Biological and Clinical Sciences Research Journal
eISSN: 2708-2261; pISSN: 2958-4728
www.bcsrj.com
DOI: https://doi.org/10.54112/bcsrj.v2024i1.1411
Biol. Clin. Sci. Res. J., Volume, ***2024****: 1411*

Original Research Article

EVALUATION OF POLYMER-COATED UREA TO REDUCE NITROGEN LOSSES IN SOIL AND ITS APPLICATION TO OKRA ABELMOSCHUS ESCULENTUS (L.) MOENCH

HASSAN J[1], BADAR S[1], KHAN Z[2]*, HAYAT U[2], KHAN A[3], IJAZ F[4], KHAN ZA[5], SHERAZ M[6], RASHEED F[7], IQBAL J[8]

[1]*Institute of Soil Science, Pir Mehar Ali Shah Arid Agriculture University, Rawalpindi, Pakistan*
[2]*Department of Soil and Environmental Sciences, The University of Agriculture, Peshawar, Pakistan*
[3] *Department of Agriculture and Agribusiness Management, University of Karachi, Pakistan*
[4]*Soil Bacteriology Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan*
[5]*Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha, Pakistan*
[6]*Crop Sciences Institute, National Agricultural Research Centre, Islamabad, Pakistan*
[7]*Soil Chemistry Section, Ayub Agricultural Research Institute, Faisalabad, Pakistan*
[8] *Cotton Research Institute, Multan, Pakistan*
*****Corresponding author email address: khan.zaryab1986@gmail.com*

(Received, 17th September 2024, Revised 9th December 2024, Published 18th December 2024)

Abstract *The application of fertilizer aims to maximize crop yields and provide essential nutrients to plants. Efficiency problems, decreased yields, and environmental impact can result from nitrogen loss by volatilization and leaching. The delayed release of nitrogen can be achieved by coating urea with biodegradable compounds. The influence of several polymer-coated urea formulations and standard urea on nitrogen availability to okra plants was investigated in this study using lab and pot assessments. Key parameters were determined using soil samples taken at a depth of 15 cm. In the lab incubation, control, conventional urea, starch polymer-coated urea, neem oil-coated urea, and acacia gum-coated urea treatments were examined over 35 days. Soil samples were collected and examined on particular days. Okra plants were grown up to the flag leaf stage in the pot experiment using the same treatments. Data analysis demonstrated higher ammonium-nitrate and nitrate nitrogen concentrations in soils treated with polymer-coated urea, with acacia gum-coated urea exhibiting the slowest release. As release rates varied over time, nitrogen levels increased. Polymer-coated urea reduced ammonium loss, increased nutrient absorption, and boosted plant growth when compared to conventional urea. Urea with acacia gum coating functioned remarkably well, leading to increased nitrogen absorption. In conclusion, biodegradable polymer-coated urea increases nitrogen usage efficiency, decreasing losses and enhancing plant development, particularly when combined with acacia gum-coated urea. The results have practical significance for agricultural sustainability and the preservation of the environment.*

Keywords: *Nitrogen loss; Okra; Polymer coated urea; Biodegradable; Incubation*

Introduction

Okra, a popular vegetable with nutritional and medicinal benefits, rapidly perishes postharvest due to changes in weight, softness, color, and damage sensitivity. These factors affect the fruit's quality, storage suitability, marketability, and transportation, despite numerous studies on postharvest practices (Aloui et al. 2017; Al-Naamani et al. 2018; Phornvillay et al. 2019; Sun et al. 2021; Dong et al. 2023; Li et al. 2023) Improving postharvest practices and enhancing nitrogen use efficiency is crucial for maintaining okra quality and reducing agricultural and environmental impacts. The large-scale use of nitrogen fertilizers contributes to atmospheric concentrations of greenhouse gases and air pollutants like nitrous oxide and ammonia (Tian et al. 2015). Studying the impact of applied nitrogen on the agroecological system can lead to increased nitrogen use efficiency, sustainable agriculture, and economic gains (Langholtz et al. 2021). Traditional urea usage inefficiency leads to excessive nitrogen loss in agriculture, posing various risks and environmental contamination (Amberger 2006). Nitrogen competition from mineral fertilizers poses a significant issue, as plants only absorb and use 20%-30% of available nitrogen, causing environmental harm and subsurface water damage. Nitrogen is crucial for plant metabolism, and synthesis of chlorophyll, proteins, and phytohormones, and is not replaced by alternative nutrients (Trenkel 1997). Polymer-coated urea fertilizers aim to reduce environmental losses and increase usage efficiency by aligning nitrogen supply with crop demand,

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.,* **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]

addressing concerns about nitrogen availability and environmental impacts in fertilizer administration (Grant et al. 2012).

Urea is the primary nitrogen fertilizer, accounting for over 50% of global agricultural nitrogen input (Lasisi et al. 2020). Urea is a diamide of carbonic acid (NH2)2CO, containing 46% nitrogen (Gould et al. 1986; Galloway et al. 2008; Coskun et al. 2017). Rapid ammonification occurs in soil due to the hydrolysis of the soil enzyme urease, secreted by microorganisms. This process generates gaseous ammonia and CO2, which evaporates in agricultural soils. Ammonium carbonate is produced when urea partially dissolves in soil water. Nitrification, facilitated by soil microorganisms, oxidizes NH4+ to NO3. Some ammonium is immobilized by organisms and stabilized by soil organs. The resulting nitrites and nitrates are used as plant fertilizers. However, nitrates can leach into groundwater, eutrophicating water resources. Denitrifying soil bacteria convert nitrates into nitrogen-containing gases, and nitrogen loss from fertilizers may occur (Korsakov et al. 2023).

Coated slow-release fertilizer is an innovative product that adjusts the nutrient-release characteristics of standard fertilizer by adding supplementary ingredients, aiming to lower costs by adjusting nitrogen delivery to individual crop needs (Harvey et al. 2016; Li et al. 2021). Hydrophobic inorganic or organic coating materials are frequently employed as constraints. A variety of hydrophobic inorganic and organic coating materials, as well as combinations, have been used to improve slow-release fertilizers. One of the most researched inorganic compounds is sulfur (Li et al. 2022). Organic polymers are the primary sustained-release and controlled-release coating materials, but semisynthetic polymers are also being explored (Tan et al. 2021) is the most common, and it is a novel polymer material created by the grafting or copolymerization of many types of naturally occurring and synthetically modified polymers (Kwon et al. 2021; Haroon et al., 2024; Hunajid and Gokce, 2024; Sami et al., 2023; Mushtaq et al., 2024). Superabsorbent resin (SAR) is a novel functional polymer material with a three-dimensional network structure, strong hydrophilic groups, and crosslinking (Cheng et al. 2019). Qiao et al. described a method for creating water-retentive, slow-release urea fertilizers by treating fertilizer surfaces with SAR, resulting in a double coating. Potato starch-coated fertilizer delivers minimal nitrogen into the soil, taking 100 hours to fully release. Charge and connecting bridge elements regulate fertilizer discharge in a resin-based gel network (Qiao et al. 2016). Slow-release coated fertilizers can be applied to the soil to increase yield and reduce nitrogen loss from leaching (Abbas et al., 2024ab; Arshad et al., 2024; Rehman et al., 2024; Liu et al. 2013). Synthetic active ingredients (SAR) derived from renewable, biodegradable, and environmentally friendly natural resources like cellulose alginate and inorganic clay minerals are gaining widespread acceptance (Khalid et al. 2018; Chaudhuri et al. 2022; Thien et al. 2022). The research aims to create optimal urea coatings for slow-release urea production, evaluate their soil nutrient release, and test the best slow-release fertilizer in a pot experiment with okra for growth and absorption.

Materials and methods

Formulation of coated urea

Three coating materials, acacia gum, neem oil, and starch, were selected based on cost-effectiveness and accessibility. These materials were used to prepare three controlled-release urea fertilizers (CRFs) by applying a 10% w/w solution through spraying. The resulting fertilizers were subjected to an 8-hour drying and stored in air-tight jars for further assessment (Figure 1).

To assess the nitrogen release characteristics of the prepared controlled-release fertilizers (CRFs) in soil, 5 g of each CRF was enclosed in a polypropylene mesh bag. The treatments included T1 (pure urea), T2 (starch-coated urea), T3 (neem-oil-coated urea), and T4 (gum-acacia-coated urea). These CRF-filled mesh bags were buried at a depth of 10 cm in individual pots containing 100 g of soil, with soil moisture set at 50% of field capacity. The pots were then incubated at 25°C in a controlled environment. This experiment followed a completely randomized design (CRD) with three replicates. Mesh bags were retrieved at intervals of 1, 3, 7, 14, 28, and 35 days during the incubation period. Upon retrieval, the mesh bags were rinsed with distilled water to remove soil particles, and their contents were analyzed for total nitrogen content using the Kjeldahl procedure (Van Schouwenberg and Walinge, 1973).

Pre-Soil Sampling and Analysis

Soil sampling was done at the start of the experiment. The samples were collected at a depth of 0- 20 cm from the University Research Farm. The soil was dried, ground, and sieved through a 2 mm sieve. The physicochemical properties of soil including soil texture (Gee and Bauder 1986), pH and EC (McLean 1983), Total organic carbon (Nelson and Sommers 1996), total Nitrogen (Bremner and Mulvaney, 1983), NO_3-Nitrogen were determined by Salicylic acid method (Vendrell and Zupancic 1990), NH4-N (Anderson and Ingram 1994), Olson phosphorus (Olsen 1954) and extractable potassium (Helmke and Sparks 1996).

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.*, **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]

Figure 1. Lab incubation experiment for nitrogen release pattern in soil

Pot Experiment

To assess the agronomic effectiveness of Controlled-Release Fertilizers (CRFs), a pot experiment was conducted. The experiment featured four treatments: T1 (control, no fertilizer), T2 (starch-coated urea), T3 (neem oil-coated urea), and T4 (acacia gum-coated urea). The experiment followed a Completely Randomized Design (CRD) with three replications. Five-kilogram pots were filled with air-dried soil, and each treatment was incorporated into the soil at the recommended nitrogen rate for okra cultivation. Okra seeds (variety: Sabzpari) were sown, maintaining soil moisture at field capacity. Following germination, two seedlings per pot were retained for growth. Pots were regularly irrigated with distilled water to maintain soil moisture at field capacity. At the stage of the first true leaves (hag leaf stage), plant height was measured. Upon crop maturity, harvest was conducted, and data on fresh shoot weight were collected. Crop samples were subsequently oven-dried at 60°C until reaching a constant weight, and dry shoot weight was recorded. Plant samples were processed, milled, and analyzed for total nitrogen content, while soil samples were analyzed for NH4-N and NO3-N levels.

Plant Analysis

Biomass Yield

Two months post-maturity, two randomly selected okra plants were uprooted from the pots, and their fresh weights were recorded. Subsequently, the two plants were subjected to drying in an oven at 100°C for three days until complete dryness. The dry matter weight was then measured and recorded. Biomass yield was determined by weighing the dried samples, and the resulting data were recorded.

Total Nitrogen

Total N was calculated by using a spectrophotometer at the wavelength of 665 nm, (Bremner and Mulvaney, 1983)

Statistical analysis

Statistical analysis was carried out to check the significance of treatment means using the Fisher Analysis of Variance method and treatment means (main effects and interaction) were differentiated by applying the Least Significant Difference test (LSD) at 5% probability level (d Steel and Torrie 1986) utilizing Statistics software.

Results and discussion

The daily temperature (°C) and rain (mm) were measured throughout the research period the highest rainfall was 100 mm and the temperature was 30 Co while the lowest rainfall was 15 mm and the temperature was 5°C (fig 2).

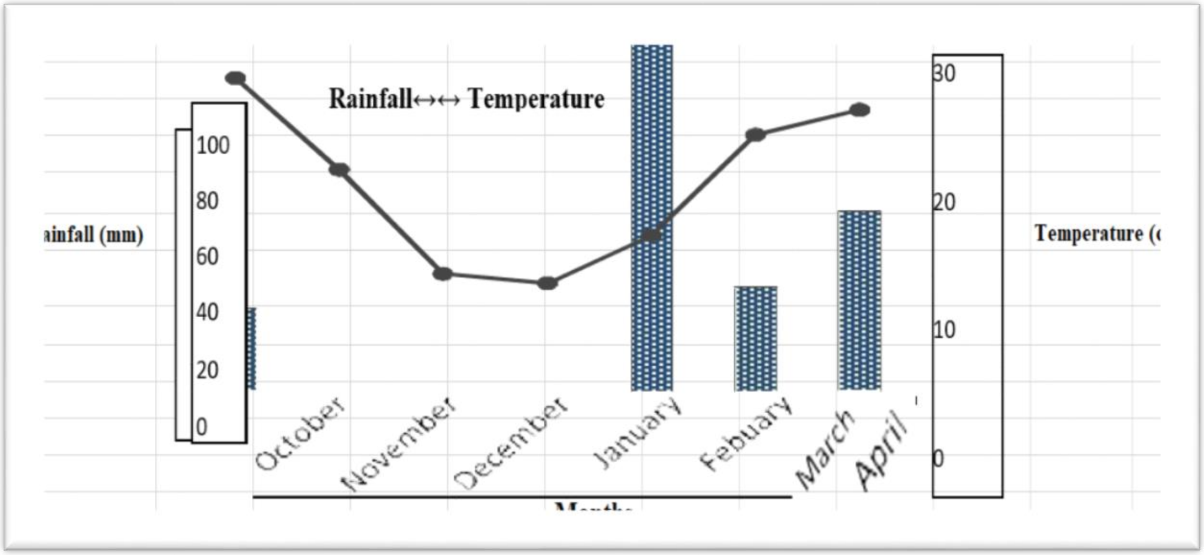

Figure 2 data for temperature and rainfall of related months

Physio-chemical properties of soil under observation and other parameters are given in table 1.

Table 1: Physio-chemical properties of the soil

Sand (%)	Silt	Clay	Texture	Moisture (%)	pH	EC (dSm-1)	Total nitrogen	Nitrate nitrogen mgkg-1	Olsen phosphorus mg kg-1	Extractable potassium mg kg-1
38.10%	32.02%	29.06%	clay loam	17%	7.7	0.2	6.63%	5.5	3.8	130

Plant parameters ammonium nitrogen

The results regarding treatments of polymer-coated urea and conventional urea in comparison with the control (no fertilizer) are presented in Figure 3. The concentrations of ammonium nitrogen in all polymer-coated treatments were low as compared to the conventional urea. However, the concentration of ammonium nitrogen increased gradually in different polymer-coated urea and conventional urea treatments as compared to the control, but their release rate varied with the N source. It was observed that a relatively rapid release of NH4-N was noticed in starch-coated urea i.e. 4.807, 10.57, 13.54, 20.213, 30.213, and 42.113 (ug per gram) at day one, three, day seven, day fourteen, day twenty- one, day twenty-eight and day thirty-five, in increasing order and polymer-coated neem oil 3.747, 6.31, 9.217, 16.213, 24.44 and 30.327(ug per gram) at day 1, 3, day 7, day 14, day 21, day 28, and day 35. In polymer-coated acacia gum, the release rate was 2.5, 4.55, 7.103, 10.123, 15.23, and 19.027(ug per gram) on day one, three, day seven, day fourteen, day twenty-one, day twenty-eight and day thirty-five respectively. Concentrations of ammonium nitrogen for conventional urea were 6.693, 11.323, 14.943, 24.213, 33.467, and 46.313(ug per gram) at day one, three, day seven, day fourteen, day twenty-one, day twenty-eight and day thirty-five, in increasing order respectively. Among all these three polymers i.e., starch, neem oil, and acacia gum, acacia gum shows the best results and slows the process of concentration of nitrogen losses in soil. It means that the use of polymer is essential to reduce the loss of nitrogen which is an essential nutrient for plant growth and development. The concentration of conventional urea was observed higher than the polymers coated urea because of its rapid N release property. According to statistical analysis, the results were significant. The hydrolysis process of urea is relatively less fast in the acacia gum-coated urea fertilizer than in the conventional urea and other two polymers coated urea due to the coatings of polymers material over the urea fertilizer (Junejo et al. 2011). The prolonged availability of urea to plants due to the delayed solubilization of urea slows nitrification, which reduces nitrate leaching and denitrification. By reducing ammonia volatilization, controlling N immobilization, delaying nitrification, and reducing losses from leaching and denitrification, urea coating also helps to improve nitrogen use efficiency (NUE). Through a regulated nitrogen release into the soil solution, polymer-coated urea offers a more precise and effective means to fulfill plant nitrogen requirements. As stated by (Hopkins et al., 2008), one of the main objectives is to improve production and efficiency while reducing excessive nitrogen loss through leaching and denitrification. By minimizing labor-intensive fertilizer application and improving urea fertilizer management, this is accomplished. The conversion of R-NH2 into gaseous ammonia (NH3) and subsequent conversion into ammonium (NH +) is known as ammonification. This process is aided by the water extraction from urea fertilizer as well as the breakdown of soil organic matter and microbial residues. However, gaseous ammonia often dissipates quickly into the environment, particularly when ammonification occurs near to the soil surface (Schlesinger and Hartley 1992).

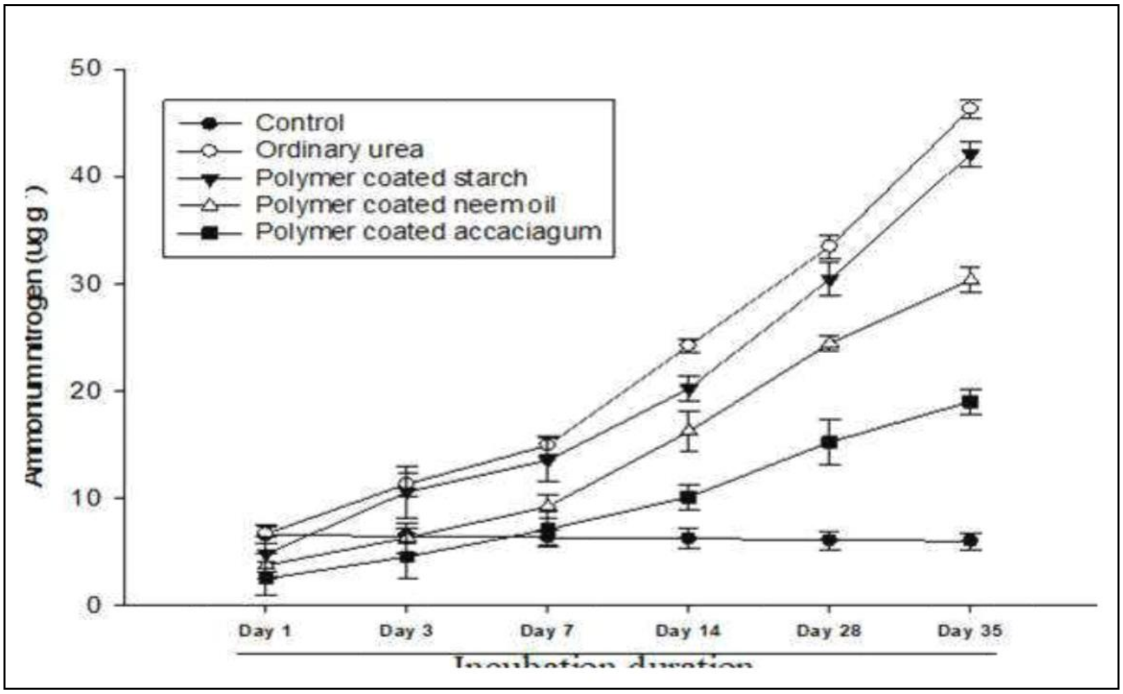

Figure 3: Ammonium-nitrogen released from PCUs and conventional urea at different time intervals during the incubation

Under certain situations, ammonium (NH4+) in the soil can be stable, but in other soil environments, it rapidly nitrifies, converting to nitrate (NO3-). The high solubility of nitrate and its attraction to soil colloids make it quickly lost by leaching. Additionally, it is capable of denitrification, which, particularly in low-oxygen environments, releases nitrous oxide (N2O) into the atmosphere. Nitrification adds to nitrogen loss as N2O. Nitrogen deficit in plants can result from several loss pathways and inadequate fertilization. Chlorosis, stunted development, increased susceptibility to infections and pests, and finally plant death are all consequences of insufficient nitrogen, which also impacts the formation of chlorophyll and proteins (Marschner 2012).

Nitrate Nitrogen:

The results regarding NO_3-N in different polymer-coated urea, conventional urea, and control are presented in Figure 4. The concentration of nitrate-nitrogen was increasing gradually in all (PCUs) and conventional urea as compared to control (no fertilizer) but their release rate was different. As the fertilizer made up of different polymer coatings is a slow-releasing fertilizer its release rate is slower than that of conventional urea. On day 1 the concentration of nitrate-nitrogen in conventional urea was 6.78 (ug g-1), in starch, it was 6.42 (ug g-1), in neem oil 6.12(ug g-1) and in acacia gum polymer coated treatment it was only 2.113 (ug g-1), while in control conditions it was 6.21 (ug g-1) At day 3, the concentration of nitrate-nitrogen in conventional urea was 8.92 (ug g-1), in starch coated urea treatment 7.32 (ug g-1), in neem oil it was 6.88(ug g- 1), while acacia gum treated still shows very low concentration i.e. 2.69 (ug g-1), whereas in control conditions it was 6.30(ug g-1) on day 3. At day 7, 12.86 (ug g-1) concentration was recorded in conventional urea whereas in PCUs i.e., starch, neem oil, and acacia gum it was 10.06 (ug g-1), 9.96 (ug g-1), and 4.88 (ug g-1) respectively, and in the control treatment, it was 6.24 (ug g-1). At the interval of day 14, the concentration was increased to 6.19 (ug g-1) in control conditions, and in polymer-coated starch urea it was 17.40(ug g-1), in polymer-coated neem oil it was 16.03 (ug g-1) and in acacia gum (PCU) shows very low concentration i.e., 6.78 (ug g-1), while the concentration of conventional urea was

21.86 (ug g-1). On day 28 the concentration was increased up to 30.12 (ug g-1) in conventional urea and in starch (PCU) it was increased to 25.31 (ug g-1) as well as in neem oil (PCU) the recorded concentration was observed at 23.02 (ug g-1) and in acacia gum coated urea it gradually increases to 11.62 (ug g-1) and in control conditions, it was 6.117 (ug g-1) observed. There was a gradual increase in the concentration at day 35, the higher concentration was observed with the value 41.29 (ug g-1) in conventional urea while, in control conditions it was 5.87(ug g-1) in starch-coated urea the amount was higher up to 30.31(ug g-1), in neem oil (PCU) the recorded amount was 27.13(ug g-1) and in acacia gum polymer coated urea gradually increases to 18.26 (ug g-1) which indicates the slow releasing process of nitrate nitrogen concentration among all the three different coated polymers. It was observed with the value 18.26 (ug g-1) in acacia gum polymer-coated urea and the concentration was higher in conventional urea at 41.29 (ug g-1). This showed an ascending order while the concentration in control was 6.21 on day l and the concentration on day 35 was 5.87 (ug g-1) showing a descending order and it was much lower than the other treatments. The release rate of conventional urea was higher as compared to polymer-coated urea, while the chances of losses of fertilizer are lesser in acacia gum polymer-coated urea. Based on statistical analysis, the results are significant. A study by (Junejo et al., 2011) showed that polymer-coated urea releases nutrients more slowly than untreated urea. Reddy (1999) investigated several coated urea types and discovered a 38-40% reduction in NH4-N loss, contributing to lower nitrogen loss in the environment. According to research by (Yaseen et al., 2006) urea with a polymer coating and regular urea both improved soil NO3-N component concentrations above NH4-N component concentrations for up to 6 weeks. Because it is expensive and environmentally harmful, addressing nitrogen loss from fertilizers is essential. Efforts have been made to improve nitrogen fertilizer efficiency, and utilizing CaC2 as a nitrification and de-nitrification retarder can efficiently keep nitrogen in NH4-N form, boosting fertilizer efficiency. Through the maintenance of NH4+ levels and the reduction of nitrogen losses through denitrification and NO3 emission, nitrification inhibitors have been certified for increasing crop yields. When employing traditional nitrogen sources at regular rates, studies have shown that NO3-N leaching for potatoes on sandy soils dramatically increased from 71 to 257 kg N ha^{1}.

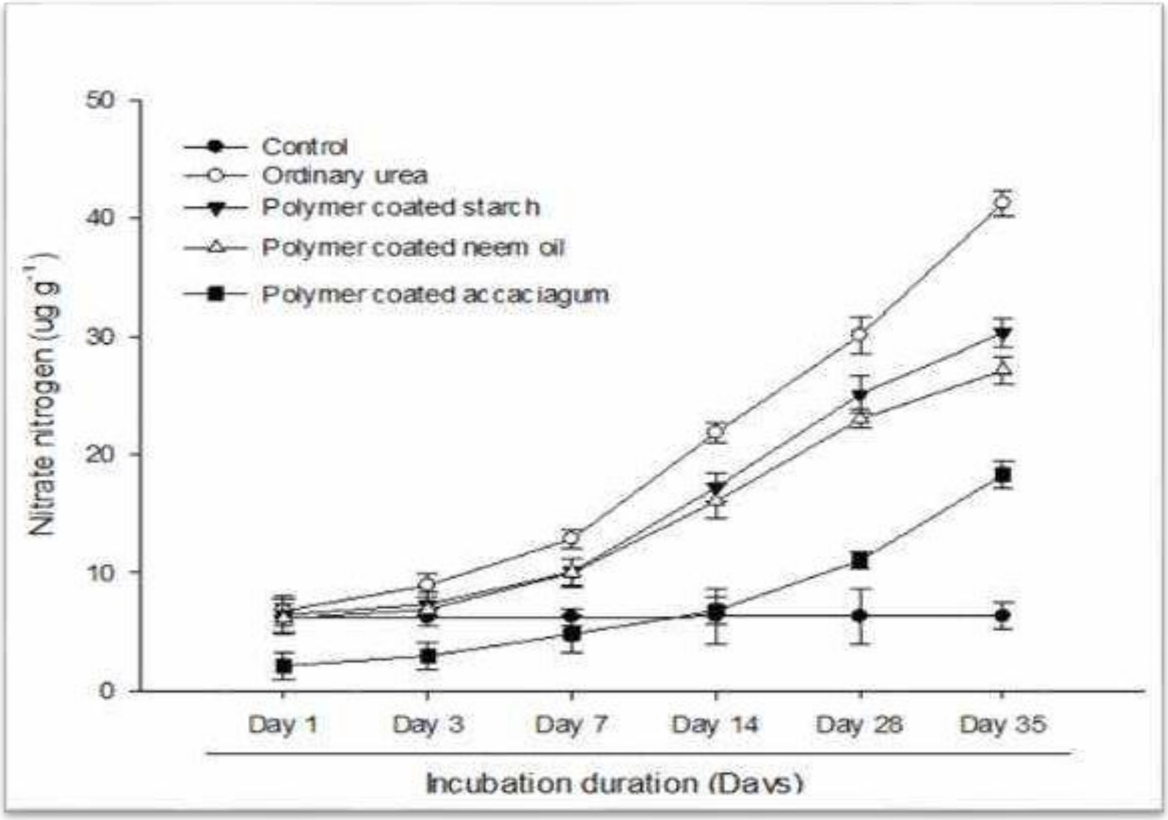

Figure 4: Nitrate-nitrogen released from PCUs and conventional urea at different time intervals during the incubation

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.*, **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]

But when controlled-release fertilizers like PCU and SCU were used, NO3-N leaching was significantly decreased to 7-62 kg ha-1 and 13-36 kg ha-1, respectively, especially when spray irrigation was used. These findings support the use of controlled-release fertilizers to reduce NO3- N leaching.

In contrast to previously reported levels at equal N application rates, the leaching of NO3-N with solvent N consistently showed lower values under the current researching conditions. However, it is notable that our results were within the lower range of NO3-N leaching related to Polymer- Coated Urea (PCU) application as recorded in the current literature. Several variables may have contributed to this result, including unusual dry weather conditions that reduced total water circulation through the soil. The majority of prior conducted research employed N during the growth stage or later, in line with current best management practices intended to reduce NO3 leaching, as opposed to several prior studies that applied N fertilizer at the time of planting (Gasser et al., 2002). According to studies on the cultivation of potatoes in sandy soils, using most of the N fertilizer after the tuber initiation stage helps to reduce NO_3-N leaching (LeMonte et al., 2009)

Effect of coated urea on N uptake by okra plants

Total Nitrogen

In contrast to traditional urea, the results of this investigation showed that coating urea with three different polymer materials significantly reduced ammonium loss, increased nutrient absorption, and enhanced plant development (table 2). Acacia gum polymer-coated urea, at 0.049g per pot, had the maximum nutrient absorption, followed by neem oil polymer-coated urea at 0.042g per pot and starch polymer-coated urea at 0.039g per pot. Nutrient absorption by okra plants from traditional urea-treated soil, on the other hand, was lower, at 0.036g per pot, while the control group had the lowest uptake at 0.016g per pot. Statistical analysis confirmed the importance of these findings. Nasima et al., (2010) reported that the application of polymer-coated urea treatments increased not only dry matter production but also plant nitrogen absorption. This rise in yield can be related to the physiological effects on the growth of plants and a reduced rate of urea hydrolysis in the soil, resulting in to reduced nitrogen fertilizer loss. Slow-release urea formulations that modify urea release from granules have been developed to lessen these losses. According to (Yu et al., 2010), polymer-coated urea, functioning as a controlled-release nitrogen source, can elevate plant nitrogen content, minimize nitrogen losses, optimize nitrogen use efficiency, and retain more nitrogen in the vicinity of the roots.

Table 2: N concentration and uptake by okra plant

Treatment	N conc. (mg g-1)	N uptake (g/plant)	N uptake (g/pot)
Control	0.133	0.0038	**0.016**
Conventional Urea	0.372	0.0108	**0.036**
Starch coated Urea	0.399	0.0129	**0.039**
Neem oil coated urea	0.412	0.141	**0.042**
Acacia gum coated urea	**0.425**	**0.149**	**0.049**

Effect of Polymer Coated Urea and conventional urea on Plant biomass

The average plant height for starch-based polymer-coated urea (PCU) was 87 cm, with an average shoot fresh weight of 78 grams per plant and an average shoot dry weight of 20 grams per plant (table 3). Nitrogen-use efficiency (NUE) was 48% for plants grown in starch PCU-treated soil (table 3). The mean plant height for neem oil-based PCU was 98 cm, with an average fresh shoot weight of 84 grams per plant and an average dry shoot weight of 22 grams per plant. For PCU made from acacia gum, the average plant height was 113 cm, and the average fresh shoot and dried shoot weights were 92 grams and 24 grams, respectively. NUE was 49% for neem oil PCU-grown plants and 52% for acacia gum PCU-grown plants. With a NUE of 41%, conventional urea-produced plants with a lower average height of 76 cm, an average fresh shoot weight of 70 grams per plant, and an average dry shoot weight of 17 grams per plant. The average plant height in the control was 65 cm, with an average fresh shoot weight of 59 grams per plant and an average dry shoot weight of 12 grams per plant.

Significant results are drawn via statistical analysis. Conventional urea has a more rapid release rate, resulting in fertilizer waste due to volatilization and leaching, limiting nutrient availability and affecting plant production. Acacia gum polymer-coated urea stands out as a slow-release fertilizer, reducing environmental losses while sustaining continuous plant availability throughout development phases. The increased nitrogen availability is attributable to the better plant growth observed with Acacia gum polymer-coated urea-treated soil. In line with other investigations, this slow-release strategy minimizes ammonium and nitrate losses (Junejo et al., 2009). Compared to conventionally treated soil, plants in the polymer-coated urea-treated soil exhibit higher nitrogen absorption. Along with reducing nitrogen loss, the better coating has a good impact on physiological plant processes.

Table 3: Effect of PCUs and Conventional urea on biomass of okra plant

Treatment	Plant height(cm)	Fresh shoot weight (g plant-1)	Dry shoot weight (g plant-1)
Control	65 e	59 e	**12 d**
Conventional urea	76 d	70 d	**17 c**
Starch coated urea	87 c	78 c	**20 b**
Polymer-coated neem oil	98 b	84 b	**22 a**
Polymer coated acacia gum	**113 a**	**92 a**	**24a**

Significant height differences were seen between treatments, but results for biomass remained ambiguous. Higher nitrogen treatment is expected to increase biomass, which is consistent with previous studies (Walker et al., 2007). Nitrogen's function in supporting both vegetative and reproductive development, as well as the formation of energy-efficient compounds managing food production and plant assembly, can be associated with the large vegetative biomass effects (WU FB and Xu, 1998). According to (Gairola et al., 2009) nitrogen plays a major role in plant growth as a vital component of chemical and biological molecules, having a significant impact on both food production and overall plant functions.

Conclusions

Higher ammonium-nitrate and nitrate nitrogen concentrations in soils treated with polymer-coated urea, with acacia gum-coated urea showing the slowest release. As release rates varied over time, nitrogen levels increased. Polymer-coated urea reduced ammonium loss, increased nutrient absorption, and boosted plant growth compared to conventional urea. Urea with acacia gum coating functioned well, leading to increased nitrogen absorption. In conclusion, biodegradable polymer-coated urea increases nitrogen usage efficiency, decreases losses, and enhances plant development, particularly when combined with acacia gum-coated urea. These results have practical significance for agricultural sustainability and environmental preservation.

References

Abbas, A., Arshad, A., Rehman, A., Bukhari, M., & Zaman, S. (2024b). Revolutionizing plant breeding programs with advancements in molecular marker-assisted selection. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 57. https://doi.org/10.54112/bbasr.v2024i1.57

Abbas, A., Rashad, A., Rehman, A., & Bukhari, M. (2024a). Exploring the response mechanisms of rice to salinity stress. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 58. https://doi.org/10.54112/bbasr.v2024i1.58

Al-Naamani, L., Dutta, J., & Dobretsov, S. (2018). Nanocomposite zinc oxide-chitosan coatings on polyethylene films for extending storage life of okra (*Abelmoschus esculentus*). Nanomaterials, **8**(1), 479.

Aloui, H., Jguirim, N., & Khwaldia, K. (2017). Effects of biopolymer-based active coatings on postharvest quality of okra pods in Tunisia. Fruits, **72**(6), 363–369.

Amberger, A. (2006). Soil fertility and plant nutrition in the tropics and subtropics. IFA, International Fertilizer Industry Association.

Anderson, J. M., & Ingram, J. S. I. (1994). Tropical soil biology and fertility: a handbook of methods. Soil Science, **157**(4), 265.

Arshad, A., Iqbal, M., Farooq, S., & Abbas, A. (2024). Genetic evaluation for seed yield and its component traits in sunflower (helianthus annuus l.) using line × tester approach. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 63. https://doi.org/10.54112/bbasr.v2024i1.63

Bremner, J. M., & Mulvaney, C. (1983). Nitrogen—total. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties, **9**(3), 595–624.

Chaudhuri, S. D., Dey, A., Upganlawar, S., & Chakrabarty, D. (2022). Influence of clay concentration on the absorption and rheological attributes of modified cellulose/acrylic acid-based hydrogel and the application of such hydrogel. Materials Chemistry and Physics, **282**(1), 125942.

Cheng, S., Liu, X., Zhen, J., & Lei, Z. (2019). Preparation of superabsorbent resin with fast water absorption rate based on hydroxymethyl cellulose sodium and its application. Carbohydrate Polymers, **225**(8), 115214.

Coskun, D., Britto, D. T., Shi, W., & Kronzucker, H. J. (2017). Nitrogen transformations in modern agriculture and the role of biological nitrification inhibition. Nature Plants, **3**(7), 1–10.

Dong, W., Shi, L., Li, S., et al. (2023). Hydrogen-rich water delays fruit softening and prolongs shelf life of postharvest okras. Food Chemistry, **399**(3), 133997.

Gairola, S., Umar, S., & Suryapani, S. (2009). Nitrate accumulation, growth and leaf quality of spinach beet (*Beta vulgaris* Linn.) as affected by NPK fertilization with special

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.*, **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]

reference to potassium. Indian Journal of Science and Technology, **2**(1), 35–40.

Galloway, J. N., Townsend, A. R., Erisman, J. W., et al. (2008). Transformation of the nitrogen cycle: recent trends, questions, and potential solutions. Science, **320**(5880), 889–892.

Gasser, M., Laverdière, M., Lagace, R., & Caron, J. (2002). Impact of potato-cereal rotations and slurry applications on nitrate leaching and nitrogen balance in sandy soils. Canadian Journal of Soil Science, **82**(4), 469–479.

Gee, G. W., & Bauder, J. W. (1986). Particle-size analysis. Methods of Soil Analysis: Part 1 Physical and Mineralogical Methods, **5**(2), 383–411.

Gould, W. D., Hagedorn, C., & McCready, R. G. L. (1986). Urea transformations and fertilizer efficiency in soil. Advances in Agronomy, **40**(1), 209–238.

Grant, C. A., Wu, R., Selles, F., et al. (2012). Crop yield and nitrogen concentration with controlled-release urea and split applications of nitrogen as compared to non-coated urea applied at seeding. Field Crops Research, **127**(2), 170–180.

Haroon, M., Waseem, M., Anwar, S., Sarfraz, Q., Sami, A., Khaliq, G., & Abass, H. (2024). Exploring the tillering potential in wheat cultivars at different planting geometry. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 82. https://doi.org/10.54112/bbasr.v2024i1.82

Harvey, A. C., Madsen, J., Douglas, C. W. I., et al. (2016). Antimicrobial graft copolymer gels. Biomacromolecules, **17**(12), 2710–2718.

Helmke, P. A., & Sparks, D. L. (1996). Lithium, sodium, potassium, rubidium, and cesium. Methods of Soil Analysis: Part 3 Chemical Methods, **5**(6), 551–574.

Hopkins, B. G., Rosen, C. J., Shiffler, A. K., & Taysom, T. W. (2008). Enhanced efficiency fertilizers for improved nutrient management: potato (*Solanum tuberosum*). Crop Management, **7**(1), 1–16.

Junaid, M., & Gokce, A. (2024). Global agricultural losses and their causes. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 66. https://doi.org/10.54112/bbasr.v2024i1.66

Junejo, N., Hanafi, M., Khanif, Y., & Yunus, W. (2009). Effect of Cu and palm stearin coatings on the thermal behavior and ammonia volatilization loss of urea. Research Journal of Agricultural and Biological Sciences, **5**(4), 608–612.

Junejo, N., Khanif, M. Y., Hanfi, M. M., et al. (2011). Reduced loss of NH3 by coating urea with biodegradable polymers, palm stearin, and selected micronutrients. African Journal of Biotechnology, **10**(24), 10618–10625.

Junejo, N., Khanif, M., Hanfi, M., Dharejo, K., & Wan, Z. (2011). Reduced loss of NH3 by coating urea with biodegradable polymers, palm stearin, and selected micronutrients. African Journal of Biotechnology, **10**(24), 10618–10625.

Khalid, I., Ahmad, M., Usman Minhas, M., et al. (2018). Cross-linked sodium alginate-g-poly (acrylic acid) structure: A potential hydrogel network for controlled delivery of loxoprofen sodium. Advances in Polymer Technology, **37**(10), 985–995.

Korsakov, K., Stepanov, A., Pozdnyakov, L., & Yakimenko, O. (2023). Humate-coated urea as a tool to decrease nitrogen losses in soil. Agronomy, **13**(8), 1958.

Langholtz, M., Davison, B. H., Jager, H. I., et al. (2021). Increased nitrogen use efficiency in crop production can provide economic and environmental benefits. Science of the Total Environment, **758**(1), 143602.

Lasisi, A. A., Akinremi, O. O., Zhang, Q., & Kumaragamage, D. (2020). Efficiency of fall versus spring applied urea-based fertilizers treated with urease and nitrification inhibitors I. Ammonia volatilization and mitigation by NBPT. Soil Science Society of America Journal, **84**(5), 949–962.

LeMonte, J., Taysom, T. W., Hopkins, B. G., Jolley, V. D., & Webb, B. L. (2009). Residual soil nitrate and potato yield with polymer coated urea. In *Proceedings, Western Nutrient Management Conference*, **8**(1), 4–5.

Li, H.-F., An, S.-D., Zhang, L., et al. (2021). Urea fertilizer with precisely regulable slow-release performance by complexing with random copolyester. *Journal of Environmental Chemical Engineering*, **9**(5), 105120.

Li, T., Wang, Z., Wang, C., et al. (2022). Ammonia volatilization mitigation in crop farming: A review of fertilizer amendment technologies and mechanisms. *Chemosphere*, **303**(1), 134944.

Li, X., Bao, Z., Chen, Y., et al. (2023). Exogenous glutathione modulates redox homeostasis in okra (*Abelmoschus esculentus*) during storage. *Postharvest Biology and Technology*, **195**(1), 112145.

Liu, J., Li, Q., Su, Y., et al. (2013). Synthesis of wheat straw cellulose-g-poly (potassium acrylate)/PVA semi-IPNs superabsorbent resin. *Carbohydrate Polymers*, **94**(1), 539–546.

Marschner, P. (2012). *Mineral Nutrition of Higher Plants* (3rd ed.). Academic Press Elsevier Ltd., United States of America, 668p.

McLean, E. O. (1983). Soil pH and lime requirement. Methods of Soil Analysis: Part 2 Chemical and Microbiological Properties, **9**(2), 199–224.

Mushtaq, R., Shafiq, M., Batool, A., Din, M., & Sami, A. (2024). Investigate the impact of zinc oxide nanoparticles under lead toxicity on chilli (*Capsicum annuum* L). *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 90. https://doi.org/10.54112/bbasr.v2024i1.90

Nasima, J., Khanif, M. Y., Hanfi, M. M., Wan, Z. W. Y., & Dharejo, K. A. (2010). Maize response to biodegradable polymer and urease inhibitor coated urea. *International Journal of Agriculture and Biology*, **12**(5), 773–776.

Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. Methods of Soil Analysis: Part 3 Chemical Methods, **5**(7), 961–1010.

Olsen, S. R. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agriculture.

Phornvillay, S., Pongprasert, N., Wongs-Aree, C., et al. (2019). Exogenous putrescine treatment delays chilling injury in okra pod (*Abelmoschus esculentus*) stored at low storage temperature. *Scientia Horticulturae*, **256**(2), 108550.

Qiao, D., Liu, H., Yu, L., et al. (2016). Preparation and characterization of slow-release fertilizer encapsulated by starch-based superabsorbent polymer. *Carbohydrate Polymers*, **147**(3), 146–154.

Rehman, A., Abbas, A., Arshad, A., Raza, G., Umar, M., & Bukhari, M. (2024). Advancements in genomic technologies and their impact on crop improvement and breeding methods. *Bulletin of Biological and Allied Sciences Research*, **2024**(1), 61. https://doi.org/10.54112/bbasr.v2024i1.61

Sami, A., Haider, M., Meeran, M., Ali, M., Abbas, A., Ali, Q., & Umar, M. (2023). Exploring morphological traits variation in chenopodium murale: a comprehensive multivariate analysis. *Bulletin of Biological and Allied Sciences Research*, **2023**(1), 43. https://doi.org/10.54112/bbasr.v2023i1.43

Schlesinger, W. H., & Hartley, A. E. (1992). A global budget for atmospheric NH3. *Biogeochemistry*, **15**(1), 191–211.

Steel, R. G., & Torrie, J. H. (1986). *Principles and procedures of statistics: A biometrical approach*. McGraw-Hill, New York, NY, USA.

Sun, M., Yang, X.-L., Zhu, Z.-P., et al. (2021). Comparative transcriptome analysis provides insight into nitric oxide suppressing lignin accumulation of postharvest okra (*Abelmoschus esculentus L.*) during cold storage. *Plant Physiology and Biochemistry*, **167**(1), 49–67.

Tan, H., Zhang, Y., Sun, L., et al. (2021). Preparation of nano sustained-release fertilizer using natural degradable polymer polylactic acid by coaxial electrospinning. *International Journal of Biological Macromolecules*, **193**(1), 903–914.

Thien, D. V. H., Lam, D.-N., Diem, H. N., et al. (2022). Synthesis of cellulose-g-poly (acrylic acid) with high water absorbency using pineapple-leaf extracted cellulose fibers. *Carbohydrate Polymers*, **288**(1), 119421.

Tian, Z., Wang, J. J., Liu, S., et al. (2015). Application effects of coated urea and urease and nitrification inhibitors on ammonia and greenhouse gas emissions from a subtropical cotton field of the Mississippi delta region. *Science of the Total Environment*, **533**(1), 329–338.

Trenkel, M. E. (1997). *Controlled-release and stabilized fertilizers in agriculture*. International Fertilizer Industry Association, Paris.

Vendrell, P. F., & Zupancic, J. (1990). Determination of soil nitrate by transnitration of salicylic acid. *Communications in Soil Science and Plant Analysis*, **21**(8), 1705–1713.

Walker, K. S., Bigelow, C. A., Smith, D. R., Van Scoyoc, G. E., & Reicher, Z. J. (2007). Aboveground responses of cool-season lawn species to nitrogen rates and application timings. *Crop Science*, **47**(5), 1225–1236.

Wu, F. B., & Xu, F. (1998). Chlorophyll meter to predict nitrogen sidedress requirements for short-season cotton (*Gossypium hirsutum L.*). *Field Crops Research*, **56**(2), 309–314.

Yaseen, M., Arshad, M., & Khalid, A. (2006). Effect of acetylene and ethylene gases released from encapsulated calcium carbide on growth and yield of wheat and cotton. *Pedobiologia*, **50**(4), 405–411.

Yu, H., Tremblay, N., Wang, Z., Bélec, C., Yang, G., & Grant, C. (2010). Evaluation of nitrogen sources and application methods for nitrogen-rich reference plot establishment in corn. *Agronomy Journal*, **102**(1), 23–30.

Declaration

Acknowledgment

Sincere thanks to faculty staff of PMAS Arid Agriculture University Rawalpindi, for their support during research and providing laboratory facility for analysis. We also thank Mr. Javaid Hassan and Zaryab Khan who helped in writing the manuscript.

Ethics Approval and Consent to Participate

Not applicable.

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.*, **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]

Consent for Publication

The study was approved by authors.

Funding Statement

Not applicable

Authors' Contribution

All authors contributed equally.

Conflict of interest

There is no conflict of interest among the authors of the manuscript.

[Citation: Hassan, J., Badar, S., Khan, Z., Hayat, U., Khan, A., Ijaz, F., Khan, Z.A., Sheraz, M., Rasheed, F., Iqbal J. (2024). Evaluation of polymer-coated urea to reduce nitrogen losses in soil and its application to okra *Abelmoschus esculentus* (l.) moench. *Biol. Clin. Sci. Res. J.*, **2024***: 1411*. doi: https://doi.org/10.54112/bcsrj.v2024i1.13411]