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Enhanced Efficiency Organo-Mineral Nitrogen Fertilizer improves Yield and Quality of Red Amaranth

Tanushry Paul[1], Biplob Kumar Saha[1]*, K. M. Mohiuddin[1], M. R. Debi[2] and Md. Kafil Uddin[1]

[1]*Department of Agricultural Chemistry, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh*
[2]*Department of Animal Nutrition, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh*

Abstract

Crop production with increased yield in a sustainable manner requires less environmental impact. Therefore, a pot experiment was accomplished to investigate the effect of newly developed enhanced efficiency nitrogen (N) fertilizer and conventional N fertilizers on the growth, yield, nutritional quality, and N use efficiency of red amaranth (*Amaranthus tricolor* cv. BARI lalshak 1). All the pots were placed at the experimental pot-house of the Department of Agricultural Chemistry, Bangladesh Agricultural University following a completely randomized design (CRD) with four replications. Brown coal-urea (BCU) was applied as enhanced efficiency N fertilizer following top dressing and basal application strategy where urea and diammonium phosphate were applied as conventional N fertilizer. All the N fertilizers were applied at five rates viz., 0, 50, 75, 100, 150 kg N ha^{-1}. The growth parameters and biomass yield of red amaranth were significantly impacted by varying amounts and types of N fertilizers. The highest dry biomass yield was obtained at 150 kg N ha^{-1} whereas the highest number of branch $plant^{-1}$ was found at 100 kg N ha^{-1}. Again, the highest biomass N concentration was found at 100 kg N ha^{-1}. Application of a higher dose of fertilizer showed the highest N concentration in the post-harvest soil. Overall, the growth parameters and biomass N concentration were the highest in BCU basal-treated soil. In contrast, BCU top-dressed soil showed a higher N concentration after harvest than all other treatments. Based on the overall findings, the use of higher-efficiency organo-mineral N fertilizer has the potential to serve as a viable substitute for traditional N fertilizers in the context of sustainable crop production with reduced environmental effects.

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Introduction

The availability of mineral nutrients throughout crucial growth phases has a direct impact on crop yield and quality. Nitrogen (N) is one of the crucial nutrients for agricultural crop production world-wide. Nutritional quality is affected differently by N fertilizer according on the cultivar, species, and harvested part (Jifon*et al.*, 2012). As N is a structural element of protein and chloroplasts, the application of enough N is necessary for appropriate plant growth and development (Barker and Bryson, 2007). Since the concentration of N in leaves is positively correlated with their chlorophyll content, area, and ability to photosynthesize, a lack of N frequently leads to lower production (Zhao *et al.*, 2005). In order to guarantee an appropriate

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*Corresponding author e-mail: bksaha@bau.edu.bd

supply of N through fertilizer while reducing losses and avoiding overapplication, N is thus one of the most critical components in the soil plant system.

Synthetic N fertilizers such as urea and di-ammonium phosphate (DAP) are the mostly used sources of N input in a multitude of global agricultural production systems. Unfortunately, the utilization efficiency of synthetic N fertilizers is very low in soil plant system and the recovery of fertilizer N hardly ever surpass by 50% (Raun *et al.*, 2002). Excessive N application may interfere in the reduction of nutritional quality of crop such as accumulation of nitrate (NO_3^-) in edible tissues (Santamaria, 2006). The lower use efficiency of N fertilizers is resulted from, leaching, denitrification and volatilization losses (Fageria and Baligar, 2005). Again, off-site movement of N in water causes the pollution of both surface and groundwater, whilst N_2O and NH_3 gases contribute to the buildup of greenhouse gases in the atmosphere.

Excess application of synthetic fertilizers and intensive agricultural practices causes the reduction of soil organic matter (SOM) over time. Thus, soil fertility and agricultural yield have been negatively impacted by the widespread loss of SOM. Furthermore, the capacity of a soil to sequester carbon is closely related to the sequestration of other nutrients, especially N. Therefore, increasing the use efficiency of N fertilizer and soil organic carbon (SOC) is a crucial objective on the worldwide level to ensure food security, maintaining better soil health, and minimizing detrimental effects on the environment. Application of slow-release fertilizer prepared by granulating organic material and synthetic N fertilizer to fulfill crop N demands may be more advantageous over the single application of organic material or synthetic fertilizer as N source. By lowering leaching and gaseous losses, slow-release fertilizer helps lower the amount of N lost from the soil-plant system (Rose *et al.*, 2016), possibly preserving the availability of N throughout the duration of the plant growth cycle. Therefore, there are consolidated reasons to hypothesize that application of slow-release fertilizer could improve biomass yield and N uptake by crop plants than conventional fertilizers. In this experiment, the efficacy of slow-release N-fertilizer which was manufactured by blending common mineral N fertilizers with organic materials was tested.

Materials and Methods

Description of the experimental area and soil

The site of the experiment was located at 24°75'N latitude and 90°50' E longitude at an elevation of 18 m above the sea level. The site belonged to the of Old Brahmaputra Floodplain Agro-Ecological Zone (AEZ-9) having non calcareous dark grey floodplain soil (FAO and UNDP, 1988). The experimental region had a sub-tropical environment, marked by high humidity, significant rainfall, moderate to high temperatures, and relatively long days throughout the *kharif* season (April to September) and little rainfall, low humidity, chilly temperatures, and brief daylight hours throughout the *rabi* season (October to March). The soil of this experiment was collected from BAU farm, Mymensingh.

Table 1. Physical and chemical properties of soil

Soil characteristics	Analytical value
Soil colour	Brownish grey
Texture	Loam
Soil pH	6.73
Organic carbon (%)	0.78
Total N (%)	0.11
Available P (ppm)	15.7
Available S (ppm)	14.9
Exchangeable K (meq 100 g^{-1})	0.14
Exchangeable Ca (meq 100 g^{-1})	6.94
Exchangeable Mg (meq 100 g^{-1})	2.95

Properties of BCU used in this experiment

Previously prepared brown coal-urea (BCU) was used in this study. Brown coal-urea granules were prepared by pan granulation process (Saha *et al.*, 2017). The size of BCU granules used in this experiment was around 3.43 mm with 3.56% moisture contain having crush strength 6.69 kg. Brown coal-urea contains 45.43% C, 5.82% H, 17.31% N.

Pot preparation and experimental set up

Fifteen kg of well-prepared soil was taken in each pot (height = 28 cm; diameter = 27 cm diameter at the top and 20 cm at the bottom). The soil was mixed properly with inorganic fertilizers as per treatments. About 3 cm empty from the top was maintained in each pot for proper irrigation and each pot was properly labeled with tag. The description of the treatments are mentioned in the Table 2.

Table 2. Showing different N rate fertilizer sources used in this experiment

Sl. No.	Treatment symbol	Rate of N (kg ha^{-1})	Source
1	N_0	0	Urea, DAP, BCU (TD), BCU (Basal)
2	N_{50}	50	Urea, DAP, BCU (TD), BCU (Basal)
3	N_{75}	75	Urea, DAP, BCU (TD), BCU (Basal)
4	N_{100}	100	Urea, DAP, BCU (TD), BCU (Basal)
5	N_{150}	150	Urea, DAP, BCU (TD), BCU (Basal)

DAP= Diammonium Phosphate, BCU (TD) = Brown Coal Urea (Top Dressing), BCU (Basal) = Brown Coal Urea (Basal)

In addition, basal application of P, K, and S were done at a rate of 24, 40, and 6 kg ha^{-1} (BARC, 2012) from triple superphosphate (TSP), muriate of potash (MOP), and gypsum, respectively during pot preparation. Half part of urea, DAP, BCU (TD), and full doses of all other fertilizers were applied during final preparation of soil. The rest part of urea, DAP and BCU (TD) were applied in 2 installments at 20 and 35 days after sowing. The number of branches plant^{-1} and number of fully opened leaves were counted and recorded at harvest for 80 plants. Stem girth was recorded at 30, 40 and 50 days after seed sowing. Dry weight was recorded after 72 hours of oven dry at 60°C at harvest and expressed in gram (g).

Digestion of plant and soil samples for total N determination

Powdered leaf samples were digested by using conc. H_2SO_4 in presence of K_2SO_4 andcatalyst mixture (K_2SO_4:$CuSO_4.5H_2O$:Se = 10:1:0.1). Nitrogen from the digest was extracted using NaOH distillation process and trapped in boric acid (H_3BO_3) indicator solution and titrated using standard H_2SO_4.

Statistical analysis

For statistical analysis the software program IBM SPSS version 20 (SPSS IBM, 2010) was used.The Kolmogorov-Smirnov goodness fit test was used to normality test of the data and the equality of variances were then tested using the modified Levene's test. A two-way ANOVA was used to analyse the data considering fertilizer type and application rate as factors in the model. The multiple comparisons were performed using Tukey range test at 5% level of significance.

3. Results and Discussion

Effect of different forms and rates of N on growth parameters and yield

The application of different treatment combinations comprising of various levels and sources of N significantly ($p < 0.05$) impacted the growth parameters (Table 3). The maximum number of leaves plant^{-1} at harvest was 9.25, which was recorded in BCU basal 150, BCU TD 150, DAP 150 and BCU basal 100. The minimum number of leaves (5.00) at harvest was recorded from urea control. The results indicated that increasing N amount among treatments increased the number of leaves. Similar trend of result was also observed by Fazal (2010). The maximum number of branches plant^{-1} were counted from BCU basal 150, BCU basal 100 and BCU basal 50 which was statistically similar with BCU TD 100 and BCU TD 50 (5.25). Again, the interaction effect of different sources and rates of N showed a significant influence on the dry biomass yield (Figure 1) of red amaranth. A significant variation in dry biomass yield per pot was recorded from all treatments. The maximum dry biomass yield per pot was obtained from BCU basal 150 while the minimum dry biomass yield was recorded from control. According to, Saha *et al.*, (2019) application of higher level BCU significantly influenced leaf biomass yield because N triggers plant vegetative growth and increases leaf area. This result is in the agreement with findings of Miah et al. (2013), who reported that plant height of red amaranth increased with increasing the N application rate. Similar findings were reported by Begum Tongos (2016). Fazal (2010) and Miah (2013) also reported a similar finding that increased N rates increased vegetative growth as well as increased plant dry weight.

Table 3. Effect of different forms and rates of N on growth parameters of red amaranth (values are mean ± standard error, n = 4).

Rates × Formsof N	Leaves plant^{-1} (No.)	Branches plant^{-1} (No.)	Stem girth (mm)
Control urea	5.00 ± 0. 15c	1.00± 0.00d	1.5 ± 0.01e
Control DAP	8.00 ± 0. 23ab	1.00± 0.00d	2.0 ±0.01cde
Control BCU TD	9.00 ± 0. 63ab	1.00± 0.00d	2.5 ± 0.2bcde
Control BCU basal	8.00 ± 0. 46ab	1.00± 0.00d	2.0 ±0.02cde
Urea 50	6.75 ± 0.25abc	3.25± 0.47abcd	1.8 ± 0.1de
DAP 50	7.75 ± 0.47ab	2.25±0.47cd	2.2 ±0.1cde
BCU TD 50	8.25 ± 0.75ab	5.25 ± 0.47a	2.5 ± 0.5bcd
BCU basal 50	8.25 ± 0.75ab	5.75 ± 0.25a	2.8 ± 0.1bcde
Urea 75	6.5 ± 0.28bc	3.25 ± 0.47abcd	1.6 ± 0.1e
DAP 75	7.75 ± 0.25ab	2.5 ± 0.28cd	2.6 ± 0.1bcde
BCU TD 75	7.25 ± 0.47abc	3.75 ±0.47abc	2.5 ± 0.2bcde
BCU basal 75	8.00 ± 0.41ab	3.75 ± 0.25abc	3.3 ± 0.5bc
Urea 100	8.50 ± 0.28ab	4.25 ± 0.47abc	2.0 ± 0.2cde
DAP 100	8.75 ± 0.63ab	3.75 ± 0.25abc	3.0 ± 0.02bcd
BCU TD 100	9.00 ± 0.41ab	5.5 ± 0.5a	2.6 ± 0.2bcde
BCU basal 100	9.25 ± 0.48a	5.75 ± 0.63a	3.6 ± 0.4ab
Urea 150	8.00 ± 1.14ab	3.75 ± 0.97abc	2.1 ± 0.4cde
DAP 150	9.25 ± 0.25a	4.25±0.25abc	2.3 ± 0.4bcde
BCU TD 150	9.25 ± 0.47a	5 ± 0.41ab	2.7 ± 0.1bcde
BCU basal 150	9.25 ± 0.25a	5.75 ± 0.25a	4.8 ± 0.3a

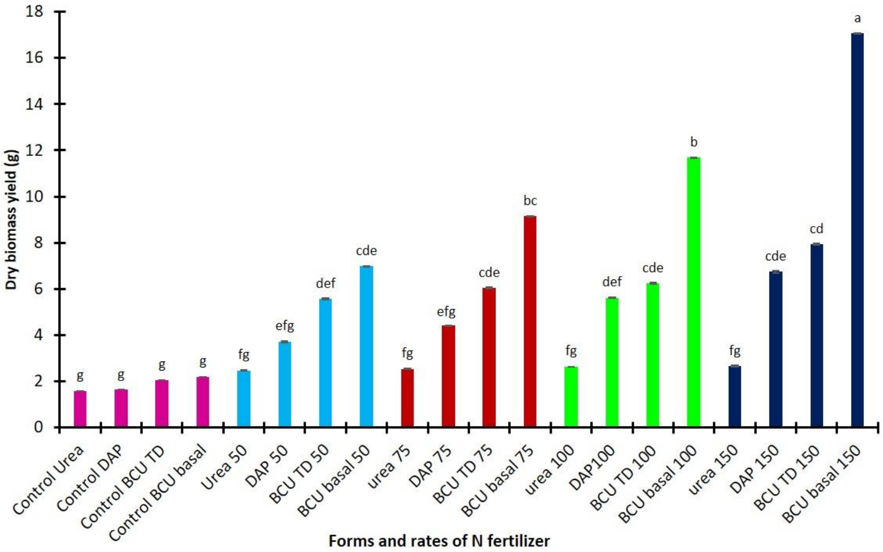

Figure 1. Effect of different forms and rates of N on dry biomass yield of red amaranth. Bars with different letters differ significantly according to Tukey-test at P ≤0.05 and the error bars indicate the standard error among the replicates (n=4).

Effect of different forms and rates of N on the biomass N concentration

The highest N concentration (3.53%) was found BCU basal 100 kg N ha^{-1} and the lowest values was obtained from all absolute controls. Among different N sources BCU basal 100 showed the higher N concentration than others (Figure 2). For the first 30 days after planting, leafy crops absorb very little N, but it is often the moment at which the most mineral N from urea becomes accessible (Smith, 2017). In compared to urea and DAP, BCU has the capability to delay fertilizer-N release because of the greater retention of N due to large surface area and strong cation exchange capacity of organic matter used in BCU (Saha *et al.*, 2017). Therefore, the gradual release of mineral N from the BCU could have enhanced the synchronization between plant demand and N supply. Similar finding was reported by Saha *et al.* (2019) in another leafy vegetable (Silver beet).

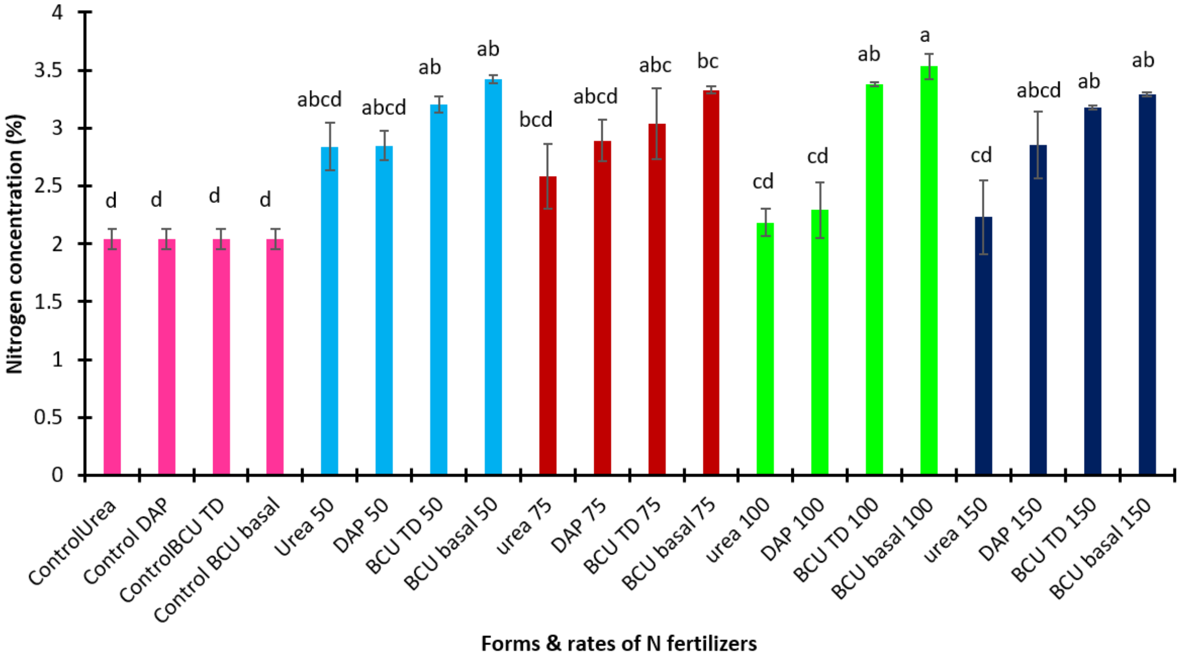

Figure 2. Interaction effect of different forms and rates of N on the biomass N concentration of red amaranth. Bars with different letters differ significantly according to Tukey-test at P ≤0.05 and the error bars indicate the standard error among the replicates (n=4).

Effect of different forms and rates of N on total N content of soil after harvest

As shown in Table 4, different N treatment combinations showed statistically significant ($p < 0.05$) increase in N content. The highest N concentration was found in BCU basal 100 kg N ha^{-1} that of the lowest N content was recorded in all absolute control. Among different fertilizer sources BCU basal 100 showed the highest N concentration in soil after harvest. In line to our finding Saha *et al.* (2019) showed the higher N concentration in post- harvest soil due to the incorporation of brown coal-urea in soil.

Table 4. Effect of different forms and rates on N content of soil after harvest (values are mean ± standard error, n = 4).

Rates × Forms of N	N content (%)
Control Urea	0.200 ± 0.00f
Control DAP	0.200 ± 0.00f
Control BCU TD	0.200 ± 0.00f
Control BCU basal	0.200 ± 0.00f
Urea 50	0.210 ± 0.00de
DAP 50	0.206 ± 0.002ef
BCU TD 50	0.210 ± 0.00de
BCU basal 50	0.220 ± 0.00c
Urea 75	0.210 ± 0.00de
DAP 75	0.206 ± 0.002ef
BCU TD 75	0.216 ± 0.002cd
BCU basal 75	0.216 ± 0.002cd
Urea 100	0.210 ± 0.00 de
DAP 100	0.210 ± 0.00 de
BCU TD 100	0.216 ± 0.004cd
BCU basal 100	0.250 ± 0.00a
Urea 150	0.210 ± 0.00 de
DAP 150	0.220 ± 0.008c
BCU TD 150	0.216 ± 0.004cd
BCU basal 150	0.230 ± 0.00b

Conclusions

To increase crop production by maintaining agricultural sustainability is crucial for both soil and environment. Slow-release fertilizers based on humified organic matter shows higher efficiency of N recovery and reduces environmental burdens. In this experiment different forms and rates of N and their interaction showed significant influence on the growth and yield parameters of red amaranth. Among different fertilizer sources, BCU showed higher response on growth, yield, and N concentration of red amaranth. Again, N in post-harvest soil was the highest in BCU treatment than all other fertilizers. So, these findings suggest the feasibility of using the BCU as a N source for sustainable crop production.

Declaration of interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of author's credit

Tanushry Paul: Conceptualization, conducted experiments, analyzed data, and drafted the original manuscript. K. M. Mohiuddin and M. R. Debi: Methodology, experimental set up, chemical analysis and assisted in drafting the manuscript.Md. Kafil Uddin: Conceptualization, datainterpretation, Review and Editing. Biplob K. Saha: Funding acquisition, Methodology, Review and Editing.

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