



## Effect of enriched biochar based fertilizers on growth, yield and nitrogen use efficiency in direct-seeded rice (*Oryza sativa*)

ARKAPRAVA ROY<sup>1\*</sup>, SUHITA PYNE<sup>2</sup> and SUMIT CHATURVEDI<sup>2</sup>

G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263 145, India

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### ABSTRACT

A field experiment was conducted at Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand during *kharif* (rainy) 2018 to assess effect of enriched biochar (EB) based fertilizers on crop growth, productivity and nutrients use efficiency in direct seeded rice (DSR). Enriched biochar based fertilizers i.e. Enriched biochar-1 (EB-1), Enriched biochar-2 (EB-2), Urea enriched biochar-1 (UEB-1) and Urea enriched biochar-1 (UEB-2) were prepared and characterized at IFS laboratory, GBPUA&T, Pantnagar. The experiment was laid out in randomized block design with eight treatments i.e. 100% Recommended dose of fertilizer (RDF) through conventional fertilizers, 75, 100 and 125% RDF through enriched biochar based fertilizers EB-1+UEB-1 and EB-2+UEB-2 and no fertilizer application as control replicated thrice. Highest growth, yield parameters and yield of DSR were recorded under application of EB-2+UEB-2 at 125% fertility level. Application of EB-2+UEB-2 at 100% fertility level also gave at par yield with its application at 125% fertility level and significantly higher yield (13.5%) as compared to application of conventional fertilizers at similar fertility level. Application of both the EB fertilizers at 75% fertility level resulted in at par yield with application of 100% fertility level through conventional fertilizers. Nitrogen uptake by grain and straw were significantly higher under application of EB-2+UEB-2 at 125% fertility level. However, among these EB fertilizers, application of 100% RDF through EB-2+UEB-2 resulted in 30.70% and 29.50% more agronomic efficiency (AE) and apparent nitrogen recovery (ANR), respectively as compared to application of conventional fertilizers.

**Keywords:** Direct seeded rice, Enriched biochar based fertilizers, Nutrient uptake, Productivity

Rice (*Oryza sativa* L.) is the most important staple food and central to the food security for over half of the world population. Direct seeded rice (DSR) is an efficient resource conserving technology (RCT) that can save about 40% of labour, 60% of water, 60% of energy (Pathak *et al.* 2011), also reduce methane emission, improve soil physical condition, system productivity is enhanced and ultimately curtail cost of cultivation which helps to increase income (Kumar and Ladha 2011). Volatilization, denitrification and leaching loss of nitrogen are likely to be more in DSR than transplanted rice (Davidson 1991). Applications of conventional fertilizers are prone to losses as well as duration of availability of nutrients is less, leading to poor plant growth and yield and less nutrient use efficiency. So, efficient nutrient management with objective of sustainable release of nutrients and minimizing losses holds key for

proper plant growth and yield of direct seeded rice.

Among the different approaches towards improvement in nutrient use efficiency; control release fertilizer may be a novel environment friendly approach. Biochar prepared from different agro wastes may work as a suitable matrix for preparing control release fertilizers which not only enhance NUE but also improve soil health. Biochar contains many functional groups, strongly adsorbs various nutrient ions, including nitrate, ammonium, phosphate, and potassium ions, to load nutrients and reduce soil nitrogen nutrient loss (Kimetu 2010). Biochar-amended soil showed reduced mean cumulative leaching of nitrate and nitrite, due to sorption by the biochar (Mukherjee *et al.* 2014). Thus, supplementing biochar with certain fertilizers renders biochar materials more suitable for stimulating plant growth (Si *et al.* 2018). Moreover, biochar-based fertilizers delay the release of nutrients in soil and display a slow-release effect and increase the crop yield significantly (Gao *et al.* 2012). Though some novel biochar based fertilizers were prepared by researchers in laboratory, these are not commercially used even days due to either higher production cost or region specificity. The main objective of this study was to compare the effect of enriched biochar based fertilizers and conventional fertilizers on growth, productivity, nitrogen uptake and nitrogen use

Present address: <sup>1</sup>Division of Agronomy, ICAR-IARI, New Delhi; <sup>2</sup>Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand.  
\*Corresponding author email: arkaprava.apr@gmail.com.

efficiency in direct seeded rice (*Oryza sativa* L.).

## MATERIALS AND METHODS

A field experiment was conducted during rainy season (2018) at N.E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand to assess utilization of enriched biochar based fertilizers for efficient nutrient management in direct seeded rice. The soil of experimental site was sandy loam in texture with bulk density of soil 1.44 Mg/m<sup>3</sup> (0–15cm). The soil was neutral in reaction (pH 7.2), medium in soil organic carbon (0.65%), low in available nitrogen (149.6 kg/ha), high in Olsen-phosphorus (26.9 kg/ha) and Ammonium acetate extractable potassium (281.1 kg/ha). The moisture content at FC and PWP was 20 and 8%, respectively.

The experiment was laid out in randomized block design with eight treatments i.e. 100% RDF through conventional fertilizers; 75%, 100% and 125% RDF through enriched biochar based fertilizer EB-1+UEB-1; 75%, 100% and 125% RDF through enriched biochar based fertilizer EB-2+UEB-2 and no fertilizer application replicated thrice. The recommended fertilizer dose (RDF) was 120 kg N+60 kg P<sub>2</sub>O<sub>5</sub> + 40 kg K<sub>2</sub>O per ha. All enriched biochar based fertilizers i.e EB-1, EB-2, UEB-1 and UEB-2 were prepared and characterized in IFS laboratory, GBPUA&T, Pantnagar. EB-1 was prepared by intercalating 12-32-16 NPK (IFFCO) + Urea+ MOP mixture solution in rice husk biochar and EB-2 was prepared by intercalating same fertilizers mixture solution along with humic acid and seaweed in rice husk biochar. Both EB-1 and EB-2 had 6-6-4 N-P<sub>2</sub>O<sub>5</sub>-K<sub>2</sub>O content. EB-1 had a pH value of 8.07 with 43.4% carbon content, whereas EB-2 had slight lesser pH value (pH 7.60) with 43.73% carbon content. UEB-1 was prepared by intercalating urea solution in rice husk biochar at 1:1 ratio and it contained 20% N along with 43.68% carbon and pH was 8.20. UEB-2 was prepared by intercalation urea solution in biochar (1:1) along with humic acid and seaweed and it contained 20% N with 43.68% carbon and pH 7.75. 12-32-16 NPK (IFFCO) fertilizer, urea and MOP were used as conventional fertilizers.

In field experiment, half dose of N and full dose of P and K were applied through conventional fertilizers mix as basal and rest half of N was applied in two equal splits at 30 and 60 DAS as top dressing through urea for treatment T1. Whereas for treatments T2, T3 and T4 half dose of N and full dose of P and K were applied through EB-1 as basal and rest half of N was applied in two equal splits at 30 and 60 DAS as top dressing through UEB-1. For treatments T5, T6 and T7 half dose of N and full dose of P and K were applied through EB-2 as basal and rest half of N was applied in two equal splits at 30 and 60 DAS through UEB-2 as top dressing.

The observations on growth parameters, yield attributes and yield of the direct seeded rice were recorded through standard procedures. Grain and straw samples of each treatment were collected at harvest and analysed for nitrogen (N) content. Modified micro kjeldahl method (Jackson 1973)

was used for determining N content in collected grain and straw samples. The standard equations (Dobermann 2007) were used to quantify the N uptake by straw, grain and total N uptake and the effect of different treatments (sources of nutrients) on the Agronomic efficiency (AE) and Apparent nitrogen recovery (ANR) in direct seeded rice.

The experimental data were analyzed by using analysis of variance (ANOVA) technique appropriate to randomized block design (OPSTAT). The critical differences at 5% level were calculated for testing the significance of difference between any two means wherever F test was significant.

## RESULTS AND DISCUSSION

**Plant height:** At all growth stages under consideration, crop grown under application of 125% RDF through EB-2 + UEB-2 produced the tallest plant than the remaining treatments (Table 1). At maturity tallest plants were recorded from application of 125% RDF through EB-2 + UEB-2 which was significantly taller than application of conventional fertilizers mixture at 100% RDF level and EB fertilizers at 75% RDF level but was statistically at par with application of 125% RDF through EB-1 + UEB-1 and 100 % RDF through both EB fertilizers (EB-1+UEB-1 and EB-2+UEB-2). It might be due to better availability of nutrients throughout the growth period from slow release fertilizer, viz. EB-2+UEB-2 developed from the combination of growth promoting organics like seaweed and humic acid. Hamdani *et al.* (2017) also reported that wheat grown under application of recommended fertilizer dose along with biochar resulted in maximum increase in plant height (33%).

**Dry matter accumulation:** At maturity, highest dry matter accumulation was obtained from application of EB-2+UEB-2 at 125% fertility level and lowest value at no fertilizer application. Dry matter accumulation under application of both the EB fertilizers at 75% RDF level were statistically at par with application of 100% RDF through conventional fertilizers, though under those treatments dry matter accumulation was less. The value under application of 100% RDF through EB-2+UEB-2 was significantly higher with 17.70% more dry matter production over application of conventional fertilizers at that same fertility level. This was mainly due to more tiller production, less mortality, more plant height as well as more nutrient uptake and availability of growth promoter organics from combination of seaweed and humic acid. Dry matter accumulation under application of both the EB fertilizers at 125% RDF level were statistically at par with application of EB based fertilizer EB-2+UEB-2 at 100% RDF level.

**Effective tillers and tiller mortality:** Rice grown under application of 125% RDF through EB-2+UEB-2 retained the maximum number of tillers (368/m<sup>2</sup>) followed by 125% RDF through EB-1+UEB-1 and 100% RDF through EB-2+UEB-2, although they were statistically at par (Table 1). Number of effective tillers under application of conventional fertilizers at 100% RDF level was 9.54 and 19.71% less than application of EB-1+UEB-1 and

Table 1 Growth parameters, yield attributes, yield and N uptake of DSR

| Treatment<br>Source      | Fertility level | Plant height at<br>maturity (cm) | Dry matter accumulation<br>at maturity (g/m <sup>2</sup> ) | Effective<br>tillers/m <sup>2</sup> | Tiller mortality<br>(%) | Grains/<br>panicle | 1000-grain<br>weight (g) | Grain yield<br>(q/ha) | N uptake (kg/ha) |       |        |
|--------------------------|-----------------|----------------------------------|------------------------------------------------------------|-------------------------------------|-------------------------|--------------------|--------------------------|-----------------------|------------------|-------|--------|
|                          |                 |                                  |                                                            |                                     |                         |                    |                          |                       | Grain            | Straw | Total  |
| Conventional fertilizers | 100% RDF        | 113.0                            | 1112.0                                                     | 315                                 | 28.8                    | 90                 | 48.09                    | 48.09                 | 51.37            | 34.78 | 86.16  |
| EB-1+UEB-1               | 75% RDF         | 108.6                            | 1074.8                                                     | 300                                 | 30.5                    | 81                 | 44.31                    | 44.31                 | 46.60            | 30.40 | 77.01  |
|                          | 100% RDF        | 119.4                            | 1234.6                                                     | 351                                 | 27.3                    | 95                 | 51.23                    | 51.23                 | 55.87            | 35.72 | 91.61  |
|                          | 125% RDF        | 122.4                            | 1389.6                                                     | 397                                 | 24.6                    | 103                | 54.37                    | 54.37                 | 61.14            | 45.52 | 106.68 |
| EB-2+UEB-2               | 75% RDF         | 110.5                            | 1093.5                                                     | 307                                 | 29.9                    | 85                 | 46.70                    | 46.70                 | 50.10            | 31.70 | 81.80  |
|                          | 100% RDF        | 121.3                            | 1308.8                                                     | 390                                 | 24.5                    | 101                | 54.55                    | 54.55                 | 60.50            | 39.33 | 99.83  |
|                          | 125% RDF        | 123.2                            | 1400.0                                                     | 413                                 | 22.5                    | 105                | 55.29                    | 55.29                 | 61.73            | 49.29 | 111.02 |
| No fertilizer (control)  | -               | 58.1                             | 633.6                                                      | 201                                 | 41.9                    | 55                 | 27.11                    | 27.11                 | 25.59            | 11.91 | 37.51  |
| SEm±                     |                 | 2.33                             | 48.48                                                      | 21.31                               | 3.05                    | 4.00               | 2.09                     | 2.09                  | 2.48             | 2.19  | 3.98   |
| LSD(P=0.05)              |                 | 7.2                              | 148.5                                                      | 65.3                                | 9.4                     | 12.2               | 6.41                     | 6.41                  | 7.59             | 6.71  | 12.18  |

EB, enriched biochar; UEB, urea enriched biochar.

EB-2+UEB-2 fertilizers at same RDF level, respectively. Utomo *et al.* (2017) reported similar result that number of maximum tillers and effective tillers of rice applied with nitrogen EB were maximum compared to the non-biochar rice. Lowest percentage of tiller mortality was recorded under application of 125% RDF through EB-2 + UEB-2 though it had no significant difference with other treatments except no fertilizer application (control). It might be due to sufficient or better nutrient availability up to maturity period. Application of 100% RDF through EB-2 + UEB-2 resulted 12.5% less tiller mortality as compared to application of conventional fertilizers at similar RDF level.

*Grains per panicle:* Effect of different treatments on rice grains per panicle was found to be significant (Table 1). Rice grown under application of 125% RDF through EB-2+UEB-2 recorded the highest number of grains per panicle (85 grains/panicle). Rice grown under the application of both of these EB fertilizers (EB-1+UEB-1 and EB-2+UEB-2) at 100% fertility level had 7.14% and 15.71% more grains per panicle respectively, compared to application of conventional fertilizers at that same fertility level but were statistically at par. Grains per panicle recorded from application of 75% RDF through both these EB fertilizers were at par with application of 100% RDF through conventional fertilizers. Minimum number of grains per panicle was recorded from no fertilizer application.

*1000-grain weight and grain yield:* Rice grown under application of 100% RDF through both the EB fertilizers had more thousand grain weight compared to application of 100% RDF through conventional fertilizers though they were statistically at par (Table 1). Grain yield under application of 125% RDF through EB-2+UEB-2 was maximum (55.29 q/ha). It was at par with application of 125% RDF through EB-1+UEB-1 and 100% RDF through both the EB fertilizers (Table 1) but was significantly superior to remaining treatments. Application of 125% RDF through EB-2+UEB-2 led to more tiller production, less tiller mortality, more dry matter accumulation, higher yield attributes and ultimately the grain yield. Osman *et al.* (2013) reported that organics like humic acid contains cytokinins and their application enhanced endogenous cytokinin and auxin levels which possibly leading to improve grain yield in rice. In present study, grain yield under application of 100 and 125% RDF through EB-1+UEB-1 was although being at par but 6.5 and 13.05% more as compared to 100% fertility dose with conventional fertilizers. On the other hand, grain yield obtained with application of 100 and 125% fertility dose through EB-2+UEB-2 was 13.43 and 14.97% more compared to conventional fertilizers at 100% RDF level, respectively. It was due to fastest release of nutrients from the conventional fertilizers which shorten the availability time to the plant and led to less uptake of nutrients, lack of growth promoting organics, thus comparatively less tillering, more tiller mortality and less dry matter accumulation ultimately reduced the grain yield. Utomo *et al.* (2017) reported that rice grown in nitrogen EB applied soil yielded higher grain compared to non-biochar treated soil. In present study,

lowest yield was obtained from no fertilizer application due to deficiencies of nutrients.

**N uptake:** Application of 100% fertility level through the EB fertilizers i.e. EB-1+UEB-1 and EB-2+UEB-2 resulted in 2.6% and 12.9% more N uptake, respectively by rice straw compared to application through conventional fertilizers but statistically these uptakes were at par (Table 1). Further increase in fertility to 125% level, application through both EB-1+UEB-1 and EB-2+UEB-2 resulted in significantly higher N uptake compared to conventional fertilizers application at 100% fertility level. Maximum N uptake by straw recorded from rice grown under application of 125% RDF through EB-2+UEB-2. It was due to application of 25% more nutrients along with more shoot and root growth which enhanced more N uptake through profuse root system and accumulation in upper parts. Grain N uptake varied significantly with application of different sources at different fertility levels. Maximum N uptake by rice grains was recorded under application of EB-2+UEB-2 at 125% fertility level followed by application of EB-1+UEB-1 at that same fertility level, which were significantly higher than application of 100% RDF through conventional fertilizers. At 100% RDF level, application of EB-2+UEB-2 resulted in 17.7% more grain N uptake which was significantly higher compared to application of conventional fertilizers. Maximum total N uptake was recorded under application of 125% RDF level through EB based fertilizer EB-2+UEB-2 followed by EB-1+UEB-1 application which were 28.8% and 23.8% more, respectively compared to application of 100% RDF level through conventional fertilizers. More vegetative growth as well as more grain yield enhanced N uptake. Total N uptake recorded from application of 100% fertilizer dose through EB-2+UEB-2 was significantly higher than application of conventional fertilizers at that same fertility dose with 15.8% more total N uptake.

**Nitrogen (N) use efficiency:** Agronomic efficiency more closely reflects the direct production impact of an applied fertilizer. Agronomic efficiency was higher under application of 100% RDF level through EB-2+UEB-2, which was 30.70% more than application of 100% RDF through conventional fertilizers (Table 2). However, application of both the EB fertilizers at 75, 100 and 125% fertility level also had higher agronomic efficiency compared to conventional fertilizers application. Huang *et al.* (2013) reported that due to addition of biochar agronomic nitrogen use efficiency was increased by 43% over no biochar addition at 100% fertility level. Slow release of nitrogen from EB based fertilizers reduced the losses of nitrogen thereby enhanced the efficiency and this might be the main factor for higher agronomic N use efficiency under EB fertilizers application.

Apparent nitrogen recovery indicates the nutrient response to the crop. Sometimes, it is used for indicating nutrient use efficiency directly. Apparent nitrogen recovery was higher under application of 100% fertility dose through EB-2+UEB-2, which was 29.5% more than application of conventional fertilizers at that same fertility dose. Even application of EB-1+UEB-1 at 75, 100 and 125% fertility

Table 2 Nitrogen use efficiency of DSR

| Treatment                |                 | N use efficiency                                 |                                |
|--------------------------|-----------------|--------------------------------------------------|--------------------------------|
| Source                   | Fertility level | Agronomic efficiency (kg grain per kg N applied) | Apparent nitrogen recovery (%) |
| Conventional fertilizers | 100% RDF        | 17.49                                            | 40.54                          |
| EB-1+UEB-1               | 75% RDF         | 19.11                                            | 43.87                          |
|                          | 100% RDF        | 20.11                                            | 45.07                          |
|                          | 125% RDF        | 18.17                                            | 46.11                          |
| EB-2+UEB-2               | 75% RDF         | 21.77                                            | 49.21                          |
|                          | 100% RDF        | 22.86                                            | 51.93                          |
|                          | 125% RDF        | 18.79                                            | 49.01                          |

EB, enriched biochar; UEB, urea enriched biochar.

levels had lower apparent N recovery as compared to EB-2+UEB-2 at those fertility levels, respectively. However, application of both the EB fertilizers at any of these fertility levels had more apparent N recovery as compared to application of 100% fertility level through conventional fertilizers. More N uptake from EB sources might be the principle reason for their higher apparent recovery.

Based on the findings of this study, it can be concluded that application of 100% RDF through EB based fertilizer EB-2+UEB-2 not only enhanced the productivity of direct seeded rice but also increased the nitrogen use efficiency.

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