2 and 3 % nano-ZnO coated urea were added to the soil. This observation may suggest a relative slower nitrification rate when urea fertilizer was coated with increasing nano zinc oxide material. These results may be due to the adverse effects of nano-ZnO material on the activity of nitrification bacteria (Singh and Nanda, 2013 and Khariri *et al*., 2016). Similar results were also obtained by Kundu *et al*. (2016) and Jadon *et al*.(2018). This means that the released nitrate from nano-ZnO coated urea is not likely to be leached out easily as water passes through the soil amended with this Zn-coated urea, it will move out slowly and be taken up by the plant, similar to the way as slow-release fertilizer works (Dimkpa *et al*., 2020).

Data presented in Table (5) showed that the average of total inorganic nitrogen (NH_4-N + NO_3-N) content increased from 168.19 in UCU treatment to 182.47, 193.11 and 205.70 mg Kg^{-1} in the soil treated with CUZn1, CUZn2 and CUZn3, respectively. These findings may be due to the effective role of coating urea with nano-Zinc oxide in reduction of ammonia loss and increasing the residual nitrogen in soil. These results matched with these reported by Dimkpa *et al.* (2020).

Table 5. The effect of Nano-ZnO coated urea fertilizer application on the total inorganic nitrogen (NH_4-N + NO_3-N) content in the soil over time.

*Treatments	NH_4-N + NO_3-N (mg kg^{-1}) Incubation time (days)					Average
	2	4	7	14	21	
UCU	176.40	226.80	159.60	137.20	140.93	168.19
CUZn1	180.60	253.40	171.27	159.60	147.47	182.47
CUZn2	185.73	244.53	195.07	172.20	168.00	193.11
CUZn3	188.53	249.20	212.33	206.73	171.73	205.70

*** UCU = soil treated with uncoated urea, where CUZn1, CUZn2 and CUZn3 treatments = soil treated with 1, 2 and 3% Nano-ZnO coated urea, respectively.**

CONCLUSION

It was concluded from this study that application of Nano-ZnO coated urea to soil reduces the NH_3-N volatilization loss, slows down the nitrification process rate and increases the nitrogen recovery in soil.

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تأثير سماد اليوريا المغلف بمادة نانو أكسيد الزنك على فقد الأمونيا بالتطاير ومحتوى النيتروجين الغيرعضوى فى التربة الرملية الطميية

فاطمة نصرالدين ثابت*

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تم اجراء تجربة تحضين معملية لمدة 30 يوم فى تصميم كامل العشوائية مكون من ثلاثة مكررات لكل معاملة بأستخدام نظام تدفق هوائى مغلق لدراسة تأثير استخدام سماد اليوريا المغلفة بمادة نانو أكسيد الزنك بنسبة (صفر% - 1% - 2% - 3%) فى تقليل فقد الأمونيا بالتطاير من سماد اليوريا المضاف إلى التربة الرملية الطميية . كما تم إجراء تجربة تحضين معملية أخرى لدراسة تأثير تغليف اليوريا بمادة نانو اكسيد الزنك على محتوى التربة من النيتروجين الأمونيومى والنتراتى على فترات مختلفة من بداية التحضين فى عبوات من البولى إيثيلين تحتوى على 500 جم من التربة تحت الدراسة ومضاف إليها اليوريا المغلفة بمادة نانو أكسيد الزنك بنفس مستويات التغليف فى تجربة التحضين الأولى . كان معدل النيتروجين المضاف فى كلتا التجربتين هو 230 ملجم نيتروجين لكل كجم تربة. وقد أوضحت النتائج ما يلى: 1- إنخفضت نسبة تطاير الأمونيا الكلية خلال فترة التحضين معنويا من 22,82 % فى التربة المعاملة باليوريا الغير مغلفة بمادة نانو اكسيد الزنك إلى 13,03 % عند إضافة اليوريا المغلفة بمادة نانو أكسيد الزنك بنسبة تغليف1 و 2 و3% (وزن / وزن).أى بنسبة إنخفاض قدرها 17,35 و 32,25 و 42,9 % على التوالى. 2- فى تجربة التحضين الثانية زاد متوسط تركيز النيتروجين الأمونيومى خلال فترة التحضين زيادة معنوية من 86,52 ملجم / كجم تربة فى معاملة التربة المسمدة باليوريا الغير مغلفة إلى 98,28 و 115,83 و 131,04 ملجم / كجم تربة عند إضافة عند معاملة التربة بسماد اليوريا المغلفة بنسبة 1 و 2 و 3% بمادة نانو اكسيد الزنك (وزن / وزن) على التوالى. 3- سجلت المعاملات المسمدة بسماد اليوريا المغلفة بمادة نانو اكسيد الزنك تركيزات منخفضة من النيتروجين النتراتى مقارنة بالتربة المسمدة باليوريا الغير مغلفة بمادة نانو أكسيد الزنك حتى اليوم الثامن من بداية التحضين ثم بدأ تركيز النيتروجين النتراتى يزداد تدريجيا بعد ذلك حتى اليوم الواحد والعشرون من بداية التحضين وتزامنت الزيادة التدريجية فى تركيز النيتروجين النتراتى مع الانخفاض التدريجى فى تركيز النيتروجين الأمونيومى فى كل المعاملات المدروسة. 4- كان معدل متوسط النيتروجين النتراتى الى متوسط النيتروجين الأمونيومى المستخلص من التربة خلال فترة التحضين فى التجربة الثانية يساوى 1: 1,06 , 1: 1,17 , 1: 1,50 , 1 : 1,75 فى معاملات التربة المسمدة باليوريا المغلفة بمادة نانو اكسيد الزنك بنسبة صفر , 1 , 2 و 3% (وزن /وزن) على التوالى. 5- زاد متوسط تركيز النيتروجين الغير عضوى الكلى (النيتروجين الأمونيومى و النتراتى) من 168,19 ملجم / كجم تربة فى التربة المعاملة باليوريا الغير مغلفة بمادة نانو أكسيد الزنك الى 182,47 و 193,11 و 205,70 ملجم / كجم تربة فى معاملات التربة المسمدة بسماد اليوريا المغلف بنسبة 1 و 2 و 3% من مادة نانو أكسيد الزنك خلال فترة التحضين فى التجربة الثانية على الترتيب. لذلك يوصى بتطبيق تقنية تغلف حبيبات سماد اليوريا بمادة نانو أكسيد لتقليل نسبة الأمونيا المتطايرة من سماد اليوريا وزيادة كفاءة أستخدام النيتروجين فى الأراضى.