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Influence of Biodegradable Polymer Coated Urea on Nitrogen Uptake and Utilization of Maize (*Zea mays* L)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Controlled release nitrogen fertilizers could be an excellent management approach for improving nitrogen fertilizer efficiency. The present study aimed to investigate the effect of coated urea fertilizers to increase nitrogen uptake and utilization of maize. The nitrogen use efficiency of maize from various biodegradable polymer-coated urea fertilizers, such as palm stearin coated urea (PSCU), pine oleoresin coated urea (POCU), and humic acid coated urea (HACU), was determined in a pot culture experiment conducted at the Department of Soil Science and Agricultural

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Chemistry, Tamil Nadu Agricultural University, Coimbatore, during 2021. The coating materials have been coated on urea with different coating thicknesses, viz., PSCU - 5, 10, 15%, POCU – 2, 4, 6%, and HACU - 5, 10, 15%. Among all the treatments, T_{11}: HACU 15% produced highest grain yield (72.0g plant^{-1}) followed by T_7: POCU 4% (69.7 g plant^{-1}) and T_4: PSCU 10% (69.0g plant^{-1}). In terms of dry matter production, T_{10}: PSCU 10% produced maximum dry matter (186.5g plant^{-1}), followed by T_{11}: HACU 15% (186.2 g plant^{-1}), and T_7: POCU 4% (185.3g plant^{-1}). The nitrogen uptake by the maize plant was higher in T_7: POCU 4 % (1.62g plant^{-1}), followed by T_{11}: HACU 15% (1.59 g plant^{-1}) and T_4: PSCU 10% (1.59g plant^{-1}). Irrespective of treatments, the highest nitrogen utilization by the maize crop was found in T_7: POCU 4% (73.9%) followed by T_4: PSCU 10% (71.1%) and T_{11}: HACU 15% (70.9%) treatments. When compared to uncoated urea fertilizer, all coated urea fertilizers outperformed uncoated urea fertilizer in terms of grain yield, dry matter accumulation, and nitrogen uptake. To improve the nitrogen use efficiency, coated urea fertilizers prove to be a promising alternative to uncoated urea fertilizers.

Keywords: Urea; coated fertilizers; nitrogen release; nitrogen utilization; nitrogen uptake.

1. INTRODUCTION

Maize (*Zea mays* L.) is one of the most widely cultivated cereal crops in the world, providing grain, silage, and biofuel [1]. Nitrogen (N) is a chemical element that has required by most cultures of economic interest, and it has been the most impact on maize output [2,3,4]. Nitrogen is insufficient in nearly all agricultural soils and cropping systems around the world. It is necessary to use prudent nitrogen management to grow crops to meet the ever-increasing demands of human populations [5].

For any agricultural production system, nitrogen is the most important externally provided ingredient. The food supply of half of the world's population is reliant on nitrogenous fertilizers, either directly or indirectly. Rice, wheat, and maize now consume more than 90% of all nitrogenous fertilizers applied to cereals. Underuse nitrogen is linked to reduced agricultural yields, whereas overuse has a variety of soil and environmental effects. As a result, the response to applied nitrogen and its effectiveness must have been carefully evaluated to achieve maximum potential and sustainable yield [6].

The consumption of reactive nitrogen (Nr) in the form of fertilizer in India has increased quickly over the last six decades, with an annual rise of 6% since 1970 [7,8], but the cropping system of nitrogen use efficiency (NUE) has decreased [9]. This increased fertilizer use has led to increasing Nr losses, one of the clearest signs of which is the yearly emission of ammonia (NH_3), the most common fertilizer related atmospheric Nr loss, which is on the rise [10]. When urea is applied to plants in bare form is prone to losses due to nitrous emissions, leaching, denitrification, and surface runoff [11,12]. Naz et al. [13] reported, this loss leads in economic loss, low plant nutrient use efficiency, and environmental damage due to water eutrophication and nitrous emissions into the stratosphere.

Controlled release urea can be used to prevent granular urea loss due to leaching, ammonia volatilization, and denitrification [14]. The thickness of the coating film has important for better-controlled release qualities [15]. The time it takes for a dissolved nutrient to diffuse out of the coated shell and into the bulk water it is immersed in is determined by the diffusional path it must travel [16].

The main goal of fertilizer research is to increase the efficiency and availability of fertilizers to plants, either by increasing the availability of existing fertilizers or by producing a new high-efficiency fertilizer. The discovery of controlled-release fertilizers (CRFs) boosted fertilizer efficiency by allowing fertilizer to be released over a longer period. CRFs are made by lowering the solubility and mobility of conventional fertilizers through physical or chemical modification [17]. The present study investigates the low-cost biodegradable polymer-coated urea to enhance the nitrogen use efficiency of maize.

2. MATERIALS AND METHODS

2.1 Collection and Preparation of Soil Sample

Soil samples have collected from Field No. 37F of the eastern block, Tamil Nadu Agricultural

University, Coimbatore. The experimental soil is a mixed black calcareous, fine, montmorillonite, isohyperthermic which belonged to the Inceptisol order, Periyanaickenpalayam soil series, and classified as Vertic Ustropept taxonomically. The soil was air-dried, processed by quartering method, then sieved with a 2mm sieve. Representative sub examples were dispossessed for further soil physico-chemical analysis by embracing standard analytical procedures are given in Table 1.

2.2 Synthesis and Characterization of Coated Urea Fertilizers

Three types of coated urea fertilizers were made with various biodegradable polymer coating materials in different thicknesses of coating, such as palm stearin coated urea 5, 10, and 15%, pine oleoresin coated urea 2, 4, and 6%, and humic acid coated urea 5, 10, and 15%, under laboratory conditions using a rotating drum. The coating thickness between urea and coated materials was examined under a scanning electron microscope (SEM) (Fig. 1) at the Department of Nano Science and Technology laboratory, TNAU, Coimbatore.

About 10kg of soil was weighed and filled in each mud pot. After that, maize (COH (M) 6) hybrid seeds were sown. There were eleven treatments and replicated thrice under completely randomized design (CRD). The treatments details of the experiment have given in Table 2. The recommended dose of fertilizer (1120 mg N pot^{-1}) was applied as three splits (25% basal, 50% at 25 DAS, 25% at 45 DAS), the entire dose of Single super Phosphate (SSP) and Muriate of Potash (MOP) applied as basal application. Plant samples were taken at the vegetative, tasseling, and harvest stages of the plant and determined for nitrogen uptake and maize N use efficiency.

Table 1. Physico-chemical characteristics of experiment soil

Soil parameters (Units)	Values	Methods
pH (1:2.5 soil/water ratio)	8.17	Jackson [18]
Electrical conductivity (dS m^{-1}) (1:2.5 soil/water ratio)	0.24	Jackson [18]
Organic carbon (%)	0.62	Walkley and Black [19]
Available nitrogen (kg ha^{-1})	179.2	Subbiah and Asija [20]
Available phosphorus (kg ha^{-1})	16.7	Olsen [21]
Available potassium (kg ha^{-1})	504.1	Stanford and English [22]
Bulk density (Mg m^{-3})	1.17	Gupta and Dakshinamurthi [23]
Particle density (Mg m^{-3})	2.45	Gupta and Dakshinamurthi [23]
CEC (cmol (P$^{+)}$ kg^{-1})	45.6	Jackson [18]
Zn (mg kg^{-1})	0.56	Lindsay and Norvell [24]
Fe (mg kg^{-1})	2.05	Lindsay and Norvell [24]
Cu (mg kg^{-1})	0.68	Lindsay and Norvell [24]
Mn (mg kg^{-1})	5.97	Lindsay and Norvell [24]
Textural class	Sandy clay loam	Piper [25]

Table 2. Treatment details of the experiment

Treatments	Abbreviations
T_1 - Control	Control
T_2 - Uncoated urea	UCU
T_3 - Palm stearin coated urea 5%	PSCU 5%
T_4 - Palm stearin coated urea 10%	PSCU 10%
T_5 - Palm stearin coated urea 15%	PSCU 15%
T_6 - Pine oleoresin coated urea 2%	POCU 2%
T_7 - Pine oleoresin coated urea 4%	POCU 4%
T_8 - Pine oleoresin coated urea 6%	POCU 6%
T_9 - Humic acid coated urea 5%	HACU 5%
T_{10} - Humic acid coated urea 10%	HACU 10%
T_{11} - Humic acid coated urea 15%	HACU 15%

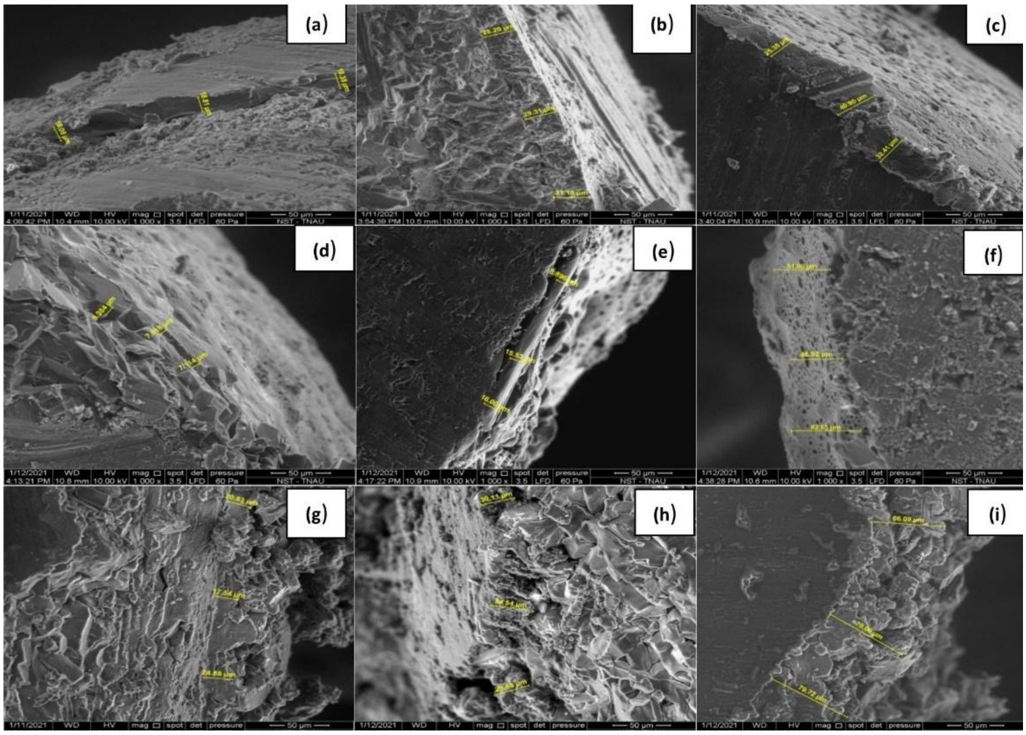

Fig. 1. Scanning electron micrograph of (a) PSCU 5%, (b) PSCU 10%, (c) PSCU 15%, (d) POCU 2%, (e) POCU 4%, (f) POCU 6%, (g) HACU 5%, (h) HACU 10%, (i) HACU 15% at x1000 magnification

Nitrogen uptake and Fertilizer N utilization calculation

$$N\ uptake\ (g\ pot^{-1}) = \frac{N\ concentration\ in\ plant\ (\%)\ x\ weight\ of\ dry\ matter\ (g)}{100}$$

$$Fertilizer\ N\ utilization\ (\%) = \frac{Fertilizer\ N\ uptake\ of\ plant\ (mg)}{Fertilizer\ N\ applied\ (mg)}\ x\ 100$$

2.3 Statistical Analysis

Using AGRES statistical package, the data from the experiments were subjected to analysis of variance (ANOVA) to determine significance. Significant critical differences (CD) were calculated at the 5% confidence level wherever treatment differences were found.

3. RESULTS AND DISCUSSION

3.1 Dry Matter Production

From the vegetative to the harvest stage, maize crop dry matter production increased (Table 3). Maize dry matter accumulation under different N treatments revealed a typical sigmoidal tendency across the maize growing season, according to Guo et al. [26]. The dry matter production of coated urea and uncoated urea differed significantly in the vegetative stage, ranging from 18.7-37.2g plant^{-1}. T_2: Uncoated urea treatment (37.2g plant^{-1}) had the maximum dry matter production, while T_1: control treatment had the lowest dry matter output (18.7g plant^{-1}). Uncoated urea produced more dry matter than any of the coated urea fertilizers at this stage. Probably, this is a result of uncoated urea's rapid dissolution, which encourages faster crop absorption than coated urea fertilizers at this early stage. Slow-release fertilizers may release too slowly from the polymer coating to be a helpful N supply in the early phases of crop development [27]. According to Mullen [28], nitrogen in the soil is lost by volatilization, immobilization, denitrification, and leaching prior to crop uptake, with the volume and pathways of loss affected by environmental conditions such as soil moisture and temperature. The medium thickness coated urea fertilizers, such as T_4: PSCU 10% (30.8g plant^{-1}), T_7: POCU 4% (26.4g plant^{-1}), and T_{10}: HACU 10% (32.3g plant^{-1}), and the high thickness coated urea fertilizers, such as T_5: PSCU 15% (28.4g plant^{-1}), T_8: POCU 6% (25.7g plant^{-1}), and T_{11}: HACU 15% (29.9g plant^{-1}), produced lesser dry matter production than T_2: uncoated urea (37.2g plant^{-1}) treatment during the vegetative stage because higher percentage coated urea takes longer to dissolve than lower percentage coated urea. Blends of slow and controlled-release urea, according to Andrade et al. [29], provide better regulated N release to maize plants, giving adequate quantities of N at each growth stage or throughout time than traditional urea.

In tasselling stage, the dry matter production was ranged from 48.6–85.3g plant^{-1}. The highest dry matter production was recorded in T_7: POCU 4% treatment (85.3g plant^{-1}) which is on par with T_4: PSCU 10%, T_8: POCU 6% and T_{11}: HACU 15% and the lowest dry matter production was recorded in T_1: control treatment (48.6g plant^{-1}). When compared to coated urea fertilizer treatments, the T_2: uncoated urea treatment produced less dry matter (59.8g plant^{-1}). According to Sofia et al. [30], the vegetative biomass of plants was treated by amended polymer composite fertilizers tend to be higher than positive and negative controls. This is since the maize plants' nitrogen requirements were met by the coated fertilizers. Because nitrogen is released slowly from coated urea fertilizers due to the degradation of coating material as time passes, medium thickness coated urea fertilizers such as T_4: PSCU 10% (82.4 g plant^{-1}), T_7: POCU 4% (85.3 g plant^{-1}), and T_{10}: HACU 10% (74.9 g plant^{-1}) produced more dry matter. The extent of yield improvement with coated fertilizers, according to Guan et al. [31], was largely dependent on the timely release of nutrients coated inside the three layers of fertilizer. Attapulgite coating reduced nutrient loss in the early growing stage as a barrier to chemical fertilizer, allowing maize plants to acquire nutrients in the middle and late developing phases.

In harvest stage, the minimum and maximum stover yields were produced from T_1: control and T_4: PSCU 10% treatments, respectively, it was ranged from 88.6-110.8g plant^{-1}. Palm stearin coated urea outperformed other coated urea fertilizers but, on par with all the treatments except control. Palm stearin is a wax containing coating material that is hydrophobic in nature, meaning it won't dissolve easily in water. As a result of the gradual release of nitrogen from PSCU, greater stover yield might have produced. According to Mathialagan et al. [32], palm stearin acts as a physical barrier between urea granules and water, preventing rapid urea disintegration. In comparison to uncoated urea, the application of palm stearin coated urea boosted maize dry matter yield from 60 to 20% pot^{-1} and increased N uptake by 77%, according to Nasima et al. [33]. In terms of grain yield, T_{11}: HACU 15% treatment had the highest yield (72.0g plant^{-1}) which is on par with T_7: POCU 4% (69.7g plant^{-1}) and T_4: PSCU 10% (69.0g plant^{-1}), the T_1: control treatment had the lowest yield (32.9 g plant^{-1}). This could be because humic-acid has a multitude of acidic functional groups, a great of specific surface area, high cation exchange capacity, and a lot of absorption capacity. According to Chen et al. [34], using humic-acid urea fertiliser improved sweet potato yield by 29.56 % while also increasing biological yield and harvest index. Total dry matter production from coated urea fertilizers differed significantly from uncoated urea fertilizers and it was ranging from 127.5-186.5g plant^{-1}. T_4: PSCU 10% treatment had the maximum dry matter accumulation (186.5g plant^{-1}), while T_1: control treatment had the lowest dry matter production (127.5g plant^{-1}). T_2: uncoated urea produced lees dry matter production (152.3g plant^{-1}) compared to all the coated urea fertilizer treatments. This could be because the nitrogen supplied from the coated urea meets the crop need whenever it is needed, resulting in higher dry matter output. Grant et al. [35] and Zhang et al. [36] found that the delayed release fertilizer's nitrogen release rate was synced with plant N absorption, resulting in fewer nitrogen losses. The nitrogen release properties of controlled release urea were also synchronised with the N requirements of wheat and maize crops during their whole growth cycles, according to Zheng et al. [37]. Among all coated urea fertilizers, the thickest coated urea produced less dry matter. This could be because the nitrogen released from the coated urea was exceedingly sluggish and did not match the crop's requirements. De Almeida et al. [38] found that using urea blends did not increase maize yields, and Garcia et al. [39] found that coated urea did not always match the crop demand, affecting dry mass and nitrogen uptake of crop.

3.2 Nitrogen Uptake

Nitrogen uptake of maize from coated urea fertilizers significantly differed from uncoated urea fertilizer treatment (Table 4). Applied N exhibited much larger uptakes of N than the typical urea plot, according to Xie et al. [40]. In vegetative stage, nitrogen uptake ranged from 0.180-0.625g plant^{-1}, with T_1: control and T_2: uncoated urea treatments recording the lowest and highest uptake, respectively. Because nutrient uptake was extremely quick at this stage, uncoated urea nitrogen uptake was at its peak. More thickness coated urea had the lowest nitrogen uptake, while less thickness coated urea had the highest nitrogen uptake. This could be because the thickness of the coating determines the amount of urea released beyond the coated layer. Nutrient release from coated fertilizer may be influenced by coating thickness, according to Shaviv et al. [41]. It is vital to remember that the higher the proportion of coated layer content, the lower the nitrogen leakage [42].

In tasselling stage, T_1: control and T_7: POCU 4% treatments had the lowest and maximum nitrogen uptake, respectively, ranging from 0.403-1.467g plant^{-1}. When compared to all the coated urea fertilizer treatments, uncoated urea treatments produced less nitrogen uptake. This could be because uncoated urea released nitrogen early and caused losses such as ammonia volatilization and nitrate leaching, preventing plants from absorbing nitrogen from the fertilizer. Coated urea fertilizers, on the other hand, postpone nitrogen release, allowing the plant to absorb more nitrogen during this stage. Andrade et al. [29] reported, Controlled-release urea and their blends have a delayed N release and promote continuous N uptake after 70 days. Likewise, the applied N rates were also more important than the N fertilizer technologies after 70 days. To help synchronise N release and uptake by maize, an appropriate blend of N fertilizers could be an attractive choice.

In harvest stage, stover nitrogen uptake ranged from 0.470-0.835g plant^{-1}, with the lowest and maximum uptakes detected in the T_1: control and T_5: PSCU 15% treatments, respectively. When compared to all coated urea fertilizers, the greatest thickness coated urea T_{11}: PSCU 15% registered greater nitrogen uptake in stover, which could be owing to the delayed nitrogen release up until this harvest stage, which induced more nitrogen uptake. The lowest and highest grain nitrogen uptake were obtained in the T_1: control and T_{11}: HACU 15% treatments, respectively, which varied from 0.323-0.885g plant^{-1}. The absorbed nitrogen from coated urea fertilizers was gladly supplied to the grains at the right period in the crop cycle. According to Noor Affendi, et al. [43], the plots fertilised with Urea coated with Cu and Zn (UCuZn) and UCuZn + nitrification inhibitor had the maximum exported N in stover and grain. Under uncoated urea, grain maize had the lowest exported nitrogen.

The maize crop's total nitrogen uptake ranged from 0.79-1.62g plant^{-1}, with the lowest and maximum uptakes recorded in the T_1: control and T_7: POCU 4% treatments, respectively. When compared to coated urea fertilizers, T_2: uncoated urea had lower total nitrogen uptake (1.13g plant^{-1}). This could be attributed to higher nitrogen losses from uncoated urea and reduced nitrogen losses from coated urea fertilizers. When compared to regular urea, Ning et al. [44] found that controlled release urea can boost total nitrogen uptake by aboveground organs and soil residual while lowering loss. Coated urea fertilizers may reduce nutrient losses by enhancing nutrient utilization efficiency. Control release fertilizers can be used to meet crop nutrient requirements in a single or divided application while also reducing pollution in the environment [43]. We might deduce from these findings that the coated fertilizers' release pattern satisfied the crop demand and provided more nitrogen to the plants.

3.3 Fertilizer Nitrogen Utilization

Fertilizer N utilization or nitrogen recovery efficiency (NRE) from the applied fertilizers was calculated based on the nitrogen uptake in treated and control pots of the maize. Fertilizer N utilization was maximum in coated urea fertilizers than uncoated urea fertilizers (Fig. 2). The highest fertilizer utilization has recorded in T_7: POCU 4% (73.9%), which is atpar with T_4: PSCU 10% (71.1%), and T_{11}: HACU 15% (70.9%), while the lower N utilization efficiency has registered in T_2: Uncoated urea treatment (30.3%). This was due to the slow release of nitrogen from the coated urea fertilizers to the longer period. Fertilizer N utilization was highest in urea applied with urease inhibitor than in urea applied without urease inhibitor, according to Gans et al. [45]. Fertilizer N utilization was 56% in his study, compared to 42.4% for conventional urea. According to Guo et al. [26], the maize crop's nitrogen recovery efficiency ranged between 20.4 and 40.2%, with the maximum NRE recorded in urea blended with slow-release nitrogen fertilizer at a ratio of 3:7 and the lowest NRE recorded with uncoated urea fertilizer treatment. According to Andrade et al. [29], due to lower N availability from N sources throughout time, declines in the NRE in uncoated urea are low throughout the cropping periods.

Table 3. Effect of coated urea fertilizers on dry matter production (g plant^{-1}) of maize

Treatments	Dry matter production (g plant^{-1})				
	Vegetative	Tasselling	Harvest		
			Stover	Grain	Total DMP
T$_1$-Control	18.7±0.72^{f}	48.6±1.15^{g}	88.6±0.53^{b}	32.9±0.64^{f}	127.5±6.89^{d}
T$_2$-UCU	37.2±1.61^{a}	59.8±1.24^{f}	101.4±1.79^{a}	46.5±0.77^{e}	152.3±8.24^{c}
T$_3$-PSCU 5%	33.2±0.10^{b}	63.7±2.59^{ef}	106.8±2.50^{a}	57.5±2.57^{d}	169.7±4.95^{b}
T$_4$-PSCU 10%	30.8±0.64^{bcd}	82.4±3.86^{ab}	110.8±6.17^{a}	69.0±0.18^{ab}	186.5±7.96^{a}
T$_5$-PSCU 15%	28.4±1.45^{de}	76.5±1.67^{bcd}	108.4±3.67^{a}	61.4±1.05^{cd}	175.4±0.37^{ab}
T$_6$-POCU 2%	32.6±0.41^{bc}	66.2±1.34^{ef}	106.5±1.55^{a}	57.5±1.86^{d}	169.6±4.85^{b}
T$_7$-POCU 4%	26.4±0.89^{e}	85.3±4.39^{a}	108.1±0.28^{a}	69.7±0.94^{ab}	185.3±6.17^{a}
T$_8$-POCU 6%	25.7±1.35^{e}	80.6±1.85^{abc}	107.4±0.95^{a}	63.8±2.89^{bc}	177.8±1.85^{ab}
T$_9$-HACU 5%	30.5±0.87^{bcd}	70.3±2.49^{de}	107.7±3.92^{a}	60.1±0.16^{cd}	173.4±3.25^{ab}
T$_{10}$-HACU 10%	32.3±1.50^{bc}	74.9±2.14^{cd}	108.3±2.31^{a}	59.5±3.28^{cd}	174.5±4.18^{ab}
T$_{11}$-HACU 15%	29.9±1.07^{cd}	82.2±1.63^{ab}	109.5±5.64^{a}	72.0±3.82^{a}	186.2±3.78^{a}
Mean	29.6	71.9	105.8	59.1	170.7
SEd	1.51	3.44	4.62	2.92	7.52

Values are mean of three replicates ± standard error (n=3); values followed by the same letter in each column are not significantly different from each other

Table 4. Effect of coated urea fertilizers on nitrogen uptake (g plant^{-1}) of maize

Treatments	N uptake (g plant^{-1})				
	Vegetative	Tasselling	Harvest		Total uptake
			Stover	Grain	
T$_1$-Control	0.180±0.003^{g}	0.403±0.015^{h}	0.470±0.010^{f}	0.323±0.001^{f}	0.79±0.020^{f}
T$_2$-UCU	0.625±0.002^{a}	0.712±0.037^{g}	0.608±0.005^{e}	0.521±0.004^{e}	1.13±0.011^{e}
T$_3$-PSCU 5%	0.485±0.007^{b}	0.841±0.036^{f}	0.641±0.018^{de}	0.667±0.012^{cd}	1.31±0.015^{cd}
T$_4$-PSCU 10%	0.431±0.002^{d}	1.343±0.003^{b}	0.753±0.030^{bc}	0.835±0.018^{a}	1.59±0.078^{a}
T$_5$-PSCU 15%	0.375±0.002^{ef}	1.125±0.054^{d}	0.835±0.009^{a}	0.700±0.007^{bcd}	1.53±0.044^{ab}
T$_6$-POCU 2%	0.505±0.008^{b}	0.907±0.011^{ef}	0.655±0.005^{de}	0.644±0.022^{d}	1.30±0.012^{d}
T$_7$-POCU 4%	0.391±0.005^{e}	1.467±0.012^{a}	0.762±0.042^{bc}	0.858±0.031^{a}	1.62±0.024^{a}
T$_8$-POCU 6%	0.357±0.017^{f}	1.225±0.012^{c}	0.773±0.011^{ab}	0.734±0.017^{b}	1.51±0.078^{ab}
T$_9$-HACU 5%	0.439±0.015^{bd}	0.942±0.017^{e}	0.592±0.033^{e}	0.697±0.036^{bcd}	1.29±0.029^{d}
T$_{10}$-HACU 10%	0.478±0.023^{c}	1.071±0.019^{d}	0.699±0.001^{cd}	0.720±0.015^{bc}	1.42±0.019^{bc}
T$_{11}$-HACU 15%	0.449±0.011^{cd}	1.299±0.026^{bc}	0.701±0.034^{cd}	0.885±0.039a	1.59±0.031a
Mean	0.429	1.030	0.681	0.689	1.37
SEd	0.015	0.037	0.032	0.031	0.057

Values are mean of three replicates ± standard error (n=3); values followed by the same letter in each column are not significantly different from each other

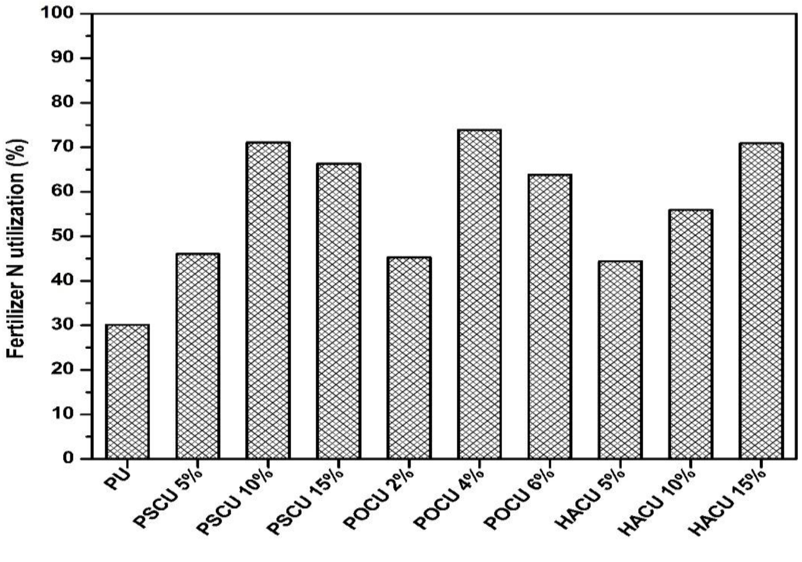

Fig. 2. Effect of coated urea fertilizers on fertilizer N utilization (%) of maize

4. CONCLUSION

Coated urea fertilizers releases nitrogen according to crop demand, has the potential to enhance nitrogen use efficiency while significantly reducing losses due to volatilization, leaching, and denitrification. According to the result of this study, coated urea fertilizer is a good alternative for uncoated urea fertilizers to enhance the nitrogen use efficiency of maize. The impacts of PSCU, POCU, and HACU on maize productivity were clearly proven in this study by releasing nitrogen over a long period of time that corresponded to the nitrogen requirement at different stages of crop growth. However, further field investigations are necessary to validate the use of this fertilizer on nitrogen use efficiency.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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