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Influence of integrated nutrient management (INM) practices on performance of *boro* rice (*Oryza sativa* L.) in new alluvial zone of West Bengal

[1]E. KWAMI, V.V. S. JAYA KRISHNA, *M. MAHATO, M. DEY AND D. DUTTA

Department of Agronomy, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal

[1]Ghana Irrigation Development Authority, Ministry of Food and Agriculture, Accra-Ghana

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ABSTRACT

Integrated nutrient management became indispensable for the long-term benefits of maintaining soil health, sustaining production and reducing environmental pollution. Hence, a field experiment was conducted at Bidhan Chandra Krishi Viswavidyalaya, West Bengal during boro seasons of 2019 and 2020 to evaluate the growth and yield performance, nutrient uptake and economics of rice (cv. Satabdi) towards various INM practices. The experiment comprised of seven treatment combinations in Randomized Block Design with three replications. On the basis of pooled data, better performance regarding growth, yield, uptake (N, P and Zn) and economics were reflected from the integrated application of 2 t ha^{-1} vermicompost + 75% RDF + 25 kg ha^{-1} $ZnSO_4$ (soil application) than other treatments. Therefore, it can be concluded that 2 t ha^{-1} vermicompost followed by 75% RDF and 25 kg ha^{-1} $ZnSO_4$ application can be remunerative and promising combination for boro rice in new alluvial zone.

***Keywords*: *Boro* rice, economics, INM practices, nutrient uptake, yield**

Rice (*Oryza sativa* L.) being the salient crop in terms of food security across the Asia, is also a major source of nutrient and energy in India (Monika, 2013). India ranks first in respect of area of about 43.78 million ha and second in terms of production of about 118.4 million tons, the productivity is very low about 2.70 t ha^{-1} (GOI, 2019) due to various constraints, including poor management of nutrients (Ladha *et al*., 2009). After the Green revolution, undoubtedly chemical fertilizer has taken a major place to increase the production for self-sufficiency in India (Brainerd and Menon, 2014), but the impact of indiscriminate and imbalance application of nutrients has led to huge consequences like, stagnant production (Jain, 2018) and drastic loss of soil health (Chhabra, 2020). Further, substitution of inorganic fertilizers through sole application of organic manures is non-remunerative and is insufficient to achieve the present level of productivity through high yielding varieties as per increasing demand (Yadav *et al.,* 2019). Thus, the adoption of suitable INM is one of the essential considerable options to keep balance with the production of crops in merge with global standards of quantity, quality and sustainability (Selim, 2020).

Moreover, under integrated nutrient management (INM) practice nutrients are being supplied through various inorganic and organic sources to obtain optimum quality production, where chemical fertilizers are supplying primary nutrients in short run, while organic manures release the nutrients over long term (Selim, 2020). Major organic sources of nutrients to the crops which are in vogue are like, farm yard manure (FYM), which is an age-old source of plant nutrients prepared from wastages of crop, dairy *etc*., vermicompost, which is basically cast of earthworms containing major and minor nutrients and growth promoters beneficial for both soil and plant (Kumar *et al*., 2018). Yeast vinasse is a fine black powder obtained as waste from bakery industries and condensed to dry material (Laime *et al.,* 2011), which is now potentially useful as an alternative organic source to supply nutrients for crop production (Mahmoud *et al*.,2019). Zinc, one of the major essential micronutrients for plant growth has been recognized for improving the tillering and dry matter accumulation in rice (Ghatak *et al*., 2005), which ultimately improves the grain production. Therefore, replenishment of such micronutrient in the form of chemical fertilizer should be considered (Dimkpa and Bindraban, 2016). Therefore, a field trial was undertaken to investigate the growth and yield performance, uptake of nutrients and economics of *boro* rice towards different INM practices.

MATERIALS AND METHODS

The trial was executed on medium Gangetic alluvial soil of instructional farm, Bidhan Chandra Krishi Viswavidyalaya, Jaguli, Nadia, West Bengal during *boro* seasons of 2019 and 2020. Analysis of initial soil samples from experimental field recorded that texture was sandy loam with pH of 7.02, organic carbon 0.60%, available nitrogen 185.91 kg ha^{-1}, available phosphorus 37.59 kg ha^{-1}, available potassium 188.16 kg ha^{-1} and zinc 0.61 mg kg^{-1}. Various weather parameters during the exploratory period are addressed in Fig.1.

Email: manimalamahato@gmail.com

The trial was framed in randomized block design comprising of seven treatments *viz*. T_1: 100% RDF (control) *i.e*., 100: 50: 50 kg ha^{-1} of N: P_2O_5:K_2O, T_2: 75% RDF+ 2 t ha^{-1} Vermicompost, T_3: 75% RDF + 2 t ha^{-1} Yeast Vinasse, T_4: 75% RDF+ 5 t ha^{-1} Farm Yard Manure, T_5:75% RDF+ 2 t ha^{-1} Vermicompost + 25 kg ha^{-1} $ZnSO_4$, T_6: 75% RDF + 2 t ha^{-1} Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$ and T_7: 75% RDF+ 5 t ha^{-1} Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$ with three replications. Rest standard agronomic and plant protection practices were followed along with proper irrigation. The seeds of medium duration rice variety Satabdi (IET-4786) were broadcasted at the rate of 50 kg ha^{-1} in nursery on 1st January and transplanted on 9th February in 2019 while in next season seeds were broadcasted in nursey on 27th December, 2019 and seedlings were transplanted on 7th February, 2020 with 20 cm row to row and 15 cm plant to plant distances in 4 m × 3 m plot. Whereas, harvesting was done on 13th May 2019 in 1st season and 9th May 2020 in 2nd season. Application of organic manures like vermicompost, yeast vinasse and FYM were incorporated into soils as per treatments in demarcated plots one week before transplanting and in case of RDF, full dose of P_2O_5 through SSP (Single Super Phosphate) and $ZnSO_4$, one fourth of N through Urea, half of K_2O through MOP (Muriate of Potash) were applied as basal (just before transplanting) and remaining dose of N were top dressed at 21 and 42 DAT split into half and one fourth respectively and remaining half dose of K_2O was top dressed at 21 DAT. Nutrient contents of all the organic sources are presented in Table 1. The parameters like plant height, dry matter accumulation, leaf area index (LAI), panicles no. m^{-2}, test weight, filled grains per panicle, grain and straw yield of rice were observed at harvest. Nutrient contents were estimated by Modified Kjeldhal method for N (Chapman and Pratt, 1961), Molybdophosphoric Blue color method for P (Chapman and Pratt, 1961), Wet digestion (Tri-acid mixture) for K (Jackson, 1973), Di acid mixture (Perchloric acid and Nitric acid mixture in 1: 4 ratio) using atomic absorption spectrophotometer for Zn and nutrients uptake were calculated by multiplying the nutrient content in plants of that treatment with their respective yield. Cost of cultivation, gross returns, net returns and benefit cost ratio were found out to evaluate the production economic viability of *boro* rice under different treatments.

Collected data from field and laboratory were statistically analysed through analysis of variance (ANOVA) and comparison among the treatment means were done using the significance level of $p \leq 0.05$ (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

Growth attributes: The pooled results of the experiment have showed a significant variation of growth attributes of *boro* rice under different treatments. The tallest plant (96.0 cm) was registered under T_5 which was non-significant with T_2 (91.5 cm), T_6 (90.6 cm) and T_7 (93.2 cm), and shortest plant (85.0 cm) was recorded under control treatment at harvest stage (Table 2). This is due to the fact that T_5 is included with 75% of fertilizer recommendation which helps to provide sufficient nitrogen at initial stages and later it is followed by vermicompost which releases nitrogen slowly that helps plant for further stages. Rice being sensitive to Zn deficiency (Rehman *et al*., 2012), subsequently, basal application of $ZnSO_4$ helps to improve plant height due to involvement of Zn in auxin production (Rehman *et al*., 2012). These findings corroborated the results of Sharma *et al*. (2014) and Naveenkumar *et al.* (2019). At 60 DAT, the pooled data recorded that T_5 has shown highest LAI (4.29) which was non-significant with T_2 (4.12), T_4 (4.11), T_6 (4.16) and T_7 (4.20), and lowest LAI was found in control (3.82) (Table 2). Vermicompost and Zn applied in plant might help in enhancing photosynthesis rate by involving in chlorophyll formation, intercellular CO_2 concentration which induces better plant height and leaf area index (Khan *et al.,* 2009 and Niaz *et al.,* 2009). These results were supported by Alloway (2008), Naveenkumar *et al.* (2019) and Ram *et al*. (2020). At harvest, maximum dry matter accumulation (DMA) was found in T_5 treated plots (1131.9 g m^{-2}) which was non-significant with T_2 (1046.4 g m^{-2}), T_6 (1048.7 g m^{-2}) and T_7 (1091.5 g m^{-2}), and minimum was found in control (881.5 g m^{-2}) in pooled data (Table 2). Accumulations of nutrients from vermicompost in plant cell in higher concentration due to slow release over longer period might have lead to higher dry matter (Verma *et al.,* 2018). Moreover, the positive effect of Zn on the biosynthesis of carotenoids and chlorophyll ultimately helped the photosynthetic mechanism and production of assimilates (Aravind and Prasad, 2004). Plants grown in INM had given more DMA compared to chemical plots might be due to leaching, volatilization, fixation and other nutrient loss process. Similar results were discovered by Malik *et al.* (2011) and Naveen kumar *et al.* (2019).

Yield attributes: Different nutrient combinations have also influenced the yield attributes of *boro* rice significantly except test weight. The pooled data reported that highest number of panicles m^{-2} were recorded in T_5 (274.9) which was at par with T_2 (264.7) and T_7 (255.3) while control treatment showed the lowest number (181.43) (Table 3). Moreover, pooled data reported that number of filled grains per panicle was the highest in T_7

Table 1: Nutrient content of different organic sources

Organic sources	N (%)	P_2O_5 (%)	K_2O (%)	Zn (%)
Vermicompost	1.81	1.0	1.22	0.03
Yeast vinasse	1.92	0.49	7.02	0.01
Farm yard manure (FYM)	0.61	0.22	0.40	0.01

Table 2: Effect of INM practices on growth attributes of *boro* rice

Treatments	Plant height at harvest stage (cm)			LAI at 60 DAT			Dry matter production at harvest stage (g m^{-2})		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1- 100% RDF (control)	85.3	84.6	85.0	3.88	3.76	3.82	880.5	882.6	881.5
T_2- 75% RDF+ 2 t ha^{-1} Vermicompost	92.6	90.4	91.5	4.21	4.04	4.12	1039.3	1053.6	1046.4
T_3- 75% RDF+ 2 t ha^{-1} Yeast Vinasse	86.6	87.0	86.8	3.92	3.97	3.94	979.9	994.9	987.4
T_4- 75% RDF+ 5 t ha^{-1} Farm Yard Manure	89.8	90.2	90.0	4.06	4.16	4.11	1018.4	1023.4	1020.9
T_5- 75% RDF+ 2 t ha^{-1} Vermicompost + 25 kg ha^{-1} $ZnSO_4$	96.3	95.6	96.0	4.32	4.26	4.29	1127.1	1136.7	1131.9
T_6- 75% RDF+ 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	91.6	90.2	90.9	4.12	4.19	4.16	1068.5	1028.9	1048.7
T_{7-}-75% RDF+ 5 t ha^{-1} Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	94.1	92.3	93.2	4.27	4.13	4.20	1085.6	1097.4	1091.5
SEm (±)	**2.01**	**1.89**	**1.98**	**0.11**	**0.18**	**0.16**	**30.6**	**31.3**	**30.7**
LSD (0.05)	**6.05**	**5.76**	**5.96**	**0.33**	**0.49**	**0.34**	**92.1**	**93.8**	**92.7**

Table 3: Effect of INM practices on yield attributes of *boro* rice

Treatments	Panicles m^{-2}			Filled grains $panicle^{-1}$			Test weight (g)		
	2019	2020	Pooled	2019	2020	Pooled	2019	2020	Pooled
T_1- 100% RDF (control)	183.2	179.6	181.4	100.8	112.6	106.7	22.6	22.0	22.3
T_2- 75% RDF+ 2 t ha^{-1}Vermicompost	267.0	262.4	264.7	96.4	100.0	98.2	22.4	22.1	22.2
T_3- 75% RDF+ 2 t ha^{-1} Yeast Vinasse	211.9	207.3	209.6	90.8	99.7	95.3	22.3	22.4	22.4
T_4- 75% RDF+ 5 t ha^{-1}Farm Yard Manure	224.1	230.3	227.2	105.1	101.1	103.1	22.5	22.3	22.4
T_5- 75% RDF+ 2 t ha^{-1}Vermicompost + 25 kg ha^{-1} $ZnSO_4$	270.4	279.4	274.9	110.8	121.7	116.3	22.4	22.6	22.5
T_6- 75% RDF+ 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	240.2	248.6	244.4	103.6	112.4	108.0	22.5	22.6	22.6
T_{7-}-75% RDF+ 5 t ha^{-1}Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	251.5	259.0	255.3	116.1	123.7	119.9	22.3	22.0	22.1
SEm (±)	**9.39**	**9.79**	**9.67**	**2.43**	**3.03**	**2.68**	**0.11**	**0.24**	**0.14**
LSD at 5%	**28.6**	**29.7**	**29.3**	**7.30**	**9.21**	**8.16**	**NS**	**NS**	**NS**

(119.9) which was at par with T_5 (116.3) and lowest (95.30) was in T_3 (Table 3). No significant variation was found in test weight among the treatments (Table 3). This was mainly due to genetic factor which governed the test weight, not being influenced largely by the nutrient management. However, the highest and lowest values were registered with T_1 (22.61 g) and T_7 (22.35 g) treatments, respectively.

Better soil physio-chemical and biological properties under organic manure treatments (Verma *et al.* 2018)

Table 4: Effect of INM practices on yield of *boro* rice

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})			Harvest Index (%)		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
T_1-100% RDF (control)	4.00	4.10	4.05	6.01	6.08	6.05	39.9	40.2	40.1
T_2-75% RDF+ 2 t ha^{-1}Vermicompost	4.69	4.73	4.71	6.77	6.70	6.74	41.0	41.1	41.0
T_3-75% RDF + 2 t ha^{-1}Yeast Vinasse	4.27	4.32	4.30	6.51	6.58	6.55	39.8	39.6	39.7
T_4-75% RDF+ 5 t ha^{-1}Farm Yard Manure	4.37	4.45	4.41	6.60	6.64	6.62	39.8	40.1	39.9
T_5-75% RDF+ 2 t ha^{-1}Vermicompost + 25 kg ha^{-1} $ZnSO_4$	5.12	5.18	5.15	7.18	7.27	7.23	41.6	41.6	41.6
T_6-75% RDF + 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	4.59	4.61	4.60	6.80	6.86	6.83	40.2	40.1	40.2
T_7-75% RDF+ 5 t ha^{-1}Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	4.72	4.76	4.74	6.90	6.95	6.93	40.4	40.3	40.4
SEm (±)	**0.16**	**0.27**	**0.19**	**0.14**	**0.23**	**0.18**	**0.42**	**0.51**	**0.45**
CD at 5%	**0.48**	**0.61**	**0.53**	**0.42**	**0.51**	**0.48**	**1.30**	**1.48**	**1.36**

Table 5: Effect of INM practices on total uptake of nutrients by *boro* rice

Treatments	N (kg ha^{-1})			P (kg ha^{-1})		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
T_1-100% RDF (control)	64.5	60.4	62.4	8.7	8.94	8.86
T_2-75% RDF+ 2 t ha^{-1}Vermicompost	84.1	79.9	82.0	13.5	15.4	14.5
T_3-75% RDF + 2 t ha^{-1}Yeast Vinasse	72.2	76.4	74.3	10.6	11.5	11.1
T_4-75% RDF+ 5 t ha^{-1}Farm Yard Manure	75.9	79.7	77.8	9.07	10.6	9.85
T_5-75% RDF+ 2 t ha^{-1}Vermicompost + 25 kg ha^{-1} $ZnSO_4$	87.8	90.4	89.1	14.2	16.0	15.1
T_6-75% RDF+ 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	80.8	84.0	82.4	11.1	12.0	11.5
T_7-75% RDF+ 5 t ha^{-1}Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	85.2	86.9	86.1	12.5	14.4	13.5
SEm (±)	**2.79**	**3.02**	**2.88**	**0.64**	**0.87**	**0.80**
CD at 5%	**8.39**	**9.01**	**8.70**	**1.93**	**2.36**	**2.20**

Table 6: Effect of INM practices on total uptake of nutrients by *boro* rice

Treatments	K (kg ha^{-1})			Zn (kg ha^{-1})		
	2019	**2020**	**Pooled**	**2019**	**2020**	**Pooled**
T_1-100% RDF (control)	160.4	163.9	162.2	0.57	0.58	0.57
T_2-75% RDF+ 2 t ha^{-1}Vermicompost	163.7	166.3	165.0	0.71	0.71	0.71
T_3-75% RDF+ 2 t ha^{-1}Yeast Vinasse	186.7	189.4	188.0	0.60	0.59	0.59
T_4-75% RDF+ 5 t ha^{-1}Farm Yard Manure	154.6	155.6	155.1	0.67	0.66	0.67
T_5-75% RDF+ 2 t ha^{-1}Vermicompost + 25 kg ha^{-1} $ZnSO_4$	182.4	184.0	183.2	1.11	1.10	1.11
T_6-75% RDF+ 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	190.5	192.6	191.5	0.99	0.99	0.99
T_7-75% RDF+ 5 t ha^{-1}Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	171.0	173.0	172.0	1.07	1.07	1.07
SEm (±)	**3.30**	**3.68**	**3.51**	**0.02**	**0.03**	**0.02**
CD at 5%	**10.1**	**10.9**	**10.50**	**0.07**	**0.09**	**0.08**

Table 7: Production economics of *boro* rice under different INM treatments (Pooled)

Treatment	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	BCR
T_1-100% RDF (control)	48851	73005	24254	1.49
T_2-75% RDF+ 2 t ha^{-1}Vermicompost	56570	85985	29415	1.52
T_3-75% RDF+ 2 t ha^{-1}Yeast Vinasse	60768	77980	17212	1.28
T_4-75% RDF+ 5 t ha^{-1}Farm Yard Manure	52558	79775	27217	1.51
T_5-75% RDF+ 2 t ha^{-1}Vermicompost + 25 kg ha^{-1} $ZnSO_4$	60536	93190	32654	1.55
T_6-75% RDF+ 2 t ha^{-1}Yeast Vinasse + 25 kg ha^{-1} $ZnSO_4$	64734	83700	18966	1.30
T_7-75% RDF+ 5 t ha^{-1}Farm Yard Manure + 25 kg ha^{-1} $ZnSO_4$	56524	85525	29001	1.51

Price of paddy: Rs.17.50/kg and Straw: Rs.0.50/kg; Input: Urea- Rs 7/kg, SSP-Rs.9/kg, MOP- Rs. 17/kg, $ZnSO_4$- Rs 50/kg, FYM-Rs.-1/kg, Vermicompost- Rs. 4.5/kg and Yeast Vinasse- Rs.-6.5/kg, mandays-Rs.328

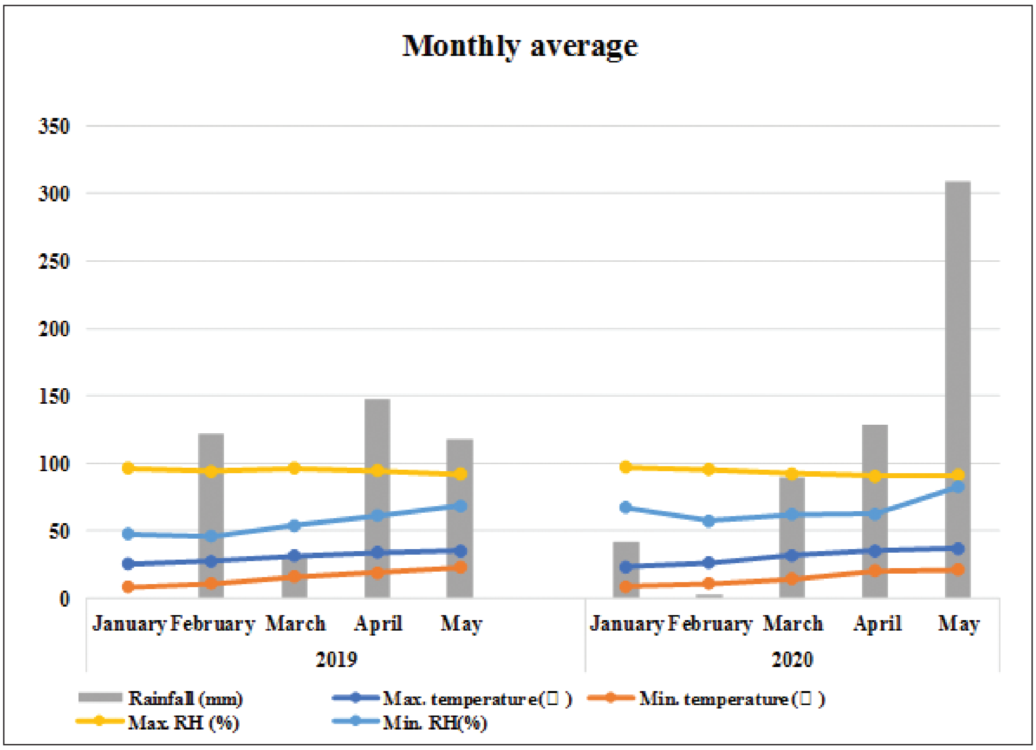

Fig 1: Meterological data during the experiment of 2019 and 2020

have facilitated the greater availability of nutrients and more photosynthates to develop reproductive structures which resulted in increased yield attributes under integrated nutrient management. Further, the positive effect of Zn on grain setting and grain development was reported by Maralian (2009) and Muthukumararaja and Sriramachandrasekharan(2012) . The results were found similar with the findings of Barik *et al.* (2008), Sharma *et al.* (2008), Hossaen *et al.* (2011) and Naveenkumar *et al.* (2019).

Yield: Significant influence on grain yield and stover yield in *boro* rice was found under various integrated nutrient management treatments during both the years of experimentation. Pooled data showed that the significant highest grain yield was obtained under T_5 (5.15 t ha^{-1}) followed by T_2 (4.71 t ha^{-1}) T_7 (4.74 t ha^{-1}) and significant lowest grain yield (4.05 t ha^{-1}) was recorded in control plot (Table 4). Similarly, the maximum straw yield was found under T_5 (7.23 t ha^{-1}), followed by T_6 (6.83 t ha^{-1}) and T_7 (6.95 t ha^{-1}). However, 100% RDF (control) showed the minimum straw yield (6.05 t ha^{-1}) (Table 4). Variation among grain and straw yield owing to variation in harvest index among the treatment was found and T_5 exhibited the maximum harvest index (41.6%), which was non-significant with T_2 (41.0 %) and T_7 (40.4 %) (Table 4). Increased grain yield of rice under

T_5 treatment was due to significant increase in yield components like number of panicles m^{-2} and number of filled grains per panicle. The results confirmed the findings of Chaudhary *et al.* (2007), Ghoneim (2016) and Naveenkumar *et al.* (2019). Accumulation of more protoplasmic constituents, accelerated cell elongation and division process might have increased the straw yield due to greater nutrient availability through inorganic and organic sources along with micronutrient. The similar results were reported by Biranvand *et al.* (2010) and Koushal *et al.* (2011).

Nutrient uptake: Integrated nutrient management practices had significant effect on uptake of nutrients (N, P, K, and Zn). The plants from T_5 plot showed highest uptake of N (89.1 kg ha^{-1}) followed by T_7 (86.1 kg ha^{-1}), T_6 (82.4 kg ha^{-1}) and T_2 (82.0 kg ha^{-1}) and the lowest uptake was registered in 100% RDF (control) (62.4 kg ha^{-1}). In case of phosphorus maximum uptake was found in T_5 (15.1 kg ha^{-1}), followed by T_2 (14.5 kg ha^{-1}) and T_7 (13.5 kg ha^{-1}) and the minimum uptake in control (8.86 kg ha^{-1}). Whereas, maximum potassium uptake was registered under T_6 (191.5 kg ha^{-1}), which was statistically at par with T_3 (188.0 kg ha^{-1}) and T_5 (183.2 kg ha^{-1}) but significantly higher than other treatments. Significantly highest Zn uptake was registered in T_5 (1.11 kg ha^{-1}) followed by T_7 (1.07 kg ha^{-1}).

The higher uptake of nutrients (N, P, K, and Zn) with the combined application of organic and inorganic sources of nutrients compare to inorganic source alone (control) was attributed to proportionate increase in dry matter and biomass production (grain+straw) which ultimately increased the total uptake of nutrients. It might be due to organic manure being the store house of nutrients, released nutrients slowly at its optimum and at the same time improved the physio-biological conditions of soil, thereby promoted the availability and absorption of nutrients by the crop (Mahato *et al.*, 2020). Coulibaly (2018) reported that greater Phosphorus uptake was found in grain and straw due to vermicompost which might have helped to solubilize the native phosphorus.

Higher uptake of K in yeast vinasse treated plots was due to high K content of this organic matter (Rajagopal *et al.*, 2014 and Mahmoud *et al.*, 2019). Further, the soil application of $ZnSO_4$ in organic manure treated plots might form the Zn-organic chelate which in turn increased the availability and uptake of Zn due to its steady release from chelating compounds synchronizing with crop requirement (Phattarakul *et al.*, 2012).

Economics: Different INM practices had significant effect on economics of *boro* rice during both the years of experimentation. However, significant highest gross return (Rs.93190 ha^{-1}), net return (Rs.32654 ha^{-1}) and benefit-cost ratio (1.55) was recorded in T_5 as compared to other INM practices. It might be due to the fact that application of nutrients in integrated manner increases the grain and stover yields. While, higher price of yeast vinasse, lower net return and benefit-cost ratio were obtained from this organic material treated plots The other treatments in terms of better economic benefits were T_2 (1.52), T_4 (1.51) and T_7 (1.51). The similar economic benefits were reported by Koushal *et al.* (2011) and Naveenkumar *et al.* (2019).

Based on the above findings, the application of 75% RDF along with 2 t ha^{-1} vermicompost and 25 kg ha^{-1} $ZnSO_4$ can be advised for obtaining better yield and economic returns. Moreover, reduction of 25% chemical fertilizers by addition of organic manure may have long-term benefits on maintaining soil health, sustaining production and reducing environmental pollution.

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