The Pharma Innovation Journal 2021; 10(10): 2495-2501

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(10): 2495-2501

www.thepharmajournal.com
Received: 04-07-2021
Accepted: 13-09-2021

B Balaganesh
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

P Malarvizhi
Professor and Head, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

N Chandra Sekaran
Professor, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

P Jeyakumar
Professor and Head, Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

KR Latha
Professor, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

A Lakshmanan
Professor and Head, Department of Nano Science and Technology, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Corresponding Author:
B Balaganesh
Ph.D., Scholar, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Effect of biodegradable polymer coated urea fertilizers for the growth and yield of hybrid maize (*Zea mays* L.)

B Balaganesh, P Malarvizhi, N Chandra Sekaran, P Jeyakumar, KR Latha and A Lakshmanan

DOI: https://doi.org/10.22271/tpi.2021.v10.i10ai.8572

Abstract
Urea is an instantaneous fertilizer, releasing nitrogen (N) rapidly after application to soil as it is effectively lost as ammonia volatilization and nitrate leaching which causes nitrogen inadequacy around roots and in the long run causes a deficiency between nitrogen demand and supply. The nitrogen from controlled-release urea can be consumed by crops more congenial than the nitrogen from uncoated urea. A pot culture experiment was carried out to investigate the response of maize crop to controlled-release urea fertilizers. Three different coated materials were utilized to coat on urea *viz*., palm stearin, pine oleoresin, humic acid. Different thicknesses of coated urea were developed such as palm stearin coated urea (PSCU) 5, 10, 15%, pine oleoresin coated urea (POCU) 2, 4, 6%, and humic acid coated urea (HACU) 5, 10, 15%. The coated urea fertilizers impacted the growth and yield of maize and increment the yield from 26.7 – 33.5% over the uncoated urea. The most noteworthy rate augmentation of yield was seen in HACU 15% (33.5%) trailed by POCU 4% (32.4%) and PSCU 10% (32.1%). It was inferred that, better synchronization between the nitrogen Release from coated urea fertilizers and growth of maize throughout the growing season.

Keywords: Biodegradable, polymer, coated, fertilizers, fertilizers, *Zea mays* L.

1. Introduction
Maize (*Zea mays* L.) is the most widely grown cereal in the world as far as production and yield, followed by wheat and rice. At this point, we are in the situation to build the food grain in quantity and quality way due to the challenge of feeding of a global populace of more than 9.7 billion by 2050 (Ehrlich and Harte, 2015; Godfry *et al*. 2010) [14, 17]. Nitrogen is one of the vital elements for the higher grain production of hybrid maize since it assumes a predominant part in the distinctive development cycles of plants. Nitrogen is a necessary part of chlorophyll and enzyme (Power and Schepers, 1989) [35] liable for significant activities for development and improvement of crops (Jat *et al*. 2013) [21]. The use of nitrogen significantly expanded the physiological growth of maize hybrids (Abubakar *et al*. 2019) [1].
Among all the nitrogen fertilizers, urea is a significant nitrogen fertilizer utilizing across the world in last four decades for fruitful crop production (Amrit Lal Meena *et al*. 2021) [4]. Nonetheless, its use efficiency is just 30–50% (Ni *et al*. 2013; Yang *et al*. 2017; Ni *et al*. 2009) [26, 7], because of high solubility in water, leaching of nitrate nitrogen in soil and volatilizing of ammonia to atmosphere. The nitrogen use efficiency esteems for cultivated grains in 2015 were 35, 41, 30, and 21% for the whole world, the United States, China, and India, separately (Omara *et al*. 2019) [33]. To ensure the necessary crop production, the necessary nitrogen is applied in the soil through plant-accessible forms i.e., nitrate (NO_3^-) and ammonical (NH_4^+) (Sanchary and Huq, 2018) [37].
In view of the great dissolution of urea, it is changed into ammoniacal and nitrate nitrogen fastly. Because of early changes, nitrogen going through different losses like denitrification, leaching, and volatilization processes which causes environmental contamination. It regularly causes perilous ecological contamination as well as economical expense (Kent and Riegel's, 2007) [23]. In addition, roughly 70% of the ecological risk related with urea-N is from nitrate leaching and runoff (David and Ju, 2015). In fact, one of the most significant environmental issues in maize cultivation is brought about by eutrophication polluting aquifers (Huang *et al*. 2017) [20]. sustainable improvement is expected to maximize yield by optimal nitrogen management while considering about ongoing environmental changes.

Slow release or controlled release fertilizers have been developed to build the proficient utilization of nutrients by crops and to lessen losses, particularly nitrogen losses because of its high mobility in soil (Azeem *et al*. 2014; Dong *et al*. 2016; Shaviv and Mikkelsen, 1993; Zhao *et al*. 2013) [6, 13, 39, 47]. This postponement in hydrolysis would bring down NH_3 losses and increment the accessibility of nitrogen for plant uptake, which could increase the performance and yield of maize. As denoted by Upadhyay (2012) [42], coated urea fertilizers protect soil from losing nitrogen by controlling the hydrolysis of urea in soil. This wonder would decrease the NH_3 losses and empower plants to take more accessible nitrogen through their roots (Blennerhassett *et al*. 2006; Cantarella *et al*. 2018) [8, 10]. Numerous scientists concentrated on the coating polymer (Li *et al*. 2016) [27], or biodegradable polymers (Mukerabigwi *et al*. 2015) [30] to work on its use and efficiency for the plants. The aim of all enhanced efficiency fertilizers is to lessen nitrogen losses and increment the utilization of nitrogen by crops. This goal can be accomplished through synchronization between the nitrogen released from fertilizers and the prerequisites of a crop, to give better plant nourishment all through the whole growing season (Andrade *et al*. 2021) [5]. This study expects to incorporate an eco-friendly and minimal expense urea fertilizer coated with biodegradable material as a binder.

2. Materials and Methods

2.1 Classification of experimental soil

During the year 2021, a pot culture experiment was carried out at the Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore. The experimental soil was a black calcareous soil with clay loam texture, belonging to the Periyanaickenpalayam soil series and taxonomically classified as fine, montmorillonitic, isohyperthermic, calcareous Typic Haplustert. The soil was air dried, then processed and sieved with a 2 mm sieve. Representative sub samples were dispossessed for further soil physico-chemical analysis by adopting standard analytical procedures are given in Table 1.

Table 1: Physico-chemical characteristics of experimental soil

Soil parameters	Value	Methods
pH (1:2.5 soil/water ratio)	8.17	Jackson (1973)
Electrical conductivity (dS m^{-1}) (1:2.5 soil/water ratio)	0.24	Jackson (1973)
Organic carbon (%)	0.62	Walkley and Black (1934)
Available nitrogen (kg ha^{-1})	179.2	Subbiah and Asija (1956)
Available phosphorus (kg ha^{-1})	16.7	Olsen (1954)
Available potassium (kg ha^{-1})	504.1	Stanford and English (1949) [41]
Bulk density (g/cc)	1.17	Gupta and Dakshinamurthi (1981) [19]
Textural class	Sandy clay loam	Piper (1966) [34]

2.2 Synthesis and characterization of coated urea fertilizers

Coated fertilizers are made with palm stearin, pine oleoresin, and humic acid as coating materials. Under lab conditions, they were coated with urea in a rotating drum. Three coating percentages were produced from each coating material, bringing about palm stearin coated urea (PSCU) at 5%, 10%, and 15%, pine oleoresin coated urea (POCU) at 2%, 4%, and 6%, and humic acid coated urea (HACU) at 5%, 10%, and 15%. Palm stearin was melted in a water bath at 60 °C and the essential amount was used to make different rates of coated urea such as PSCU 5, 10, 15%. Pine oleoresin normally contains water and turpentine, which was separated using a hot air oven at 70 °C. Further, petrol was used to dissolve the raw resin. Then, it was coated on urea in various percentages such as POCU 2, 4, 6%. To make humic acid coated urea, coating with vegetable oil first, then, added 5, 10, and 15 grams of humic acid to 100 grams of urea to accomplish 5, 10, 15% coated urea, separately. At last, to ensure adequate binding, the entirety of the coated fertilizers was placed in a hot air oven for 48 hours. After that, characterization was done using Scanning Electron Microscope (SEM) (Figure 1).

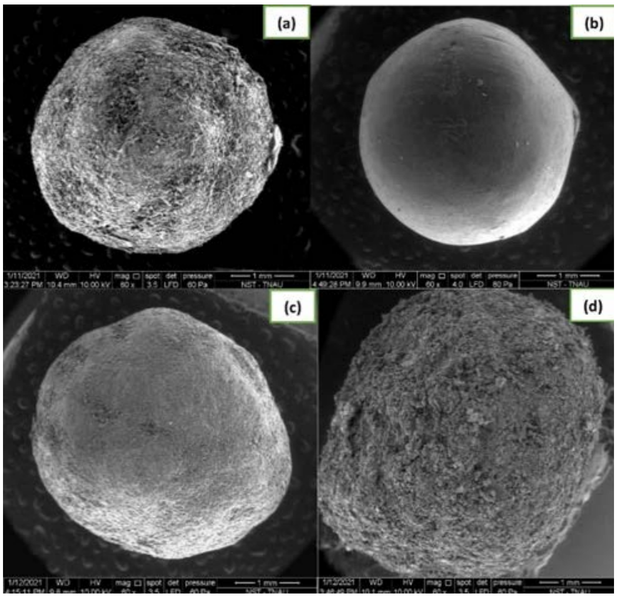

Fig 1: Scanning electron micrograph of (a) uncoated urea, (b) palm stearin coated urea (c) pine oleoresin coated urea (d) humic acid coated urea at 60x magnification

The scanning electron microscope images showed the surface morphology of coated granules. It can be seen there was no coating layer observed in uncoated urea, but layers are visible in other images differentiated by phase separation and their granule shapes. These coated layers serve as a barrier to the release of urea into the soil.

Hybrid maize Co-6 (COH (M) 6) selected as test crop for this experiment. The experiment was laid out in Completely Randomized Design (CRD). There are eleven treatments were replicated thrice. The treatments are, T_1 – Control, T_2 – Uncoated urea, T_3 – PSCU (5%), T_4 – PSCU (10%), T_5 – PSCU (15%), T_6 – POCU (2%), T_7 – POCU (4%), T_8 – POCU (6%), T_9 – HACU (5%), T_{10} – HACU (10%), T_{11} – HACU (15%). Each pot was filled with 10 kg of 2mm sieved soil and single plant was maintained in each pot. Recommended levels of fertilizer were applied based on Soil test crop response (STCR) values. Three splits of coated urea (25% basal, 50% at 25 DAS, 25% at 45 DAS), entire dose of Single super Phosphate as basal application and Muriate of Potash as two splits (50% basal, 50% at 25 DAS). When the plant grows at vegetative stage, tasselling stage and harvest stage plant and soil samples were collected and analysed.

Plant height, stem girth, root length, and root weight were all measured biometrically. The length and girth of the cob, the number of grains cob^{-1}, number of rows cob^{-1}, number of grains row^{-1}, the 100-grain weight, and the grain and stover yields were all reported. The cob's length and girth were measured and expressed in centimetres. The number of grains, number of rows cob^{-1}, number of grains row^{-1} were counted and the weight of 100 grains recorded in grammes. Each treatment's grain weight (yield) was calculated and given in grammes per plant^{-1}. The stover yield was recorded after drying and expressed in g plant^{-1}.

2.3 Statistical Analysis

Using the statistical programme AGRES, 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. Non-significant comparisons were denoted with the letter NS.

3. Results

3.1 Growth Traits

The impact of various coated urea fertilizers on plant height and stem girth of maize at different stages of maize are presented in Table 2. The plant height significantly differed between the treatments. The measured plant height went between 39.3-61.2, 97.6-127.2, and 117.9-152.8cm at vegetative, tasselling, and harvest stages respectively. The mean plant height of various stages went between 84.9-107.6cm. The most noteworthy mean plant height was recorded in PSCU 10% was 107.6cm, trailed by HACU 15% and POCU 4%, the two of which were 106.3cm. Moreover, all the coated fertilizer treatments produced more plant height than that of uncoated urea treatment (100.6cm). The control treatment had the shortest plant height (84.9cm) of any of the treatments. As far as stem girth measurement, there were no significant differences found between the treatments. The stem girth was ranged between 4.61-5.36, 7.52-8.88, and 10.6-12.3cm at vegetative, tasselling, and harvest stages individually. The most noteworthy mean stem girth was recorded in HACU 15%, trailed by PSCU 10% and POCU 4%, with values of 8.74, 8.71, and 8.66cm, respectively. The stem girth of uncoated urea treatment showed 8.49cm, which was comparable to all the coated urea treatments.

Table 2: Influence of coated urea fertilizers on plant height and stem girth of maize

Treatments	Plant height (cm)				Stem girth (cm)			
	Vegetative	Tasseling	Harvest	Mean	Vegetative	Tasseling	Harvest	Mean
Control	39.3	97.6	117.9	84.9	4.60	7.50	10.60	7.57
UCU	61.2	108.8	131.7	100.6	5.40	8.20	11.80	8.47
PSCU 5%	45.6	111.4	149.5	102.2	5.10	8.70	12.10	8.63
PSCU 10%	42.8	127.2	152.8	107.6	4.90	8.40	12.30	8.53
PSCU 15%	41.6	124.6	148.4	104.9	4.80	8.50	12.20	8.50
POCU 2%	47.3	113.4	147.3	102.7	5.30	8.60	12.10	8.67
POCU 4%	44.5	122.4	152.1	106.3	5.10	8.30	12.20	8.53
POCU 6%	43.9	120.5	151.8	105.4	5.00	8.70	12.00	8.57
HACU 5%	47.0	117.2	150.6	104.9	5.20	8.80	12.20	8.73
HACU 10%	47.1	119.2	151.4	105.9	5.20	8.60	12.10	8.63
HACU 15%	47.5	118.7	152.6	106.3	5.00	8.80	12.20	8.67
Mean	45.2	116.4	146.0		5.05	8.46	11.98	
SEd	2.52	5.15	6.69		NS	NS	NS	
CD (.05)	5.23	10.7	13.8		NS	NS	NS	

The root length and root volume of maize at different stages are presented in Table 3. Regarding treatments, there were significant contrasts in root length were found. The root length of maize ranged between 15.1-19.9, 20.9-29.8, and 24.3-33.6cm at vegetative, tasselling, and harvest stages respectively. The longest mean root length was found in HACU 15% (27.8cm), trailed by HACU 10% (26.8cm) while, PSCU 15% had the shortest root length among the coated fertilizer treatments (25.1cm). The root length of the uncoated urea treatment was 23.9cm, which was more limited than the root length of all coated urea treatments. In terms of root volume, values ranged between 15.1-28.9, 31.2-43.1, and 35.4-53.5cm^{-3} at vegetative, tasselling, and harvest stages respectively. The most elevated mean root volume was found in HACU 15% (41.7 cm^{-3}) trailed by HACU 10% (41.0cm^{-3}). The most minimal root weight among the coated fertilizer was recorded PSCU 15% (38.4 cm^{-3}). When contrasted with coated fertilizer treatments, uncoated urea treatment showed less root volume which was 34.2 cm^{-3}.

Table 3: Influence of coated urea fertilizers on root length and root volume of maize

Treatments	Root length (cm)				Root volume (cm^{-3})			
	Vegetative	Tasseling	Harvest	Mean	Vegetative	Tasseling	Harvest	Mean
Control	15.1	20.9	24.3	20.1	15.1	31.2	35.4	27.2
UCU	18.9	25.1	27.8	23.9	22.4	37.3	42.8	34.2
PSCU 5%	18.2	27.4	31.4	25.7	26.3	40.2	49.7	38.7
PSCU 10%	17.6	27.1	33.4	26.0	27.0	41.2	53.5	40.6
PSCU 15%	17.6	26.8	30.8	25.1	24.9	39.6	50.8	38.4
POCU 2%	18.1	26.9	30.9	25.3	26.1	41.8	51.2	39.7
POCU 4%	18.0	28.4	31.9	26.1	27.8	42.0	52.4	40.7
POCU 6%	17.9	26.4	32.5	25.6	26.6	41.2	50.9	39.6
HACU 5%	18.5	27.3	30.8	25.5	26.0	42.2	51.8	40.0
HACU 10%	18.4	28.9	33.2	26.8	27.2	43.1	52.6	41.0
HACU 15%	19.9	29.8	33.6	27.8	28.9	42.6	53.5	41.7
Mean	18.0	26.8	30.9		25.3	40.2	49.5	
SEd	0.69	1.05	1.19		1.10	1.59	1.73	
CD (.05)	1.43	2.19	2.48		2.28	3.31	3.58	

3.2 Yield Traits

Maize yield parameters of coated urea fertilizer treatments showed significant differences between all the imposed treatments (Table 4). The most elevated cob length (14.0cm) and cob girth (18.8cm) was seen in HACU 15%, POCU 4% and the least cob length and cob girth among the coated urea fertilizer were POCU 2% and PSCU 15% (12.6cm and 17.4cm separately) which was comparable to uncoated urea treatments. Total number of grains per cob was greatest in HACU 15% (236 grains cob^{-1}) which was on par with PSCU 10%, POCU 4% and POCU 6% treatments. The minimum grains cob^{-1} among coated urea fertilizer treatments were registered in uncoated urea treatment (136 grains cob^{-1}). The number of rows per cob^{-1} maximum in PSCU 10% (14.7), trailed by POCU 4% (14.3). The number of grains row^{-1} was maximum in POCU 6% (18.5), followed by HACU 15% (18.3). Both number of cob^{-1} and number of grains row^{-1} were comparable with uncoated urea fertilizer treatments with the values of 12.6 and 15.7 respectively. The maximum hundred grain weight of grains were recorded in PSCU 10% (30.8g) trailed by HACU 15% (30.5g). The grain yield and straw yield of coated urea composts had huge impact from uncoated urea fertilizer treatment. The maximum grain yield among the coated fertilizer treated pots recorded in HACU 15% (72.0g $plant^{-1}$) trailed by POCU 4% (69.7g $plant^{-1}$) and the minimum grain yield was recorded in uncoated urea treatment (46.5g $plant^{-1}$) however the most extreme straw yield was recoded in PSCU 10% (110.8g $plant^{-1}$) and the minimum was recoded in uncoated urea treatment (101.0g $plant^{-1}$). In all the above said yield parameters control pots enrolled lesser qualities than every one of the treatments.

Table 4: Influence of coated urea fertilizers on yield parameters of maize

Treatments	Cob length (cm)	Cob girth (cm)	Number of grains cob^{-1}	Number of rows cob^{-1}	Number of grains row^{-1}	100 grain weight (g)	Grain yield (g $plant^{-1}$)	Straw yield (g $plant^{-1}$)
Control	10.1	14.5	136	11.4	13.2	24.2	32.9	88.6
UCU	11.8	16.7	171	12.6	15.7	27.2	46.5	101.4
PSCU 5%	13.1	17.8	201	13.3	16.4	28.6	57.5	106.8
PSCU 10%	13.8	18.6	224	14.7	17.6	30.8	69.0	110.8
PSCU 15%	12.9	17.4	214	13.1	17.5	28.7	61.4	108.4
POCU 2%	12.6	17.5	199	12.0	17.3	28.9	57.5	106.5
POCU 4%	13.3	18.8	234	14.3	18.4	29.8	69.7	108.1
POCU 6%	13.0	18.1	232	14.1	18.5	27.5	63.8	107.4
HACU 5%	13.6	18.2	213	13.6	17.5	28.2	60.1	107.7
HACU10%	13.7	18.6	211	13.5	17.5	28.2	59.5	108.3
HACU15%	14.0	18.8	236	14.2	18.3	30.5	72.0	109.5
Mean	12.9	17.7	206	13.3	17.0	28.4	59.0	105.7
SEd	0.59	0.59	10.7	0.50	0.92	1.40	3.43	1.91
CD (.05)	1.22	1.23	22.2	1.05	1.92	2.91	7.11	3.97

4. Discussion

Scientific and judicious nitrogen management adds to diminish N losses, increment plant growth, and improve crop yield and N use efficiency. Growth attributes such as plant height, and stem girth are the main characteristics that decide the vigour and potential of the maize crop (Krishnaraj *et al.* 2020) [25]. Coated urea fertilizers produced more plant height and stem circumference interestingly, with uncoated urea treatment. This may be because of the sluggish release of nitrogen that met the necessity of maize crop. Chalk *et al.* (2015) [11] reported, controlled-release urea builds proficiency and decreases N losses by better synchronizing nitrogen availability with plant demand. Plant height achieved the most extreme in the vegetative phase of maize which got uncoated urea treatment, while coated urea fertilizer treatments recorded the least tallness. This might be due to uncoated urea fulfils the crop needs very short term because uncoated urea has gone through fast hydrolysis and achieved losses as ammonia volatilization and nitrate leaching. The typical urea transient nitrogen immobilization and nitrogen supply caused poor nitrogen uptake of plant (Alijani *et al.* 2013), while controlled release urea would defer nitrogen release and uptake by plant is more throughout growing season. Moreover, in tasselling and harvest stage coated urea treatment pots recorded the greatest plant height yet uncoated urea treatment recorded the least tallness. This may be because the quick dissolution of uncoated urea got the crop necessity up to the vegetative stage and neglected to remunerate in the remainder of the stages. However, coated urea fertilizers supply the nitrogen and met the crop needs by supplying nutrient through their root for longer period. This finding is steady with Espindula *et al*. (2013) [15], the capacity of coated urea delayed the hydrolysis, which would make nitrogen stay longer in soil and assist the roots absorb the nitrogen adequately, subsequently decidedly adding to improve the growth. Indeed, soil nitrogen shortfalls or excesses were clearly connected to growth stage highlights difference in nitrogen supply and crop nitrogen demand (Shi *et al*. 2012) [40].

As far as coating materials, palm stearin coated fertilizers performed well in growth characteristics of maize interestingly, with pine oleoresin and humic acid coated urea fertilizers. This may be because of wax present in palm stearin which is hydrophobicity in nature. This may not permit water to enter to contact the urea granules and prevent the quick release of nitrogen. Wax as the sealant of the porous coating may make a move in two ways to control the nitrogen release rate. First and foremost, it could diminish the holes and abatement the immediate loss of nitrogen through the pores (Li *et al*. 2012) [36], Secondly, the increment of the wax would change the coating from hydrophilicity to hydrophobicity, which could bring down the nitrogen dispersion through the coating layer (Yang *et al*. 2012) [45].

Root length and root volume of maize at different development phases of maize were impacted by coated urea fertilizer treatments. The mean root length was higher in humic acid coated urea fertilizers when contrasted with other coated urea fertilizer treatments because humic acid assuming a significant part in root development. At the point when root development expanding, naturally root volume and plant development would be expanded. This was upheld by Nardi, 2017 [31], Ludwig, 2013 [28], synergistic impacts with the expansion of humic substances that might advance plant improvement by stimulating root and shoot development.

Because of the application of coated urea fertilizers, yield traits of maize increased and significantly varied from uncoated urea and control treatments. Nitrogen released gradually from coated urea fertilizers prompts an incredible synchronization with plant growth. The continuous release of nitrogen from controlled release urea, synchronized with the crop nitrogen demand, which decreases nitrogen losses to the environment and increases nutrient availability to the crop. Then again, controlled release urea is superior to uncoated urea at delaying root senescence because of the prolonged soil nitrogen availability, which viably promotes nitrogen assimilation and biomass amassing by plants (Shao *et al*. 2009; Ye *et al*. 2013) [38, 46]. Furthermore, controlled release fertilizers release nitrogen up to cob formation stage, yet uncoated urea neglected to supply nitrogen to this period. The release rate of N from controlled release urea was delayed before the cob formation stage, while the requirement of nitrogen by plants was additionally lower than in later stages. In any case, the nitrogen release peak for controlled release urea was from cob formation to silking stages, which related well with the pinnacle nitrogen uptake of maize likewise during the cob formation to silking stages. The outcomes proposed that nitrogen release characteristics of controlled release urea firmly coordinated with the demand for nitrogen in the later developing stages of crop (Zheng *et al*. 2016) [48]. More thickness coated urea, for example, PSCU 15%, POCU 6% not delivered expected nitrogen to the crop, however HACU 15% delivered slowly to the crop since when contrasted with palm stearin and pine oleoresin, humic acid is less hydrophobic. So, PSCU 10%, POCU 4% and HACU 15% recorded greatest cob length, cob girth, number of grains cob^{-1}, number of rows cob^{-1}, number of grans row^{-1} and 100 grain weight. At the point when the nitrogen uptake is most extreme, usage of plant will be extraordinary to produce more number and quality of grains. Khan *et al*. (2014) [24] reported, the improvement in yield parameters like number of rows of ears, number of grain rows, and number of grain ears because of the utilization of nitrogen from controlled release urea.

The grain and straw yield of maize influenced by various coated urea fertilizers and altogether varied from uncoated urea fertilizer treatment. Because of the effective and timely uptake of nitrogen, grain yield increased in coated urea fertilizer treatments. Xie *et al*. (2020) reported, polymer coated urea released nitrogen potentially during crop growth brought about predominant nutrient retention, extended development. Grain yield increment occurred in coated urea over uncoated urea ranged from 26.7 – 33.5% (Figure 2). The most noteworthy augmentation occurred in HACU 15% (33.5%) trailed by POCU 4% (32.4%) and PSCU 10% (32.1%). Nur Mahfuzah Noor Affendi *et al*. (2018) [32] reported that, deferring the urea hydrolysis rate is helpful for limiting nitrogen losses and increasing nitrogen uptake, eventually producing higher yield. Among the treatments, the selected enhanced efficiency of urea fertilizer with Cu and Zn (urease inhibitors) biochar coated urea, geopolymer coated urea treatments were better than uncoated urea treatment in increasing the yield of the maize with increment of 74% and, 50.25%, 32.42% respectively. Super urea (controlled release urea) further increased the grain yield of maize by 38.06% with 90 kg N. Agrotain urea further increased the grain yield by 30.55% with 90 kg N when contrasted with treatments getting untreated urea at 90 kg N (Amir Zaman Khan *et al*. 2015) [3].

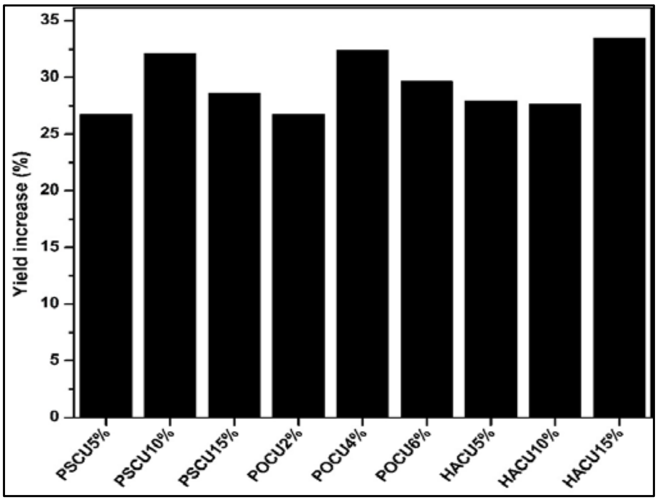

Fig 2: Percent yield increase from coated urea over uncoated urea

5. Conclusion

It was decided that the use of coated urea fertilizers substantially increased the plant growth and yield of maize crop when compared to uncoated urea. Coated urea fertilizers reduced the nitrogen losses sch as ammonia volatilization and nitrate leaching, thereby utilization of nitrogen by plant was high. This biodegradable polymer coated urea will be a good alternative for uncoated urea and other synthetic polymer coated urea exists in the market to improve the fertilizer use efficiency. Furthermore, it suggests that palm stearin and pine oleoresin and humic acid coated urea may be a good alternative nitrogen source to neem oil-coated urea in future.

6. Acknowledgement
The authors would like to express their gratitude to the Department of Soil Science and Agricultural Chemistry, as well as the Department of Nano Science and Technology at Tamil Nadu Agricultural University, for their invaluable assistance and laboratory facilities in carrying out this research.

7. References
1. Abubakar AW, Manga AA, Kamara AY, Tofa AI. Physiological evaluations of maize hybrids under low nitrogen. Advances in Agriculture 2019;2624707. https://doi.org/10.1155/2019/2624707
2. Alijani K, Bahrani MJ, Kazemeini SA. Short-term responses of soil and wheat yield to tillage, corn residue management and nitrogen fertilization. Soil and Tillage Research 2012;124:78-82. https://doi.org/10.1016/j.still.2012.05.005
3. Khan AZ, Afzal M, Muhammad A, Akbar H, Khalil SK, Wahab S. Influence of slow release urea fertilizer on growth, yield and N uptake on maize under calcareous soil conditions. Pure and Applied Biology 2015;4(1):70.
4. Amrit Lal Meena, Minakshi Karwal, Sunil Kumar, Mishra RP. Black urea: A new paradigm shifts for humic acid coated slow release urea fertilizer. Agriallis – Science for agriculture and allied sector: A monthly e newsletter 2021;3(1).
5. Andrade AB, Guelfi DR, Chagas WF, Cancellier EL, de Souza TL, Oliveira LS *et al*. Fertilizing maize croppings with blends of slow/controlled-release and conventional nitrogen fertilizers. Journal of Plant Nutrition and Soil Science 2021;184(2):227-37. https://doi.org/10.1002/jpln.201900609
6. Azeem B, Ku Shaari K, Man ZB, Basit A, Thanh TH. Review on materials & methods to produce controlled release coated urea fertilizer. Journal of controlled release 2014;181:11-21. https://doi.org/10.1016/j.jconrel.2014.02.020
7. Ni B, Liu M, Lü S. Multifunctional slow-release urea fertilizer from ethyl cellulose and superabsorbent coated formulations. Chemical Engineering Journal. 2009;155(3):892-8. https://doi.org/10.1016/j.cej.2009.08.025
8. Blennerhassett JD, Quin BF, Zaman M, Ramakrishnan C. The potential for increasing nitrogen responses using Agrotain treated urea. In Proceedings of the New Zealand Grassland Association 2006, 297-301.
9. Bouwman AF, Lee DS, Asman WA, Dentener FJ, Van Der Hoek KW, Olivier JG. A global high-resolution emission inventory for ammonia. Global biogeochemical cycles 1997;11(4):561-87. https://doi.org/10.1029/97GB02266
10. Cantarella H, Otto R, Soares JR, de Brito Silva AG. Agronomic efficiency of NBPT as a urease inhibitor: A review. Journal of advanced research 2018;13:19-27. https://doi.org/10.1016/j.jare.2018.05.008
11. Chalk PM, Craswell ET, Polidoro JC, Chen D. Fate and efficiency of 15 N-labelled slow-and controlled-release fertilizers. Nutrient Cycling in Agroecosystems. 2015;102(2):167-78. https://doi.org/10.1007/s10705-015-9697-2
12. Norse D, Ju X. Environmental costs of China's food security. Agriculture, Ecosystems & Environment. 2015;209:5-14. https://doi.org/10.1016/j.agee.2015.02.014
13. Dong YJ, He MR, Wang ZL, Chen WF, Hou J, Qiu XK, *et al*. Effects of new coated release fertilizer on the growth of maize. Journal of soil science and plant nutrition. 2016;16(3):637-49. http://dx.doi.org/10.4067/S0718-95162016005000046
14. Ehrlich PR, Harte J. Opinion: To feed the world in 2050 will require a global revolution. Proceedings of the National Academy of Sciences 2015;112(48):14743-4. https://doi.org/10.1073/pnas.1519841112
15. Curitiba Espindula M, Soares Rocha V, Alves de Souza M, Campanharo M, de Sousa Paula G. Rates of urea with or without urease inhibitor for topdressing wheat. Chilean journal of agricultural research 2013;73(2):160-7. http://dx.doi.org/10.4067/S0718-58392013000200012
16. Glibert PM, Harrison J, Heil C, Seitzinger S. Escalating worldwide use of urea–a global change contributing to coastal eutrophication. Biogeochemistry 2006;77(3):441-63. https://doi.org/10.1007/s10533-005-3070-5
17. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF *et al*. Food security: the challenge of feeding 9 billion people. science 2010;327(5967):812-8. https://doi.org/10.1126/science.1185383
18. Good AG, Beatty PH. Fertilizing nature: a tragedy of excess in the commons. PLoS biology. 2011;9(8):e1001124. https://doi.org/10.1371/journal.pbio.1001124
19. Gupta RP, Dakshinamurthi C. Procedures for physical Analysis of soils. IARI, New Delhi 1981.
20. Huang T, Ju X, Yang H. Nitrate leaching in a winter wheat-summer maize rotation on a calcareous soil as affected by nitrogen and straw management. Scientific reports 2017;7(1):1-1. https://doi.org/10.1038/srep42247
21. Jat ML, Satyanarayana T, Manundar K, Parihar CM, Jat SL, Tetarwal JP, *et al*. Indian Journal of Fertilizer. 2013;9(4):80-94.
22. Kawakami EM, Oosterhuis DM, Snider JL. Nitrogen Assimilation and Growth of Cotton Seedlings under N a C l Salinity and in Response to Urea Application with NBPT and DCD. Journal of Agronomy and Crop Science 2013;199(2):106-17. https://doi.org/10.1111/jac.12002
23. Kent A, Riegel's. Handbook of Industrial Chemistry and Biotechnology, 11th ed. 1&2, Verlag, Springer 2007.
24. Khan MJ, Malik A, Zaman M, Khan Q. Nitrogen use efficiency and yield of maize crop as affected by agrotain coated urea in arid calcareous soils. Soil Environ. 2014;33(1):01-6.
25. Krishnaraj M, Senthil K, Shanmugasundaram R, Prabhaharan J, Subramanian E. Effect of chelated iron and zinc application on growth and productivity of maize (*Zea mays* L.) in subtropical climate. Journal of Pharmacognosy and Phytochemistry 2020;9(6):1212-6.
26. Yang L, An D, Wang TJ, Kan C, Jin Y. Swelling and diffusion model of a hydrophilic film coating on controlled-release urea particles. Particuology 2017;30:73-82. https://doi.org/10.1016/j.partic.2016.03.005
27. Li L, Sun Y, Cao B, Song H, Xiao Q, Yi W. Preparation and performance of polyurethane/mesoporous silica

composites for coated urea. Materials & Design. 2016;99:21-5. https://doi.org/10.1016/j.matdes.2016.03.043
28. Ludwig M. Evolution of the C 4 photosynthetic pathway: events at the cellular and molecular levels. Photosynthesis research 2013;117(1):147-61. https://doi.org/10.1007/s11120-013-9853-y
29. Lunt OR. Controlled-release fertilizers. Achievements and potential. Journal of Agricultural and Food Chemistry 1971;19(5):797-800. https://doi.org/10.1021/jf60177a034
30. Mukerabigwi JF, Wang Q, Ma X, Liu M, Lei S, Wei H, *et al*. Urea fertilizer coated with biodegradable polymers and diatomite for slow release and water retention. Journal of Coatings Technology and Research. 2015;12(6):1085-94. https://doi.org/10.1007/s11998-015-9703-2
31. Nardi S, Ertani A, Francioso O. Soil–root cross-talking: The role of humic substances. Journal of Plant Nutrition and Soil Science 2017;180(1):5-13. https://doi.org/10.1002/jpln.201600348
32. Nur Mahfuzah Noor Affendi, Mohd Khanif Yusop, Radziah Othman. Efficiency of Coated Urea on Nutrient Uptake and Maize Production, Communications in Soil Science and Plant Analysis 2018;49(11):1394-1400. https://doi.org/10.1080/00103624.2018.1464182
33. Omara P, Aula L, Oyebiyi F, Raun WR. World cereal nitrogen use efficiency trends: review and current knowledge. Agrosystems, Geosciences & Environment. 2019;2(1):1-8. https://doi.org/10.2134/age2018.10.0045
34. Piper CS. Soil and plant analysis, Hans. Pub. Bombay, Asian Ed 1966, 368-374.
35. Power JF, Schepers JS. Nitrate contamination of groundwater in North America. Agriculture, ecosystems and environment 1989;26(3, 4):165-87. https://doi.org/10.1016/0167-8809(89)90012-1
36. Li QS. Synthesis and performance of polyurethane coated urea as slow/controlled release fertilizer, Journal of Wuhan University Technology Material Science 2012;27(1):126. https://doi.org/10.1007/s11595-012-0421-7
37. Sanchary IJ, Huq SM. Efficiency of Black Urea Fertilizer over White Urea. Journal of Agricultural Studies. 2018;6(1). https://doi.org/10.5296/jas.v6i1.12372
38. Shao G, Li Z, Ning T, Zhang M, Jiang X, Wang Y *et al*. Effects of normal urea and release-controlled urea on root and shoot growth and yield of maize in different water conditions. Acta Agronomica Sinica 2009;35(1):118-23. https://doi.org/10.3724/SP.J.1006.2009.00118
39. Shaviv A, Mikkelsen RL. Controlled-release fertilizers to increase efficiency of nutrient use and minimize environmental degradation-A review. Fertilizer research. 1993;35(1):1-2. https://doi.org/10.1007/BF00750215
40. Shi Z, Li D, Jing Q, Cai J, Jiang D, Cao W, *et al*. Effects of nitrogen applications on soil nitrogen balance and nitrogen utilization of winter wheat in a rice–wheat rotation. Field Crops Research 2012;127:241-7. https://doi.org/10.1016/j.fcr.2011.11.025
41. Stanford G, English L. Use of the flame photometer in rapid soil tests for K and Ca. Agronomy journal. 1949;41(9):446-7.
42. Upadhyay LS. Urease inhibitor: A review. Indian Journal of Biotechnology 2012;11:381-388.
43. Xiaoyu N, Yuejin W, Zhengyan W, Lin W, Guannan Q, Lixiang Y. A novel slow-release urea fertiliser: Physical and chemical analysis of its structure and study of its release mechanism. Biosystems engineering. 2013;115(3):274-82. https://doi.org/10.1016/j.biosystemseng.2013.04.001
44. Xie Y, Tang L, Yang L, Zhang Y, Song H, Tian C, *et al*. Polymer-coated urea effects on maize yield and nitrogen losses for hilly land of southern China. Nutrient Cycling in Agroecosystems 2020;116(3):299-312. https://doi.org/10.1007/s10705-019-10038-9
45. Yang YC, Zhang M, Li Y, Fan XH, Geng YQ. Improving the quality of polymer-coated urea with recycled plastic, proper additives, and large tablets. Journal of agricultural and food chemistry 2012;60(45):11229-37. https://doi.org/10.1021/jf302813g
46. Ye Y, Liang X, Chen Y, Liu J, Gu J, Guo R *et al*. Alternate wetting and drying irrigation and controlled-release nitrogen fertilizer in late-season rice. Effects on dry matter accumulation, yield, water and nitrogen use. Field Crops Research 2013;144:212-24. https://doi.org/10.1016/j.fcr.2012.12.003
47. Zhao B, Dong S, Zhang J, Liu P. Effects of controlled-release fertiliser on nitrogen use efficiency in summer maize. PloS one. 2013;8(8):e70569. https://doi.org/10.1371/journal.pone.0070569
48. Zheng W, Zhang M, Liu Z, Zhou H, Lu H, Zhang W, *et al*. Combining controlled-release urea and normal urea to improve the nitrogen use efficiency and yield under wheat-maize double cropping system. Field Crops Research 2016;197:52-62. http://dx.doi.org/10.1016/j.fcr.2016.08.004