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Agronomic efficiency and productivity of transplanted *kharif* rice (*Oryza sativa*) as influenced by fertilizer briquettes

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Rice (*Oryza sativa* L.) is a crop of Asian origin grown all over south-east Asia and India. With a production of 114.45 million tonnes covering a land area of 43.90 million ha, it is the most widely grown food grain in India (Agricultural Statistics at a Glance 2022). In order to enhance the production of cereal crops, farmers apply fertilizers indiscriminately, which causes excessive losses of applied nutrients. Deep placement of fertilizer as briquettes could help in overcoming the aforementioned problems and optimizes yield of lowland rice. Fertilizer deep placement particularly urea deep placement (UDP) in transplanted rice has been widely recognized as an effective fertilizer management practice that increases productivity and reduces the quantity of fertilizer use (Savant and Stangel 1990). Such fertilizer management practices are gaining worldwide acceptance for their different monetary and ecological benefits. Since, with the use of fertilizer as briquettes rice yield increases up to 15–20% while applying one-third less than the recommended dose (Huda *et al.* 2016). Fertilizer briquettes are loose material made up of fertilizers that are compressed into dense mass. They are generally made by mechanical compaction or melt granulation and contain the necessary amount of NPK. Fertilizer briquettes are oval shaped which weighs around 1–2 g. They are compressed by the help of a briquette producing machine. Deep placement of fertilizer briquettes improves fertilizer use efficiency along with higher yield and thus gives higher net return to farmer. Fertilizer briquettes are applied in the anaerobic soil zone at a depth of 7–10 cm which contributes to lower the concentration of fertilizers in floodwater and thus improves the nutrient uptake (Kapoor *et al.* 2008). However, multi-nutrient briquette is able to supply micronutrient (Zn, Fe etc.) (Kakde and Patil 2022) and organic sources can also be incorporated i.e. biofertilizer along with NPK. This micronutrient though required in minute amount but still has significant effect on crop yield and quality whereas; biofertilizer helps in fixing and solubilising nutrients, and also improves crop productivity and soil health. It was found that almost no work was reported in manufacturing of fertilizer briquette supplying N, P, K, Zn and biofertilizer together in rice in Assam and thus need arise of conducting such abovementioned experiment.

An experiment was conducted during the rainy (*kharif*) season of 2022 at Instructional cum Research Farm of Assam Agricultural University, Jorhat, Assam. The experiment comprised of 13 treatments arranged in randomized block design (RBD) with three replications. The treatments were T_0, Control; T_1, Recommended dose of fertilizer (RDF); T_2, RDF + $ZnSO_4$ @10 kg/ha; T_3, RDF + $ZnSO_4$ @10 kg/ha + biofertilizer; T_4, [Fertilizer deep placement (FDP)] 80% recommended dose of nitrogen (RDN) +100% P and K; T_5, (FDP) 80% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha; T_6, (FDP) 80% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer; T_7, (FDP) 100% RDN + 100% P and K; T_8, (FDP) 100% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha; T_9, (FDP) 100% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer; T_{10}, (FDP) 120% RDN + 100% P and K; T_{11}, (FDP) 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha; T_{12}, (FDP) 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer. The net area of each plot was 4 m × 3 m. Experimental plot was found to be sandy loam in nature. Initial available N, P_2O_5, and K_2O of soil were 290.56, 20.52 and 126.74 kg/ha, respectively and DTPA Zn was 0.86 mg/kg of soil. Applications of fertilizers were done in accordance with the treatments. In treatment T_0, no fertilizers were applied while in case of T_1, RDF were applied (N, P_2O_5 and K_2O @60, 20 and 40 kg/ha, respectively). In T_1, 30 kg/ha of N was applied initially before transplanting as basal through urea and diammonium phosphate (DAP) along with entire amount of P_2O_5 and K_2O as DAP and muriate of potash (MOP). Remaining amount of N was applied in two equal splits i.e. first at tillering stage and

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second at panicle initiation stage. In T_2, zinc was applied as basal along with RDF, while in T_3, along with zinc and RDF, biofertilizer was also applied using seedling root dip treatment just before transplanting. Whereas from T_4 to T_{12}, fertilizers were placed as briquettes at 7–10 cm depth in the anaerobic soil zone with the help of manual applicator after 10th day of transplanting. Application of NPK as briquettes was done in T_4, T_7 and T_{10}, whereas in T_5, T_8 and T_{11} NPKZn as briquettes and in T_6, T_9 and T_{12}, NPKZn + biofertilizer as briquettes were placed @1 briquette at the centre of four hills in alternate rows. Sowing of Ranjit sub 1 was done on 20 June 2022 in the nursery and transplanted on 20 July 2022. Randomly selected 5 plants were tagged and used for observation like plant height. From two randomly selected marked sites of 1 m^2 in each plot, number of tillers at 30, 60, 90 and 120 days after transplanting (DAT) and panicles at harvest were counted, and average was recorded on m^2 basis. Harvested products from net plot area were sun dried treatment wise for 4 days, weighed and yield was recorded in q/ha. Agronomic efficiency (AE) was calculated based on inorganic N applied as:

$$AE = GY_f - GY_0/Na$$

where GY_f, Grain yield in fertilized plot; GY_0, Grain yield in control plot; and N_a, Amount of N applied.

The method stated by Cochran and Cox (1957) was used to analyse the entire data referring to various parameters under observations.

Plant height, tillers/m^2, panicles/m^2 and grain yield of transplanted *kharif* rice were significantly influenced by fertilizer management practices (Table 1). Placement of fertilizers as briquettes improved rice growth and yield over conventional method of fertilizer application. Deep placement of recommended dose of fertilizers as briquettes in T_7 resulted significant lengthening of plant height, proliferation of tillers/m^2 at different stages of rice consequently improved panicles/m^2 and grain yield by 34.50 and 18.40%, respectively as compared to T_1 where recommended dose of fertilizer had been applied conventionally (N, P_2O_5 and K_2O @60, 20 and 40 kg/ha, respectively) (Table 1). Such results were attributed to timely availability of nutrients throughout the peak nutrient demand period of rice due to slow and steady release of nutrients from the briquettes. However, it is very clear from the data that with the increasing rate of nitrogen in briquette there was a betterment of all the growth and yield attributing characteristics along with grain yield of rice.

Significantly higher plant height and tillers/m^2 were recorded in FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer (T_{12}) over all other treatments except FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha (T_{11}) and FDP, 120% RDN + 100% P and K (T_{10}) at 30, 60, 90 and 120 DAT. The increase in growth parameters was due to application of higher rate of N (120% RDN) along with ensured availability of applied nutrients throughout the growth stages of rice from briquettes. Furthermore, deep placement of briquettes closure to the effective root zone synchronized crop demand with supply of nutrients from the briquettes. Additionally, synergistic effect of N and Zn contributed to improvement in height of the plant with proper lengthening of internodes (Table 1) (Kakde and Patil 2022).

Deep placement of 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer as briquette (T_{12}) recorded significantly greater panicles/m^2 (260.05) over all other treatments, while, FDP, 120% RDN + 100% P and K +

Table 1 Effect of fertilizer management practices on growth parameters, yield attributes and grain yield of transplanted *kharif* rice

Treatment	Plant height (cm)				Tillers/m^2				Panicles/m^2	Grain yield (q/ha)
	30 DAT	60 DAT	90 DAT	120 DAT	30 DAT	60 DAT	90 DAT	120 DAT		
T_0	34.40	51.13	62.73	70.53	46.67	148.40	128.73	119.80	109.68	29.04
T_1	42.57	66.90	78.30	86.01	66.60	200.60	175.87	162.20	150.70	38.26
T_2	43.30	67.57	81.93	91.18	84.40	215.23	198.37	187.93	175.67	38.45
T_3	42.47	66.57	82.70	91.33	86.60	221.47	203.27	193.73	178.38	38.81
T_4	45.10	75.33	87.77	101.50	87.20	240.27	216.93	207.53	200.00	41.37
T_5	45.43	79.83	96.00	109.73	88.60	248.27	225.93	217.27	201.35	41.85
T_6	48.50	80.00	97.23	110.97	99.93	254.40	238.73	224.20	202.00	42.26
T_7	50.50	80.23	99.07	112.33	126.60	307.67	283.67	273.20	202.69	45.30
T_8	51.40	85.60	108.23	119.43	137.67	309.60	291.93	281.77	205.00	46.00
T_9	51.33	85.77	109.53	119.50	143.07	313.33	297.78	285.20	213.73	46.26
T_{10}	59.07	94.87	122.87	131.00	153.27	354.73	325.00	309.33	237.00	50.30
T_{11}	60.87	99.13	125.47	135.00	159.93	362.93	338.27	321.13	252.10	52.59
T_{12}	62.87	99.73	126.47	137.00	166.60	374.27	349.60	325.47	260.05	53.85
SEm±	2.63	4.00	5.12	5.14	5.71	16.95	13.36	11.78	10.98	2.21
CD (*P*=0.05)	7.67	11.67	14.93	15.02	16.68	49.49	38.98	34.38	32.05	6.46

Refer to the methodology for treatment details. DAT. Days after transplanting.

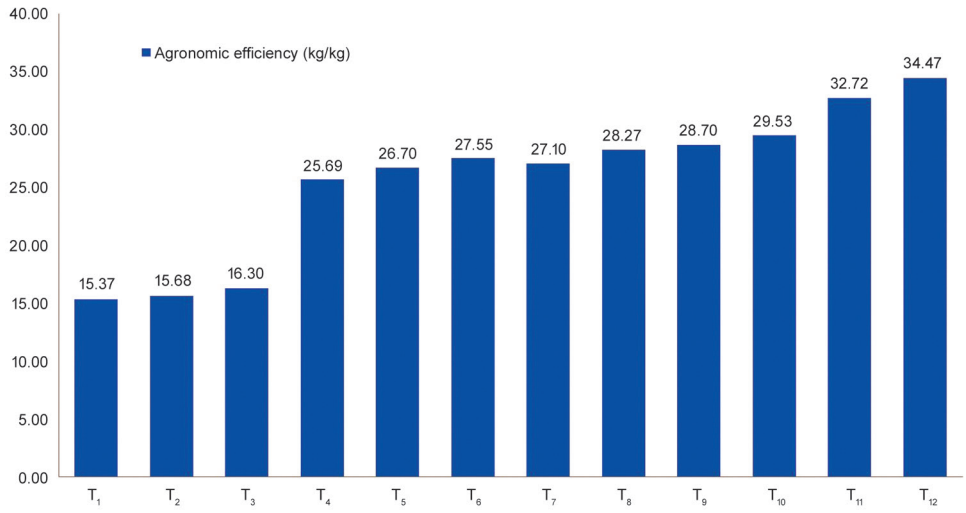

Fig. 1 Agronomic efficiency of fertilizer management practices in transplanted *kharif* rice. Refer to the methodology for treatment details.

$ZnSO_4$ @10 kg/ha (T_{11}) and FDP, 120% RDN + 100% P and K (T_{10}) were found to be statistically at par with T_{12} (Table 1). Similar result was noted with regard to grain yield of the crop. Treatment T_{12} was statistically at par with FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha (T_{11}) and FDP, 120% RDN + 100% P and K (T_{10}), however, was significantly superior over rest of the treatments with respect to grain yield. Enhanced vegetative growth of the plants under slow and steady release with improvement in availability of nutrients under these treatments led to better partitioning of photosynthates from photosynthetic area to the developing grain which reflected as higher number of panicles/m^2 and thus the yield of the crop (Islam *et al.* 2011, Kalita *et al.* 2017). Moreover, application of $ZnSO_4$ and biofertilizer along with NPK as briquettes in T_{12} promoted the availability of Zn, P and K along with N which showed positive impact on plant growth, panicles/m^2 and grain yield of the crop.

Among the treatments, agronomic efficiency (AE) was highest in FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer (T_{12}) (34.47 kg/kg) followed by FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha (T_{11}) (32.72 kg/kg) and FDP, 120% RDN + 100% P and K (T_{10}) (29.53 kg/kg) which was due to better assimilation of nutrients in the fertilized plot which led to boost in grain yield under these treatments compared to control (Fig. 1). The increase in panicles/m^2 and grain yield was mainly due to enhanced growth of rice under adequate availability of nutrients in these abovementioned treatments. These findings were in line with Islam *et al.* (2011) and Hussain *et al.* (2015).

SUMMARY

An experiment was conducted during rainy (*kharif)* season of 2022 at the research farm of Assam Agricultural University, Jorhat, Assam to evaluate the effect of fertilizer briquettes on growth and productivity of transplanted rice. The field experiment was laid out in RBD comprising of 13 treatments, replicated thrice. Growth of rice, panicles/m^2 and yield were subjected to significant variation under different fertilizer management practices. Higher plant height, tillers/m^2, panicles/m^2, yield and agronomic efficiency were recorded under FDP, 120% RDN + 100% P and K + $ZnSO_4$ @10 kg/ha + biofertilizer (T_{12}). This might be owing to reduced losses of nutrients and efficient uptake by plants compared to broadcasted method of fertilizer application where most of the applied fertilizers were susceptible to various losses availing lesser amount of nutrients for crop uptake.

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