The Growth, N Uptake, N Use Efficiency by Corn due to Application of SRF-Urea

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Abstract. Nitrogen (N) is one of essential elements for plant, needed in the largest number, and often supplied through urea. However, the efficiency of N-uptake by plant from Urea was about 30-50% due to N loss as nitrate (NO_3^-) and N gas (e.g. NH_3 and N_2O). This problem could be more severe in light soil with low SOM and CEC. This study was to investigate how slow-release fertilizer (SRF) urea could mitigate these issues. The SRF urea was produced from Urea at 100% and 80% of the recommended rate, coated by biochar either rice husk (Rh) or corn cob (Cc) biochar, pyrolyzed at 450 °C in a muffle furnace for one hour and sieved for 0,5 mm diameter. Two control treatments, without and with urea at the recommended rate, and both treatments were not coated by biochar, were established. All treatments were applied to corn plants grown on sandy soil in greenhouse pots. The plant was harvested at 42 days after planting (DAP). The result showed that compared to Control without urea, Urea application, with and without biochar in average increased corn biomass in average 51.6% and N uptake about 154%. The SRF of P2 and P5 tended to have highest plant biomass. Increased nutrient use efficiency by treating both Cc and Rh biochar-coated urea at 80% of the recommended rate, which tended to result in the highest efficiency. Biochar-coated urea could be the alternative SRF-urea to increase plant growth and N uptake efficiency from urea in sandy soil.

1 Introduction

Nitrogen (N) is an essential element needed in highest number for plants to grow and complete the plant life cycle. A sufficient N concentration in soil is necessary for plants to grow normally. N in soil is very mobile and easy to lose from the soil as gas or leach as nitrate, in which these processes reduce available nitrogen, which can lead to nitrogen deficiency in plants. The N deficiency could make the plant grow stunted, create chlorosis in the leaf, and finally decrease the yield. To provide sufficient N for plant, urea is usually applied to the plant. However, the nutrient use efficiency (NUE) in tropical areas was about 30-50%, and about 50-70% was lost via denitrification, leaching, and volatilization, leaching, and denitrification [1][2]. To overcome this problem, a Slow-Release Fertilizer (SRF urea) could be used.

SRF is a technology that slows down the release of nutrients from fertilizer. This technology can improve NUE compared to conventional fertilizer as nutrients will be released slowly and hence meet the needs of plants [3][4][5]. Accordingly, SRF retards nutrient release due to the molecular interaction, so nutrient elements will not be released quickly to the surrounding area [6]. SRF can be made by refining fertilizer particles and adding coating material that will wrap the surface of fertilizer particles, thereby slowly releasing nutrients [7]. The coating material can be organic or organic material, such as Biochar and bentonite.

Biochar is a carbonaceous material resulting from pyrolyzed carbon-rich material without oxygen or in limited oxygen and is used for soil amendment [8]. Biochar can be made from several biomass sources, such as wood waste, green waste, bamboo [9][10][11], and harvest waste, including rice husk and corn cob [12][13]. Biochar is porous and highly capable of enhancing soil properties [14]. Application of Biochar to soil can increase soil pH [15] and CEC, and hence improve N use efficiency [16][17], contributing to soil microbe activities [18]. Biochar also improves the water-holding capacity of soil. These processes may enhance N uptake and N use efficiency by plant.

Urea coated with Biochar reduced ammonia volatilization by 14% and increased efficiency use by 60% compared to conventional fertilizer [16]. Using Biochar in NPK fertilizer increases N use efficiency by cotton plants by up to 28% [19]. Biochar used for coating urea could have retarded the released N from Urea and provided N for a longer time to result in increased plant growth [20]. Biochar could also reduce N loss as N gas or nitrates leaching, as biochar is porous and had high CEC, and therefore, N was more available to plants when biochar was used for urea coating [21]. The increase of NUE by plants is due to the rise of N retention by soil mixed with biochar, hence reducing N loss [17][22].

Using Biochar to form SRF with Urea may have some effects, either directly from biochar to plant growth or the reduction of N from SRF-urea,

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influencing NUE, plant growth, and soil characteristics. Biochar with its specific properties could have different effects on N release by Urea, plant growth, and plant nutrient absorption. These effects could be detected clearly in soil with low clay content and organic C, such as sandy soil. Therefore, the objective of this study was to investigate the effect of biochar (corn cob and rice husk biochar) as coating material to form SRF-urea at difference rates (100% and 80% of recommendation rates) on growth, biomass production, N content, N uptake, and NUE of corn grown on sandy soil.

2 Methods

2.1 Biochar

Corn cob (Cc) and rice husk (Rh) biochar were produced by pyrolyzing the raw material in a muffle furnace at 450 ºC for one hour. Both biochars were then sieved to pass 0.5 mm. The element content in both biochars is presented in Table 1.

Table 1. The content of some elements (%) in both Cc and Rh biochar.

Element	Cc Biochar	Rh Biochar
Mg	1.0	1.0
P	3.4	2.0
S	0.6	0.7
K	18.9	12.8
Ca	5.9	8.5
Mn	0.9	0.9
Fe	1.5	41.8
Ni	0.1	-
Cu	0.4	0.7
Zn	0.1	0.2

2.2 Soil

The sandy soil was collected from the Bangkalan area at 0-20 cm depth. The soil was air-dried and sieved to pass a 2.0 mm sieve and then kept for next use. The characteristics of the soil were described at Table 2.

Table 2. Some characteristics of sandy soil used in this study.

Characteristics	Unit	Value
pH (H2O)	-	6.23
Total N	g/100g	0.06
Available P	mg/kg	13.07
Total P	mg/kg	128.40
Organic C	g/100g	0.55
CEC	cmol/kg	0.52
Exc. K	cmol/kg	0.10
Exc. Ca	cmol/kg	4.57
Exc. Mg	cmol/kg	1.28

2.3 SRF-Urea

SRF of biochar-coated Urea was produced from Urea (at 100% and 80% of the recommended dose) that was coated by either rice husk (Rh) or corn cob (Cc) biochar. Biochar use was 6.0 g per recipe of one tablet of SRF (or in total was about 400 kg/ha). There were four SRFs: two of urea (100% and 80% of the recommended rate) coated by Rh biochar and two of urea at a similar rate coated by Cc biochar. SRF was produced manually by mixing urea accordingly with biochar (6.0 g), bentonite (1.0 g), and casava starch for glue and rounded by hand. All SRFs were placed in a drying oven at 50 ºC for 2 hours to dry them. All SRFs were kept in plastic containers before use.

2.4 Pot trial

About 15 kg of the soil prepared previously was put in a pot. All pots were placed in a greenhouse and arranged in a completely randomized design. The soil moisture in the pot was kept in field capacity condition gravimetrically by weighing and adding water based on water loss. Corn was planted by placing seed corn at a 3.0 cm depth from the soil surface, and the growth of corn was maintained for up to 42 days.

All SRF were applied 10 days after planting. The other two treatments as control were set up by planting corn in similar soil with no fertilizer and with fertilizer without coating at the recommended rate. Six treatments (Table 3) were arranged in a completely randomized design, and each treatment was replicated four times.

At six weeks (42 days) after planting, the plant height was measured. Corn was then harvested, and corn biomass (after being dried in a drying oven at 70 ºC for 48 hours), the N content (of fresh leaf and shoot sample) were determined.

Table 3. Treatments employed in this study.

Code	Treatment
P0	Control, without fertilizer
P1	Urea at 100% of RR (300 kg urea/ha) without coating
P2	Urea at 80% of RR (240 kg urea/ha) coated with Rh biochar
P3	Urea at 100% of RR (300 kg urea/ha) coated with Rh biochar
P4	Urea at 80% of RR (240 kg urea /ha) coated with Cc biochar
P5	Urea at 100% of RR (300 kg urea/ha) coated with Cc biochar

Analysis of variance (ANOVA), $p<0.05$, was carried out using SPSS, and the differences among mean values were assessed by the Duncan Mean Range Test (DMRT), $p< 0.05$.

3 Results and discussion

Slow-release fertilizers (SRF) are designed to make fertilizer use more economical by reducing leaching and runoff losses. This approach minimizes environmental impact while enhances crop yield. SRF should be coated with a biodegradable organic or inorganic material to control release rates and maximize crop yield per fertilizer unit. Consequently, using slow-release fertilizers is regarded as an optimal management practice (BMP) for effective crop production. In this study, two biochars, namely Corn cob (Cc) and Rice husk (Rh) biochar, were employed as the coated material for thesl SRF.

Biochar, an organic amendment made from biomass through pyrolysis, is a carbon-rich solid. It enhances soil fertility, supports climate change mitigation, and is useful for carbon sequestration in agriculture treatment by retaining soil nutrients available to plants. Corn cob (Cc) and rice husk (Rh) biochar were analyzed by SEM (Scanning Electron Microscopy) before used. SEM aimed to observe biochar morphology, surface structure, pore arrangement and distribution. The result showed that Cc had a pore diameter of 3.20 - 9.57 µm, while Rh had 4.63 - 9.40 µm (Fig 1). The particle size, shape, and internal structure of biochar are important for influencing soil water retention, field capacity, permanent wilting point, and plant-available water. This is due to the characteristics of its pores, with pore sizes between 0.5 and 50 µm able to hold water against gravity and serve as storage pores, releasing water for plant use [23].

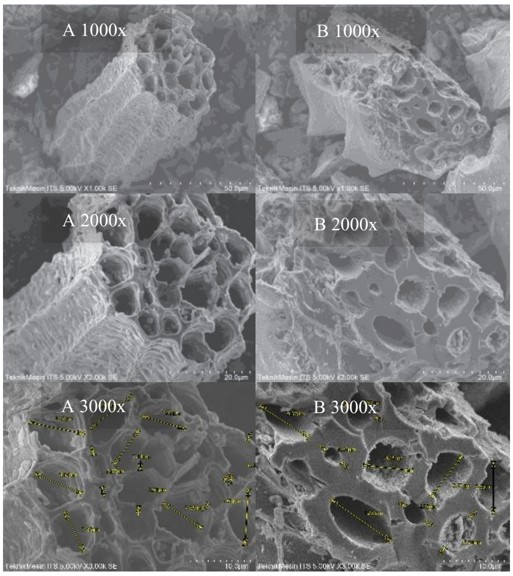

Fig 1. Corn cob (Cc) (A) and rice husk biochar (Rh) (B) at 1000 x, 2000x and 3000x magnification.

Application of Urea, either with coating (SRF) and without coating, significantly increased plant height and biomass (Table 4). Moreover, Urea without coating (P1) and all SRF gave similar plant growth. Compared to Control, application of Urea increased corn biomass to 77.5% (P1) and from 71.25% - 97.5% under SRF Urea. Treatment of P5 tended to have the highest increase both in plant height and biomass, indicating Cc biochar tended to have better effect as coating material.

Moreover, urea application both coated (SRF urea; P2-P5) and not coated (P1) significantly increased N content. However, there was no defference in N content between the plant under SRF and not SRF. Such phenomena were similar to N uptake by plant and N uptake efficiency. The SRF urea at 80% of the recommended rate tended to have highest NUE.

Table 4. Plant height (cm) and biomass (g/plant) of corn grown on sandy soil due to treatments of without urea (P0, control), urea application without coating (P1), and SRF of biochar coated urea (P2, P3, P4, and P5).

Treatment	Plant height (cm)	Plant biomass (g/plant)
P0	130.3 a	28.7 a
P1	167.7 b	44.3 b
P2	160.3 b	39.9 b
P3	160.1 b	46.0 b
P4	151.1 b	41.7 b
P5	169.7 b	45.5 b
ANOVA 5%	*	*

The value followed by a similar notation was not significantly different based on DMRT 5%.

Table 5. N content, N uptake, and N uptake efficiency (NUE) by corn grown on sandy soil due to due to treatments of without urea (P0, control), urea application without coating (P1), and SRF of biochar coated urea (P2, P3, P4, and P5).

Treatment	N Content (%)	N Uptake (mg/plant)	NUE
P0	0.81 a	230 a	12,8 a
P1	2.20 b	980 b	24,5 b
P2	2.02 b	810 b	25,3 b
P3	2.10 b	970 b	24,3 b
P4	1.93 b	800 b	25,0 b
P5	2.03 b	920 b	23,0 b

4 Discussion

Application of both coated (SRF) and uncoated Urea increased plant growth. Urea addition would directly provide N to corn. Thereby, corn was able to grow better and increased leaf area. The increment of leaf area made plant could enhance photosynthesis that produced higher photosynthate for building the higher plant biomass. The use of SRF, on average, increased biomass to 80%, while uncoated Urea increased the biomass to 77.5%, indicating that SRF could provide sufficient N for corn to grow better in the soil. The application of SRF-urea increased plant biomass higher than that under uncoated Urea, which was also reported by [24]. SFR enhanced soil N availability and extended its presence from vegetative to generative phase. SRF was indirectly also as a nitrification inhibitor and thereby increases the concentration of available soil N under arid climate conditions.

Further, the application of SRF-urea increased N content, N uptake and N uptake efficiency. As a result, nutrient use efficiency with SRF was higher than that of uncoated Urea, especially at the SRF-urea of 80% of the recommended rate. A study by [25] also showed similar results: reduced nutrient concentration increased nutrient use efficiency by wheat. Biochar used for coating urea could have retarded the released N from Urea and provided N for a longer time to result in increased plant growth [19]. Biochar could also reduce N loss as N gas or nitrates leaching, and therefore, N was more available to plants when Biochar was used for urea coating [20]. In this study, Biochar from corn cob tended to give better results; this is probably related to biochar characteristics where corn cob biochar was more porous (Fig 1) and contained higher Ca, P, and K compared to rice husk biochar (Table 1).

In addition, future studies should consider changes in total N content and organic C in the soil, indicating the capacity of SRF reduces N loss and improves C sequestration; these are crucial aspects in relation to lowering GH emission and, hence, soil productivity.

5 Conclusions

The application of Urea improved corn growth and produced higher biomass and N content than that of unfertilized plants. The use of SRF-urea as biochar-coated urea gave higher biomass and N uptake and N uptake efficiency. Furthermore, changes in total N and organic C in the soil warrant future studies.

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