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Yield Attributes, Yield and Nutrient Uptake of Rice (*Oryza sativa* L.) as Influenced by Zinc Fortified Briquettes in Medium Black Soil

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ABSTRACT

Background: Briquettes is more efficient than conventionally applied nutrients as it reduce the loss of nutrients by obtaining higher yield and decreased the expenditure cost of fertilizers. Indian soils are 49 per cent deficient in zinc which is characterized by widespread Zn deficiency in human beings.

Methods: Three different zinc fortified briquettes *viz*., UB-DAP, UB-suphala and UB-KAB were tested in field experiments during *kharif* season of 2016-19 to compare and calculate variations in yield, yield attributing characters and nutrients uptake by rice (*Oryza sativa* L.).

Result: The results showed that treatment UB-KAB fortified with 10 kg $ZnSO_{4.}7H_2O$ ha^{-1} (T_8) registered higher growth, yield parameters and Zn concentration in grain indicating zinc-sulfate-heptahydrate (ZSHH) offers vital solution to curtail Zn malnutrition. Further, UB-KAB fortified through ZSHH (T_8) significantly enhanced the grain (55.2 q ha^{-1}) and straw (63.6 q ha^{-1}) yield of rice over RDF and absolute control. Application of UB-KAB fortified with 10 kg $ZnSO_{4.}7H_2O$ ha^{-1} (T_8) significantly increased nutrient uptake of N (97.2 kg ha^{-1}), P (20.2 kg ha^{-1}), K (95.5 kg ha^{-1}), Zn (262.4 g ha^{-1}) and S (53.9 kg ha^{-1}) over fertilizer control (75% RDF) and absolute control. The applications of KAB fortified with zinc sulphate assume great significance in improving rice productivity.

Key words: Briquette, Rice, UB-KAB, Yield, Zinc sulphate.

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half the population of the world. Almost 90% of global rice is produced in Asia and in India it is grown on 43.79 M ha^{-1} with production and productivity of 112.91 MT and 2.57 t ha^{-1}, respectively (DOES 2019). Deep point placement of urea super granules (USG) or pilow shaped USG so called briquettes is more efficient than conventionally applied nutrients (Savant and Stangel 1998). The use of NPK briquette, which is a mixture of urea, triple super phosphate (TSP) and muriate of potash (MOP) reduce the loss of nutrients. With urea diammonium phosphate (UDP), rice farmers consistently achieve yield gain of 15%-20% using one-third less fertilizer (IFDC 2017). In countries where rice is a major staple food, Zn deficiency is most prevalent. About 49% zinc (Zn) reported to be deficient in Indian soils (Rattan *et al.,* 2009).

Cakmak (2008) reported regions in the world with Zn deficient soilscharacterized by widespread Zn deficiency in human. As the requirement of Zn in rice is high, under Zn deficient soil condition the rice plants become deficient in Zn, the growth is restricted and quality of rice grain deteriorates and human health is adversely affected (Singh 2008). Majority of farmers are applying NPK fertilizers without addition of organic manures and micronutrients to the soil. The zinc (Zn) has emerged as one of the yield-limiting factor as nearly 36.5% of Indian soils are deficient in available Zn (Shukla and Behera 2019). Zinc fertilization to cereal crops improves productivity and grain Zn concentration (Phattarakul *et al*., 2012) and thus improves grain nutritional value for human beings. However, the vast majority of Zn fertilizer trials and resulting fertilizer recommendations in rice have been in the context of managing the Zn deficiency, with very few studies related to Zn bio-fortification (Impa *et al*. 2010). Deep placement of all essential fertilizers may be more efficient and farmers can be more benefited from this compared to broadcast method. The application of briquettes obtained 25% higher yield and decreased the expenditure cost of fertilizers by 20-30% when fertilizer briquettes were used as the source of plant nutrients. Selection of appropriate Zn sources for soil application is considered to

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be an alternative strategy to improve plant availability of Zn under lowland conditions. Generally, $ZnSO_4$ is the most widely applied Zn source for its high solubility and low cost. Therefore, the present study was undertaken to find out the increase in yield, yield attributes and quality of rice with Zn fortified briquette in medium black soil of Konkan region of Maharashtra.

MATERIALS AND METHODS

Field experimentation was carried-out during *kharif* (June–October) seasons 2016-2019 at Regional Agricultural Research Station, Dr. B.S. Konkan Krishi Vidyapeeth, Karjat, Maharashtra, India (18°91′ N latitude and 73°32′ E longitude; 51.75 m Altitude). The climate of the region is hot moist sub-humid to humid with a mean annual rainfall of 3300 mm of which > 90% is received through south-west monsoons during June-October. The soil of the experimental field belongs to sub-group of *Typic haplustepts*. The soil (0-22.5 cm layer; taken initially before experimentation) of the experimental site was clay loam in texture having pH 6.7, EC of 0.21 dS m^{-1} (1:2.5 soil and water ratio), soil organic carbon 9.6 g kg^{-1}, alkaline $KMnO_4$ oxidizable-N 127.95 kg ha^{-1}, 0.5 M $NaHCO_3$ extractable-P 14.92 kg ha^{-1} and 1 N NH_4OAc extractable-K 318.53 kg ha^{-1}. The diethylene-triamine–penta–acetic acid (DTPA) extractable-Zn 0.32 mg kg^{-1} and Sulphur in soil was 19.11 kg ha^{-1}.

The experiment was laid-out in randomized block design replicated thrice consisted of eleven treatments. Selection of rice Cv KJT-3 was done keeping in view their yield potentiality and special characteristics for growing in high rainfall area. The fortified briquettes were placed at 7-10 cm deep in soil followed by transplanting @ 1 briquette for every four hills using modified 20 × 15 cm spacing to all treatment except RDF and absolute control. The FYM @ 10 t ha^{-1} on fresh weight basis was applied to all treatment except absolute control and RDF was given to treatment T_2 in which 50 per cent N and full dose of P and K were applied at the time of transplanting and rest of the 50 per cent N was applied in two split dose at tillering and at panicle initiation stage, respectively. Observations on growth attributes (plant height, number of tillers $hill^{-1}$, yield components (length of panicle, number of kernel per panicle, grain yield and test weight) and crop productivity were recorded.

Nutrient contents at harvest in the plant was determined by drying the samples in hot air oven at 60°C±2°C till a constant dry weight was obtained. Nitrogen in samples was analyzed by using Kjeldahl's apparatus (Piper 1966). The plant samples were digested in di-acid mixture (HNO_3 and $HClO_4$ in the ratio of 9:4) and P content was determined by using Vanado-molybdo-phosphoric acid yellow colour method (Piper 1966) and potassium content was determined by using the flame photometer (Jackson 1973). The Zn concentration in rice grain and straw was determined as per the procedure described by (Singh *et al*., 1999) by Atomic Absorption Spectrophotometer (AAS). The sulphur content in grain and straw was estimated by using Chesnin and Yein (1951). The N, P, K, Zn and S uptake was computed by multiplying the nutrient content with plant biomass. Analysis of variance (ANOVA) for the randomized block design was performed and the least significance difference (LSD) at a 5% level of probability was used to test the significance of differences among treatment means (Panse and Sukhatme 1967).

RESULTS AND DISCUSSION

Growth, yield attributes and yield of rice

Plant height, number of tillers per plant or hill depends on the genotype, environment as well as the plant nutrition. The significantly higher values of plant height (107.8 cm), number of tillers $hill^{-1}$ (13.5), number of effective tillers $hill^{-1}$ (7.7), length of panicles (26.2 cm), number of kernel $panicle^{-1}$ (129.2), fertility percentage (92.1%) and test weight (23.8 g) were recorded in the treatment receiving UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} (Table 1). Absorption of more nutrients in the treatment KAB briquettes resulted into vigorous growth through more number of leaves at all growth stages of crop. The highest number of tillers due to application KAB briquettes ultimately resulted into higher photosynthetic activity, the synthesis of higher amount of photosynthate by rice at all the crop growth stages. These results are in conformity with Virendra Kumar and Ladha (2011).

Further, higher organic matter production and higher supply and uptake of nutrients through FYM and chemical fertilizers, resulting in more leaf area coverage and thereby producing more leaf dry weight and thus improved yield attributing characters and yield of rice. Likewise, comparatively lower plant height, tillers/hill, number of effective tillers/hill, length of panicle, grain per panicle, fertility percentage and 1000 grains weight are responsible characteristics for lowest grain yield in RDF and absolute control treatment. These observations were in agreement with the findings of Pooniya *et al.* (2012).

Grain and straw yield

Among different fortified briquette, significantly highest grain (55.2 q ha^{-1}) and straw (63.6 q ha^{-1}) yield was registered with UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ per ha (Table 1). The application of briquette increased leaf chlorophyll index that increased the ability of crop canopy to capture photosynthetic active radiation (PAR) thus, converting it into higher yields. This proper and adequate supply of Zn increased the uptake of Zn during the grain formation stage and ultimately improved the yield attributes and yields. In case of application of Urea-DAP briquettes, it was placed deeply (5-6 cm) in reduced zone of soil layer so that it slowly get released essential plant nutrient into soil, mostly under puddled condition which enhanced the growth parameters due to more availability of nutrients and reduces percolation losses of nutrients. The increased yield attributes might be due to increased growth and development parameters which

Table 1: Yield and yield attributes of rice cultivar as influenced by application of zinc fortified briquettes. (pooled data).

Treatments	Plant height (cm)	No of tillers hill^{-1}	Length of panicle (cm)	No. of kernel panicle^{-1}	Test weight (g)	Fertility percentage (%)	No. of effective tillers	Yield (q ha^{-1}) Grain	Yield (q ha^{-1}) Straw
T_1- Absolute control	82.70	10.30	20.10	101.30	13.19	54.96	5.90	27.48	31.22
T_2- RDF (100:50:50 NPK kg ha^{-1})	97.00	12.10	23.50	116.02	19.25	74.38	6.93	43.75	49.18
T_3- UB-DAP + 5 kg $ZnSO_4$ ha^{-1}	98.10	12.30	23.80	117.33	22.43	86.67	7.00	50.98	56.55
T_4- UB-Suphala + 5 kg $ZnSO_4$ ha^{-1}	98.30	12.30	23.90	117.66	23.08	89.17	7.02	52.05	61.70
T_5- UB-KAB + 5 kg $ZnSO_4$ ha^{-1}	103.20	12.90	25.10	123.41	23.44	90.57	7.37	52.78	61.61
T_6- UB-DAP + 10 kg $ZnSO_4$ ha^{-1}	98.80	12.40	24.00	118.32	20.31	78.49	7.06	46.17	53.15
T_7- UB-Suphala + 10 kg $ZnSO_4$ ha^{-1}	102.50	12.80	24.90	122.76	20.53	79.33	7.32	46.66	55.06
T_8- UB-KAB + 10 kg $ZnSO_4$ ha^{-1}	**107.80**	**13.50**	**26.20**	129.17	23.83	92.08	7.70	55.17	63.56
T_9- UB-DAP + 15 kg $ZnSO_4$ ha^{-1}	98.70	12.30	23.90	117.99	19.61	75.76	7.05	44.56	51.28
T_{10}- UB-Suphala + 15 kg $ZnSO_4$ ha^{-1}	100.60	12.60	24.40	120.29	21.07	81.42	7.18	47.89	56.49
T_{11}- UB-KAB + 15 kg $ZnSO_4$ ha^{-1}	105.00	13.10	25.50	125.55	21.00	81.12	7.50	47.72	55.67
S. E. ±	0.95	0.12	0.23	1.08	0.49	1.89	0.06	1.82	2.35
C. D. @ 5%	2.80	0.35	0.68	3.19	1.44	5.57	0.18	5.33	6.88

ultimately resulted in increased grain. Similar results were also obtained by Patil *et al.* (2018). The briquette application can save 30% N compared to Prilled Urea (PU), increases absorption rate, improves soil health and ultimately increases rice yield IFDC (2017). Further, the addition of Zn increase in yield may be attributed to Zn has more residual effect. This is in conformity with the findings of Suresh and Salakinkop (2016) as photosynthetic pathways depends on enzymes and coenzymes which are synthesized by micronutrients.

Nutrient uptake

As in case of grain yield and yield components higher N, P, K, S and Zn uptake was observed in $ZnSO_4.H_2O$ fortified briquette treated plots presented in Table 2, which were resulted from higher grain yield and higher nutrient concentration in grains and straw. The significantly highest total N (97.2 kg ha^{-1}) P uptake (20.2 kg ha^{-1}) and K uptake (95.5 kg ha^{-1}) was recorded with application of Konkan Annapurna fortified Briquettes (KAB) with $ZnSO_4.H_2O$ @ 10 kg ha^{-1} (T_8) and found at par with treatment T_3, T_4 and T_5. The increase in N uptake by plant parts indicates the absorption of nitrogen by rice crop is enhanced due to integration of N and P content in briquette. The deep placed UB-SSP, UB-DAP and UB-KAB tends to become available to the rice plants (roots) about 2-3 weeks after transplanting. Similar results were reported by Patil *et al.* (2018). The high concentration of P in the soil solution near the UB-KAB placement sites may have helped to ensure adequate P uptake by the rice plants and thus resulted in overall higher efficiency of the deep-placed UB-KAB as a NP sources. Deep placement of UB-SSP, UB-DAP and UB-KAB must have resulted into enhanced N and P use efficiency resulting into better supply of all three major essential nutrients and increase in total dry matter production of rice. Total uptake of K by rice crop was quite higher in comparison to the uptake of N, P and S with other treatments. Kapoor *et al*. (2008) also observed that significantly higher N, P and K uptake and N and P use efficiencies with deep placement of NPK briquette compared to broadcast application.

The highest Zn concentration in grain (66.4 g ha^{-1}), straw (196.0 g ha^{-1}) and total Zn uptake (262.4 g ha^{-1}) was recorded when treated with UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} which was significantly higher than all other treatments but remained statistically at par with T_3, T_4, T_5 and T_{11} in grain, T_5 in straw and T_5 in total Zn uptake, respectively (Table 2). The favourable influence of $ZnSO_4$ application on yield of rice may be attributed to its role in various enzymatic reactions, growth processes, hormone production and protein synthesis and also the translocation of photosynthates to grain is more than to stem and leaves thereby leading to higher grain yield which was reflected on the Zn uptake. These results are in agreement with Dore *et al*. (2018).

Among different fortified briquette treatments UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} resulted into higher sulphur concentration in grain and straw than other

Table 2: Nutrient content and uptake by rice crop as influenced by application of zinc fortified briquettes (pooled data).

Tr	N concentration		Total N	P concentration		Total P	K concentration		Total K	Zn concentration		Total Zn	S concentration		Total S
	Grain	Straw	uptake	Grain	Straw	uptake	Grain	Straw	uptake	Grain	Straw	uptake	Grain	Straw	uptake
T_1	32.49	15.10	47.59	5.81	3.43	9.23	9.92	38.90	48.82	7.03	20.49	27.52	7.93	5.28	13.21
T_2	54.19	23.98	78.17	9.91	5.68	15.60	16.50	62.11	78.61	11.99	34.64	46.63	15.24	11.25	26.49
T_3	61.31	25.82	87.12	11.13	5.93	17.05	18.79	69.85	88.64	53.86	150.03	203.90	24.43	20.34	44.77
T_4	60.90	28.02	88.92	11.09	6.90	17.99	18.69	71.51	90.20	52.58	158.59	211.17	23.91	20.76	44.67
T_5	63.03	27.04	90.07	11.41	6.76	18.17	19.18	72.54	91.72	58.05	173.80	231.85	25.00	21.55	46.54
T_6	53.52	23.00	76.53	9.77	5.51	15.28	16.83	61.12	77.95	48.27	142.49	190.76	16.54	12.69	29.24
T_7	53.32	24.35	77.68	10.04	5.54	15.57	16.48	63.02	79.51	47.58	143.94	191.52	15.61	11.84	27.44
T_8	67.39	29.78	97.17	12.54	7.64	20.18	20.74	74.78	95.52	66.43	196.01	262.44	28.30	25.62	53.92
T_9	49.91	22.49	72.40	9.06	5.35	14.41	15.28	59.14	74.41	43.57	128.58	172.15	14.34	10.37	24.71
T_{10}	54.59	24.29	78.88	9.89	5.47	15.36	16.40	64.62	81.03	44.67	135.12	179.79	15.36	11.36	26.72
T_{11}	54.73	24.64	79.37	9.91	6.08	15.99	16.57	64.86	81.43	50.78	151.93	202.71	15.47	11.39	26.86
S. E. ±	2.61	1.16	3.61	0.47	0.41	0.66	0.82	2.43	3.13	5.52	7.76	12.37	0.43	0.37	0.74
C. D. @ 5%	7.72	3.43	10.65	1.39	1.20	1.96	2.42	7.16	9.24	16.28	22.89	36.47	1.46	1.27	2.51

T_1- Absolute control, T_2- RDF (100:50:50NPK kg ha^{-1}), T_3- UB-DAP + 5 kg $ZnSO_4$ ha^{-1}, T_4- UB-Suphala + 5 kg $ZnSO_4$ ha^{-1}, T_5- UB-KAB + 5 kg $ZnSO_4$ ha^{-1}, T_6- UB-DAP + 10 kg $ZnSO_4$ ha^{-1}, T_7- UB-Suphala + 10 kg $ZnSO_4$ ha^{-1}, T_8- UB-KAB + 10 kg $ZnSO_4$ ha^{-1}, T_9- UB-DAP + 15 kg $ZnSO_4$ ha^{-1}, T_{10}- UB-Suphala + 15 kg $ZnSO_4$ ha^{-1} and T_{11}- UB-KAB + 15 kg $ZnSO_4$ ha^{-1}

treatments in all experimental years (Table 2). The S concentration in rice grain (28.3 kg ha^{-1}), straw (25.6 kg ha^{-1}) and total uptake of S (53.9 kg ha^{-1}) was recorded highest with UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} and it was significantly higher than other zinc fertilization treatments during 2016-2019. Sulphur played crucial role in diversion of photosynthate towards the shoot at every growth stages and marked variation was noticed at panicle initiation (PI) and maturity stages. It indicate role of sulphur much more in signaling process of photosynthate especially after onset of reproductive stages (Rahamn *et al.* 2008). Also, the total uptake of N, P K, Zn and S may be increased due to addition of inorganic fertilizers through addition of FYM. An increase in uptake of these nutrients when organic and inorganic fertilizers were applied was also reported by Najnappa *et al.* (2001).

CONCLUSION

For obtaining higher growth parameter and yield rice, the application of UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} after transplanting of rice may be the better options in terms of nutrient uptake, yield attributes and yield of rice than other fertilization strategy. Therefore, it can be concluded that rice should be grown with the use of Konkan Annapurna Briquettes (UB-KAB) fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1}. Hence, the application of UB-KAB fortified with 10 kg $ZnSO_4.7H_2O$ ha^{-1} may be recommended in medium black soils of Konkan region.

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