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Assessment of Balance Nutrition (N, P, K, Zn and B) and Green Manuring on Yield, Nutrient Uptake, Economics and Soil Fertility of Rainfed Rice (*Oryza sativa* L.) in Drought Prone Areas of Odisha

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Authors' contributions

This work was carried out in collaboration among all authors. Author JU designed the study and wrote the protocol. Authors AP and PJM performed the statistical analysis and wrote the first draft of the manuscript. Authors MB, SKJ and DP managed the literature searches and analysis of the study. Authors FHR and LMG edited the whole draft and managed analysis. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was carried out in participatory mode on farmers' field at Bhoimunda village of Jharsuguda block under Jharsuguda district, Odisha during *Kharif* season of 2017, 2018 and 2019 to study the efficiency of nutrient management along with green manuring crop on productivity, profitability and soil fertility of rice under Western Central Table Land Zone of Odisha, India. The adopted village was selected by Krishi Vigyan Kendra, Jharsuguda, Odisha under National Innovations in Climate Resilient Agriculture (NICRA) project. The experiment was laid out in Randomized Block Design with four treatments replicated five times taking rice (cv. Sahabhagi

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dhan) as test crop. The treatments comprised of four *viz.* T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1}), T_2: Recommended dose of fertilizer (NPK @ 60:30:30 kg ha^{-1}), T_3: 75% RDF + Green manuring of dhaincha (*Sesbania aculeata*) with seed rate of @ 25 kg ha^{-1} and T_4: Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + Green manuring. Results revealed that application of Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} along with green manuring producing dry biomass 5044 kg ha^{-1} (T_4) recorded significantly higher growth and yield attributes, grain yield (4.04 t ha^{-1}), straw yield (5.15 t ha^{-1}), harvest index (43.92%) as well as nutrient uptake in grain and straw of the crop over farmers practice. The same treatment recorded significant improvement in soil pH, organic carbon, available macronutrients (N, P and K) and micronutrients (Zn and B) status of soil after harvest of the crop. The highest benefit: cost ratio (1.62) and returns (Rs. 28559 ha^{-1}) were recorded with the same treatment (T_4) over farmers practice. The present study showed that use of green manuring along with balance nutrition, is an important strategy to maintain and/or improve soil fertility for sustainable crop production in drought prone areas as well as remunerative rice production by the farmers in Odisha, India.

Keywords: Balance nutrition; green manuring; yield; nutrient uptake; economics; soil fertility.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for about half of the global population, grown in 160 million ha (Mha) with 493 million tons (Mt) milled rice production [1,2]. The population of the country is burgeoning, which may stabilize around 1.4 and 1.6 billion by 2025 and 2050, requiring annually 380 and 450 mt of food grains respectively [3]. Hence, increasing productivity and keeping pace with the rising food demand with minimal environmental disturbance has become a challenge to the farmers and scientists. Therefore, adequate nutrient management is essential to enhance productivity of rice as it is an exhaustive feeder crop [4]. Within Eastern India, Odisha is one of the main rice producing states [5], but average rice yields in Odisha are distinctly lower than the national average [6]. In Odisha, most of the rice is produced in small landholdings varying in crop management practices and constraints such as drought and floods, which influence rice yields and the need for supplemental nutrients [7]. In general, in the post Green Revolution period in India, deficiencies of Zn and B have been found to constrain sustainable growth in productivity of several field crops, where intensive agriculture is practiced [8]. The soils are poorly fertile with low organic matter, available nitrogen, phosphorus and medium in potash, and these soils are also highly deficient in micronutrients like boron and molybdenum [9]. About 44 percent of soils of Odisha are deficient in B [10,11]. The zinc deficiency in soils of Odisha ranged from 0 to 76% with state mean of 19% and crops grown on these soils contain less amount of Zn. About 1 million people of the state are affected from Zn deficiency [12]. Micronutrient deficiency is one of the major causes of the declining crop productivity trends because of the escalated nutrient demand from the more intensive and exploitative agriculture [13]. Cultivation of high yielding varieties responsive to fertilizer and excess use of inorganic fertilizers has depleted the inherent soil fertility. Several long-term experiments conducted all over India indicated a decrease in rice productivity due to continuous use of chemical fertilizers [2].

In recent times, farmers have mostly relied on chemical fertilizers, particularly N fertilizers, to boost rice yields. Initially, rice yields were increased by applying large amounts of chemical fertilizers. However, this has led to soil problems, declining crop yields, and global environmental issues. Thus, we need to develop and adopt environmentally friendly alternatives that can supplement or replace chemical fertilizers.

Keeping this in consideration, the present investigation has been undertaken to study the efficiency of nutrient management along with green manuring crop on productivity, profitability and soil fertility of rice under NICRA project in rainfed uplands of Western Central Table Land Zone of Odisha, India.

2. MATERIALS AND METHODS

2.1 Site Description and Experimental Design

The field experiments were carried out in participatory mode on farmers' field during *Kharif* seasons of 2017, 2018 and 2019 at Bhoimunda village of Jharsuguda district under the National Innovations in Climate Resilient Agriculture (NICRA) project by Krishi Vigyan Kendra, Jharsuguda, Odisha. The Jharsuguda district is located under Western Central Table Land Zone and North Western Plateau Zone of Odisha, India. The fields are situated at 21°55'2742.18''N latitude, 83°57'37.83"E longitude, experiencing hot dry summer with an average annual rainfall of 2017, 2018 & 2019 was 1365.80 mm and the mean minimum and maximum temperature of three years was 22°C and 45°C, respectively. The soil of experimental site (initial values) was shallow depth, well drained, sandy loam in texture (Sand: 61.24%, Silt: 20.24% and Clay: 18.52%), slightly acidic (pH- 5.90), non-saline (EC- 0.052 dSm^{-1}), low in organic carbon (4.81 g kg^{-1}), available N (190.12 kg ha^{-1}), available P (12.51 kg ha^{-1}), available Zn (0.59 mg kg^{-1}), available B (0.45 mg kg^{-1}), medium in available K (160.22 kg ha^{-1}), and high in available S (22.41 mg kg^{-1}), available Cu (1.66 mg kg^{-1}) and available Fe (32.11 mg kg^{-1}) contents, respectively.

The experiment was laid out in Randomized Block Design with four treatments replicated five times taking rice (cv. Sahabhagi dhan) as test crop. Sahabhagi dhan is a high yielding variety which was released from National Rice Research Institute (NRRI), Cuttack, India in 2009. It is suitable for direct sown as well as transplanted condition in rainfed upland rice ecosystem, and tolerant to drought and resistant to leaf blast, moderately resistant to sheath rot, leaf folder, and brown spot and stem borer. Green manuring of dhaincha (*Sesbania aculeata*) was sown @ 25 kg seed ha^{-1} during first week of June of each year (i.e. 2017, 2018 and 2019). The dhaincha (*Sesbania aculeata*) crop producing dry biomass of 5044 kg ha^{-1} was incorporated into the soil after 40 DAS and allowed it for 15 days to facilitate decomposition prior to planting of rice followed in all plots, including the fallow plots (without dhaincha). Rice cv. Sahabhagi dhan (21 days old seedlings) was transplanted on last week of July in hills 15 cm apart and in rows 20 cm apart during *Kharif* season of each year. The treatments comprised of four *viz.* T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1}), T_2: RDF (NPK @ 60:30:30 kg ha^{-1}), T_3: 75% RDF + Green manuring and T_4: Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + Green manuring. Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} (T_4) was made basing upon the normal Recommended Dose of Fertilizer (i.e. NPKZnB @ 60:30:30:5:1 kg ha^{-1}) in which 25% more N, P, B and Zn were added. The farmer's practice (NPK @ 50:20:20 kg ha^{-1}) is considered as control treatment and it is widely adopted in the locality of rainfed upland rice ecosystems of Western Central Table Land Zone and North Western Plateau Zone of Odisha. Urea, Diammonium Phosphate (DAP), Muriate of Potash (MOP), Borax, and Zinc sulphate were used as source of N, P, K, Zn and B, respectively. The entire amount of P and 25% of N and K were applied at final land preparation as basal and 50% of N and K was top-dressed at tillering stages (3 weeks after transplanting), and rest 25% of N and K was top-dressed at panicle initiation (PI) stages of rice crop. Borax and Zinc sulphate fertilizers were applied as basal soil application during transplanting mixed with FYM @ 2 t ha^{-1} in each respective treatment except control. Since the soil had adequate amounts of available S, Fe and Cu, these were not supplied through fertilizers. All the other cultural practices were followed uniformly throughout the growing period of crop. The observations of rice data were recorded at harvest and grain yield was recorded at 14% moisture content. The economics of rice cultivation was calculated based upon the prevailing market prices of the local area.

Plant samples were collected, cleaned, dipped serially into deionized water for 10 (seconds) and 0.1 N hydrochloric acid (HCL; for 5 sec.) and then dried in hot air oven at 60-70ºC for 48 hours, dry matter yields were recorded. Dried plant samples were ground using stainless steel mechanical grinder. Dried and ground plant samples were analyzed for total recoveries of N, P, K, Zn and B. All recoveries were obtained on dry weight basis. Initial and post harvest soil samples were collected at the depths of 0-15 cm, air dried, ground, and passed through a 2-mm sieve following standard methods detailed hereafter.

2.2 Analytical Methodologies for Soil and Plant Samples

A composite soil sample was analyzed for physico-chemical properties before conducting the experiment. The method involved in analyses of initial and post harvest soil samples, and plant samples are depicted as follows:

Chart 1. The method involved in analyses of initial and post harvest soil samples, and plant samples

Parameter	Methodology	Citation
Soil analyses		
Soil Texture	Hydrometer method	Bouyoucos (1962) [14]
pH	(in 1:2.5:: Soil : Water)	Jackson (1967) [15]
EC	(in 1:2.5:: Soil : Water)	Jackson (1967) [15]
Organic carbon	Wet oxidation method	Jackson (1973) [16]
Available N	Hot alkaline $KMnO_4$ Method	Subbiah and Asija (1956) [17]
Available P	0.03 N NH_4F + 0.025 N HCL (pH 3.5) and 0.5 M $NaHCO_3$ at pH 8.5	Bray and Kurtz (1945) [18] and Olsen et al. (1954) [19]
Available K	Neutral N NH_4OAc extraction	Jackson (1973) [16]
Available S	Extraction with 0.15% $CaCl_2$	Massoumi and Cornfield, 1963 [20]
Available Zn	DTPA extractant	Lindsay & Norvel (1978) [21]
Available B	Hot water extraction	Berger and Truog (1939) [22]
Plant analyses		
Total N	Concentrated H_2SO4 digestion	Jackson (1973) [16]
Total P, K, Zn	Tri-acid mixture (HNO_3:H_2SO_4:$HClO_4$:: 9:1:4) digestion	Jackson (1973) [16]
Total B	Dry ashing followed by 0.36 *N* H2SO4 extraction	Gains and Mitchell (1979) [23]

2.3 Statistical Interpretation

The growth and yield related characters of rice, nutrient concentration, nutrient uptake, and soil parameters like pH, Organic carbon, and available nutrient (N, P, K, Zn and B) status of post harvest soil were subjected to analysis of variance (ANOVA). Significance (p=0.05) was tested using Windows-based SPSS software (version 18.0, Chicago, USA).

3. RESULTS AND DISCUSSION

3.1 Growth and Yield Attributes

The experimental pooled data revealed that the application of inorganic sources along with green manuring induced marked variation in growth and yield attributes of rice (Table 1). Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + Green manuring (T_4) recorded maximum growth and yield attributes *viz.* plant height (83.05 cm), number of tillers/m^2 (301.13 cm), number of panicle/m^2 (226.12), number of filled grains/panicle (129.48), panicle length (24.94 cm) and test weight of 1000 grain (23.76 g) at harvest. This treatment was found at par with 75% RDF + GM for plant height, number of panicles/m^2, panicle length and test weight of 1000 g but significantly higher for number of tillers/m^2 and number of filled grain/ panicle. Farmer's practice (T_1) recorded significantly lower values than all other treatments. It might be due to favorable effect Soil Test Based NPKZnB soil application resulting in better absorption and availability on Zn, S and B throughout the growth period in adequate amounts and their synergistic effect in improving yield attributes.

3.2 Grain Yield, Straw Yield and Harvest Index

From the pooled data of three years (Table 1), the highest grain yield (4.04 t ha^{-1}), straw yield (5.15 t ha^{-1}) and harvest index (43.92 %) was observed in Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + Green manuring, that was significantly superior than 75% RDF with green manuring (T_3) which was found at far with RDF (T_2) and significantly superior than farmers practice. Soil test based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + green manuring plots recorded 43.26, 31.71 and 4.77% higher grain yield, straw yield and harvest index compared to farmers practice. It also indicates that B and Zn interacted synergistically to boost the yield of rice crop in acid soils. Similar results were also reported by Panwar et al. [24]. Kumar et al. [25] also reported that application of RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} recorded significantly higher growth and yield of rice. Similar trend of result was also reported by Phonglosa et al. [11]. This might be due to direct or cumulative effect of supplied macro (N, P and K) and micro (Zn and B) nutrients on metabolic process of rice. Boron and zinc are known to influence translocation of metabolites and thereby improving source and sink strength in plants [26].

Table 1. Effect of nutrient management on growth and yield attributes of rice (pooled data of three years)

Treatment	Plant height (cm)	No. of tillers/m^2	No. of panicle/m^2	No. of filled grains/panicle	Panicle length (cm)	Test weight of 1000 grain (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1})	80.11	289.97	219.35	123.32	23.21	22.27	2.82	3.91	41.92
T_2: RDF (NPK @ 60:30:30 kg ha^{-1})	81.72	298.30	223.61	126.35	24.28	22.94	3.25	4.37	42.63
T_3: 75% RDF + Green manuring (GM)	82.23	298.77	225.13	127.94	24.73	23.40	3.41	4.53	42.94
T_4: Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1} + GM	83.05	301.13	226.12	129.48	24.94	23.76	4.04	5.15	43.92
LSD (p= 0.05)	1.44	6.37	3.15	1.50	0.86	0.58	0.27	0.35	0.73

Table 2. Nutrient uptake in rice as influenced by nutrient management (pooled data of three years)

Treatment	N uptake (kg ha^{-1})		P uptake (kg ha^{-1})		K uptake (kg ha^{-1})		Zn uptake (g ha^{-1})		B uptake (g ha^{-1})	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1})	28.76	19.53	3.69	3.95	3.95	43.01	59.56	149.31	25.69	29.50
T_2: RDF (NPK @ 60:30:30 kg ha^{-1})	36.40	24.10	5.27	5.07	5.23	49.51	76.54	179.31	39.72	44.21
T_3: 75% RDF + Green manuring (GM)	39.56	26.77	6.31	6.39	6.41	52.55	90.54	209.38	51.90	59.39
T_4: Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + GM	48.02	32.04	8.68	8.35	8.47	62.39	125.53	258.15	73.07	89.69
LSD (p= 0.05)	2.42	1.78	1.24	1.16	1.21	4.28	18.05	27.75	16.54	17.48

Table 3. Status of post harvest soil as influenced by nutrient management (pooled data of three years)

Treatment	pH	Organic C (g/kg)	Av. N (kg/ha)	Av. P (kg/ha)	Av. K (kg/ha)	Av. Zn (mg/kg)	Av. B (mg/kg)
T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1})	5.8	4.80	192.22	12.88	161.23	0.60	0.45
T_2: RDF (NPK @ 60:30:30 kg ha^{-1})	6.1	4.83	194.16	15.55	165.20	0.63	0.47
T_3: 75% RDF + Green manuring (GM)	6.5	5.78	201.42	17.41	166.21	0.65	0.50
T_4: Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1} + GM	6.8	5.91	206.44	18.66	170.42	0.70	0.57
LSD (p= 0.05)	0.30	0.17	4.22	1.62	2.41	0.06	0.05

Table 4. Economics of rice cultivation as influenced nutrient management (pooled data of three years)

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1: Farmer's practice (NPK @ 50:20:20 kg ha^{-1})	39577	52170	12593	1.32
T_2: RDF (NPK @ 60:30:30 kg ha^{-1})	40492	60125	19633	1.48
T_3: 75% RDF + Green manuring (GM)	40698	63085	22387	1.55
T_4: Soil Test Based NPKZnB @ 75:38:30:6.25:1.25 kg ha^{-1} + GM	46088	74648	28559	1.62

Notes. Cost of seed, Rs. 2200 q^{-1}; Urea, Rs. 6.6 kg^{-1}; DAP, Rs. 24.90 kg^{-1} ; MOP, Rs. 17.20 kg^{-1} ; Borax, Rs. 200.00 kg^{-1}; Zinc Sulphate, Rs. 55 kg^{-1}, Labour wages, Rs. 200 $M.U^{-1}$; Selling price, Rs. 18.50 kg^{-1}

3.3 Nutrient Uptake

The study of pooled data of three years indicated that the effect of organic manures and chemical fertilizers were significant on the uptake of N, P, K, Zn and B by the rice grain (Table 2). The highest uptake of N (48.02 kg ha^{-1}), P (8.68 kg ha^{-1}), K (8.47 kg ha^{-1}), Zn (125.53 g ha^{-1}) and B (73.07 g ha^{-1}), respectively, were recorded in the treatment combination Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1} + Green manuring followed by 75% RDF + Green manuring, RDF and farmers practice. Similar trend of nutrient uptake was also observed in rice straw (Table 3). This might be ascribed to greater dry matter production as well as nutrient concentration with combined use of inorganic and organic fertilizers. These results corroborate with the findings of Sabina Ahmed et al [27], Behera et al. [28] and Baishya [29].

3.4 Post Harvest Soil Fertility Status

Pooled analysis of data (Table 3) of three years indicated that the soil pH, organic carbon and nutrient status of the post-harvest soil were influenced with application of balance nutrients along with green manuring of dhaincha (*Sesbania aculeata*). Application of Soil Test Based N P K Zn B along with green manuring was found to restore significantly higher organic carbon (5.91 g kg^{-1}) of the post-harvest soils than the control (farmer’s practice). Supplementation of balance nutrients with green manuring recorded significantly higher proportions of available N (206.44 kg ha^{-1}), P (18.66 kg ha^{-1}), K (170.42 kg ha^{-1}), Zn (0.70 mg kg^{-1}) and B (0.57 mg kg^{-1}) in post-harvest soils over control (farmers practice). It might be due to addition of organic matter in the form of green manures and balance nutritions which were improved the physico-chemical properties of soils. Dhaincha is an ideal crop for green manure, as it is quick growing, succulent, easily decomposable with low moisture requirements, and produces maximum amount of organic matter and nitrogen in the soil [30]. Organic fertilizers are environmentally sustainable and can maintain soil health when used in intensive rice agriculture. They help to conserve the amount and quality of organic matter in the soil, and supply N, P, K, and essential micronutrients [31,32,33]

Dwivedi et al. [34]; Fageria [35]; Pooniya and Shivay [36] were reported that dhaincha fixed more atmospheric N biologically and its residue incorporation in soil also added higher amounts of organic matter, which is a good indicator of soil fertility and status of available nutrients in the soil.

3.5 Economics

Economics is the prime consideration that finally decides the adoption of any recommended practice at farming situations, and whether an agronomic management plan should be technically and economically viable to be sustainable [37]. In the present study, gross return, net return and gross B:C ratio were influenced by balance nutrient management and green manuring (Table 4). Net return (Rs. 28559/-) was found to be highest in Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1} and green manuring in the study, and it was because of increased grain yield received at balance dose of nutrients along with green manuring. Lowest net return (Rs. 12593/-) and B:C ratio (1.32) was recorded with farmer’s practice (NPK @ 50:20:20 kg ha^{-1}). Economic assessments were determined based on the observed nutrients and green manuring response with current prices of these fertilizers and MSP of rice. This indicates that balance nutrition (Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1}) with green manuring of dhaincha (*Sesbania aculeata*) @ 25 kg seed ha^{-1}) resulted the most economical treatment with respect to increasing net profit over control (Farmer’s practice). The results were also reported by Jeet et al. [38] and Sahoo et al. [39].

4. CONCLUSION

In conclusion, the present study clearly highlights the large variability observed in nutrient supplying capacity of sandy loam soil of red and lateritic soils in Western Central Table Land Zone and North Western Plateau Zone of Odisha. From the profit analysis point of view, it can be concluded that application of Soil Test Based N P K Zn B @ 75:38:30:6.25:1.25 kg ha^{-1} along with green manuring of dhaincha (*Sesbania aculeata*) @ seed rate of 25 kg ha^{-1} found to be most effective for sustainable rice production, profitability and soil fertility. The present study also outlines the sustainability of nutrient management, noting that only dependence on organic manure or chemical fertilizers could not serve the purpose of the food security of the ever growing populations in drought prone areas of Odisha, India.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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