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Evaluating integrated nutrient management practices on yield and yield attributes of transplanted *Boro* rice (*Oryza sativa* L.)

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Abstract
Two years field experiment was conducted during *boro* season of 2022-2024 to study the effect of organic and in-organic nutrient application in transplanted *boro* rice on yield and yield attributing characters in the Agricultural Experimental Farm of University of Calcutta, Baruipur, West Bengal, India. Integrated nutrient practices in cultivation is essential to keep the soil healthy for sustaining production as addition of organic nutrients more than that of synthetic fertilizers increase the organic carbon level of soil thus keeps the soil fit for crop production. There were ten treatments performed in randomized block design replicated thrice consisting of 50% RDF NPK+FYM 5 t ha^{-1}, 75% RDF NPK+FYM 5 t ha^{-1}, 50% RDF NPK+FYM 7 t ha^{-1}, 75% RDF NPK+FYM 7 t ha^{-1}, 50% RDF NPK+Vermicompost 2 t ha^{-1}, 75% RDF NPK+Vermicompost 2 t ha^{-1}, 50% RDF NPK+Vermicompost 3 t ha^{-1}, 75% RDF NPK+Vermicompost 3 t ha^{-1}, 100% RDF NPK (120:60:60) and Control plot. The results from pooled analysis indicated that 75% RDF NPK+Vermicompost 3 t ha^{-1} indicated best yield attributing characters along with highest grain and straw yield also best biological yield and harvest index was obtained. The control plot revealed lowest yield and yield attributing characters. 100% NPK of RDF also showed good result compared to other integrated nutrient practices where as least result was obtained from 50% RDF NPK+FYM 7 t ha^{-1} and 50% RDF NPK+FYM 5 t ha^{-1}.

Keywords: Boro rice, harvest index, randomized block design, vermicompost

1. Introduction
Rice is among one of the ancient grain cultivated since time immemorial. It is one of the instant energy giving food with less content of protein 6-7% and carbs percent ranging 72-75%. It is also known as “Global Grain” due to its cultivation in about 117 countries (Bhosale and Jondhale, 2019) [7]. About 20% of the dietary energy and protein is alone supplied by rice in developing world. Among all other continents, Asia is the largest producer and consumer of rice which is about 90% of the world’s rice production. Compared to other countries, India has the largest rice growing area of 44 m ha with 131 mt of production ranking second in position after China (Govindan and Chinnusamy, 2014) [14]. Rice contributes a major portion of food grain in national food grain supply with 43-46% of total cereal and food grain produced in the country. In India it is cultivated between 8° to 34° N latitude. West Bengal ranks first in area and production and Punjab ranks first in productivity. It can be a major key to attain sustainable development goal in zero hunger (Das *et al.*, 2019) [11]. With the rapidly growing population, the production and productivity of rice need to be raised by 50% from the present condition to fulfill the food grain demand. Among nutrients, nitrogen is very important for rice as it directly influences yield in irrigated rice. Usage of high dose of chemical fertilizer in order to increase yield and productivity under intensive cropping system, the soil organic content is deteroiting day by day. The use of chemical fertilizer on large scale started after the green revolution to gain adequate grain production but due to inappropriate and overuse use of synthetic fertilizers resulted in poor soil health and non-increment in yield (Jain, 2018 and Chhabra 2020) [16, 9].

Deficiency of micro-nutrients, soil-water contamination and changes in soil physio-chemical properties are also observed due to excessive use of and injudicious use of chemical fertilizers. Another factor is that use of low dose of nutrients tends to decrease the level of nutrients in the soil which may affect to attain the production level on a huge scale. The tendency of Indian farmers is to apply more amounts of nitrogenous fertilizers in an improper ratio with potassic and phosphatic fertilizer to increase the yield of paddy. The farmers are merely using organic soil nutrients as they are fully relying on inorganic nutrients only. Both organic and chemical fertilizers must be used to achieve required yields and the soil for cropping will also be enriched with optimum amount of necessary nutrients resulting in better and maintained soil health. The wetland paddy with high grain yield quality tend to uptake a good amount of macro and micro soil nutrients in order to produce better yield and if deficiency of any nutrient occurs then it will result in low yield (Pawar *et al.,* 2017; Shankar *et al.,* 2018) [27, 37]. Application of major organic sources like farmyard manure, vermicompost, poultry manure etc are being given value today for improving soil health. Different organic and chemically synthesized sources of nutrients ameliorate the soil physical, chemical and biological properties of soil and also improve porosity and enzymatic activity. The use of farmyard manure as a source of organic nutrient for crops not only adds nutrients but also increases the population of essential soil microbes. Vermicompost, farmyard manure, BGA (Blue Green Algae) applied with 75% and 50% recommended dose of NPK enhances the population of Actinomycetes due to the release of extracellular nitrogen substance and fixation of atmospheric nitrogen than sole application of inorganic sources of NPK (Bharose *et al.*, 2017) [5]. Presently, when sustainability of the crop and soil productivity is the recent issue, the integrated use of organics and in-organics needs to be highlighted to use nutrient and energy more productively than conventionally managed system (Madar *et al.*, 2002; Blaise and Prasad, 2005).
Considering all the points in view, the experiment was conducted at the Experimental Farm of University of Calcutta situated at Baruipur, West Bengal during boro season of 2022-2023 and 2023-2024 (December-April) on Gangetic alluvial soil condition.

2. Materials and Methods

2.1. Experimental period and location

The experiment was conducted during the boro season of 2022-2023 and 2023-2024 (December to April) to investigate “Effect of organic and inorganic nutrient management in transplanted summer rice under Gangetic alluvial soils of West Bengal” at the University of Calcutta Agricultural Experimental Farm located at Baruipur, West Bengal (22º22´ N, 88º26´ E) and 9 m latitude. The topography of the experimental plot was low land, more or less uniform with a drainage condition. The soil was medium fertile, clay loam in texture and slightly acidic in reaction representative of the new Gangetic alluvial soil of West Bengal. The physio-chemical properties of soil consisted of sand (26.6%), Silt (31.8%), Clay (41.6%). The available nitrogen, phosphorus and potassium was (176.07, 31.78, 261.31) kg ha^{-1} and the organic carbon content was 0.85 respectively. The meteorological data showed an average temperature of 14.50 ºC-38.17 ºC and average rainfall of 0.5 mm-34 mm.

2.2 Design of the experiment with treatment details

The experiment was laid out in a Randomized Block Design (RBD) replicated thrice with ten treatments. The treatment details were as follows: T_1-50% RDF NPK+FYM 5 t ha^{-1}, T_2-75% RDF NPK+FYM 5 t ha^{-1}, T_3-50% RDF NPK+FYM 7 t ha^{-1}, T_4-75% RDF NPK+FYM 7 t ha^{-1}, T_5-50% RDF NPK+Vermicompost 2 t ha^{-1}, T_6-75% RDF NPK+Vermicompost 2 t ha^{-1}, T_7-50% RDF NPK+Vermicompost 3 t ha^{-1}, T_8-75% RDF NPK+Vermicompost 3 t ha^{-1}, T_9-100% RDF NPK (120:60:60) kg/ha and T_{10}-Control plot. The variety used was MTU-1153 (Chandra) a non-aromatic paddy cultivar transplanted after 40 days from nursery to main field with spacing of (20 × 20) cm during the 2nd week of January in fine puddled soil and harvested during the second week of April. Irrigation was provided as required and twice hand-weeding was undertaken. The required organic fertilizer was applied 5 days before transplanting and the inorganics *viz*., urea, SSP and MOP were broadcasted treatment wise where SSP and MOP in full dose before transplanting along with 25% urea as basal and rest 50% and 25% at tillering stage and panicle initiation stage. The recommended dose of fertilizer (120, 60 and 60) kg ha^{-1} of N, P_2O_5 and K_2O was used.

2.3. Package and practices

The recommended dose of fertilizer (120, 60 and 60) kg ha^{-1} of N, P_2O_5 and K_2O was used. The required organic fertilizer as per treatment was applied 5 days before transplanting and the inorganics *viz*., urea, SSP and MOP were broadcasted treatment wise where SSP and MOP in full dose before transplanting along with 25% urea as basal and rest 50% and 25% at tillering stage and panicle initiation stage.

2.4. Observations recorded

The yield attributing characters such as effective tillers hill^{-1}, panicle length, spikelets panicle^{-1}, filled grains panicle^{-1}, unfilled grains panicle^{-1}, sterile grain%, test weight was recorded at harvest and calculated. The yield components like grain and straw yield, biological yield and harvest index was measured and calculated in hectare. The pooled data from two experimental seasons are presented.

2.5. Statistical analysis

Analysis of Variance (ANOVA) for RBD was used for data analysis by following the procedure laid out by Gomez and Gomez, 1984 [13]. The data from both the seasons were pooled and analysed using combined analysis of variance (pooled ANOVA) to find the effect of treatments across seasons and if any interactions present. The pooled analysis was calculated using LSD at p=0.05 level of significance through SPSS software package. With the help of Fisher and Snedecor’s F-test at probability level of 0.05 the significance of different sources of variations were tested. The critical difference at 5% level of significance was determined by statistical table’s formulation by Fisher and Yates. The standard error of mean and the value of C.D. at p=0.05 level of significance was indicated in the tables (1 and 2) of the results to compare the difference between the mean values.

3. Results and Discussion

3.1. Yield attributes

From table 1 the effective tiller production m-2 at harvest showed highest in treatment with T_8 (75% RDF of NPK+Vermicompost 3 t ha^{-1}) (313.33) tillers m 2. Application of 75% RDF of NPK+Vermicompost 2 t ha^{-1} (306.67) tillers m^{-2} was found to be next of 75% RDF NPK+Vermicompost 3 t ha^{-1}. Application of 100% RDF of NPK-(297.50) tillers m^{-2} occupied the third position in order of merit in exhibiting tiller production.

50% RDF of NPK either with FYM 7 t ha^{-1} or FYM 5 t ha^{-1} was found to be inferior to other integrated nutrient management practices for exhibiting tiller production. The T_{10}-(Control plot)-(172.50) tillers m^{-2} at harvest showed minimum effective tiller production with advancement in maturity.Various metabolites secreted by earthworms are responsible for promoting tillering in rice crop. The nutrient supplied from vermicompost is readily available for absorption and utilization of crop. Similar findings were recorded by (Hasanuzzaman *et al.*, 2010; Bi *et al.*, 2012; Fageria, 2014; Bhatt *et al.*, 2017 and Jana *et al.*, 2020) [15, 8, 12, 6, 17].

The panicle length of rice as affected by integrated nutrient management showed significant variation. From table 1 the treatment with T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(24.46) cm showed significant increase in panicle length over other integrated nutrient management practices. Similarly, application of 75% RDF of NPK+Vermicompost 2 t ha^{-1}-(24.30) cm registered greater panicle length of rice over other nutrient treatments. Rice treated with 100% RDF of NPK-(23.97) cm also recorded higher panicle length of rice. The T_{10}-(Control plot)-(20.37) cm showed shorter panicle length in rice compared to other treatments.The balanced supply of nitrogen and other micro nutrients through organics in combination with inorganics helped in greater cell division, improved photosynthetic rate throughout the growth period that promoted larger length of panicles. Such can be corroborated with the findings of (Meena *et al.*, 2013, Reddy and Kumar 2006, Shankar and Laware 2011, and Barik *et al.*, 2006) [24, 32, 36, 2].

The total number of spikelets as influenced by different nutrient management practices from table 1 showed that the treatment with application of T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(179.77) indicated highest amount of spikelets panicle^{-1} whereas, treatment with non- application of nutrients in T_{10}-(Control plot)-(152.07) spikelets panicle^{-1} showed lowest count. The improvement in spikelets panicle^{-1} in 75% RDF of NPK+Vermicompost 3 t ha^{-1} might be due to integrated nutrient practices that provided conducive environment necessary for the rice crop to increase the spikelet count through proper nutrient conversion and absorption from the soil, whereas the plot without application of any nutrients showed lesser spikelet count compared to other treated plots due to absence of essential nutrients to the rice crop. Such finding was reported by (Kumar *et al.*, 2017).

The number of filled grains panicle^{-1} as influenced by integrated nutrient management from table 1 showed significant variation. The treatment with T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(159.67) recorded highest amount of filled grains panicle^{-1} on the other hand, the treatment with 50% RDF of NPK either with FYM 5 t ha^{-1} or FYM 7 t ha^{-1} recorded lowest number of filled grains per panicle. The T_{10}-(Control plot) produced lowest filled grains panicle^{-1}-(112.83). Organic fertilizers have the potency in uplifting the crops yield as they consist required amount of most of the essential plant nutrients. Increasing number of grains in each panicle might be due to improved photosynthesis process finally resulting towards proper supply of photosynthates from the source to the sink (grain). These results are well corroborated with the findings of (Bhatt *et al.*, 2017; Jana *et al.*, 2020; Nowshin *et al.*, 2020 and Sathiya *et al.*, 2009) [6, 17, 26, 34].

Unfilled grains panicle^{-1} from the experimental result in table 1 revealed that through the integrated nutrient management practices adopted in rice showed that T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(20.10) with lowest amount of unfilled grains per panicle where as the control plot with no nutrient management practice resulted in highest unfilled grains per panicle T_{10}-(Control plot)-(39.23). The highest number of unfilled grains was recorded in control plot due to nil application of any nutrient management practices which might have created a barrier for the rice crop to develop more filled grains like rest of the treatments. Without application of any nutrient, a nutrient crisis might have developed in the plant system due to which a greater number of unfilled grains was produced. The nitrogen supplied through the integrated nutrient treatments provided the crop with essential nutrients at slower pace along with other growth promoters, enzymes etc. which led to filling up of grains more in number. Such findings were also reported by (Barik *et al.*, 2006 and Norman *et al.*, 2005) [2, 25].

The data from the table 1 showed that maximum percentage of unfilled grain was recorded in T_{10}-(Control plot) with (25.83%) due to non-application of nutrient. The effect of application of integrated nutrient management practices in treat ment with T_8-(75% NPK of RDF+Vermicompost 3 t ha^{-1})-(11.19%) recorded lowest percentage of unfilled grain. The treatment with 50% RDF of NPK with either FYM 5 t ha^{-1} or FYM 7 t ha^{-1} produced more amount of unfilled grain percentage of over 75% RDF of NPK+Vermicompost 3 t ha^{-1}. The effect of integrated nutrient management practices revealed that all the treatments have less significant variation. The application of integrated nutrient provided enough food to the crop to convert them into filled grains whereas in control plot though soil contains its own nutrient but the crop was not able to uptake the required amount of nutrient from soil for producing filled grains as most of nutrients may be in unavailable for the crop to uptake. Similar findings were reported by (Singh *et al.*, 2010) [38].

The treatment with T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(22.78) g gave highest test weight as indicated in table 1 which was found to be statistically at par with T_6-(75% RDF+ Vermicompost 2 t ha^{-1}), T_9-(100% RDF of NPK) and T_7-(50% RDF+Vermicompost 3 t ha^{-1}) while significant difference was found with other treatments. The treatment with application of 50% RDF of NPK either with 5 t or 7 t FYM ha^{-1} recorded lower test weight compared to 75% RDF of NPK+Vermicompost 3 t ha^{-1} and other treatments whereas the T_{10}-(Control plot)-(20.10) g produced lowest test weight.Test weight in rice is an important factor for analyzing yield of rice. Through integrated nutrient management practices, the grain weight was affected causing the grain weight to increase in 75% RDF of NPK+Vermicompost 3 t ha^{-1} due to supply of nitrogen and other nutrients in slower pace from vermicompost and inorganic RDF constantly to the rice crops further increasing photosynthetic activity in leaves and better translocation of photosynthates from leaves to grain. Similar findings were corroborated with (Maurya *et al.*, 2016; Rathwa *et al.*, 2018) [23, 31].

Table 1: Effect of organic and inorganic nutrient management on yield attributes of transplanted *boro* rice (2 years Pooled value):

Treatments	Effective tiller m^{-2}	Panicle Length (cm)	Spikelets Panicle^{-1}	Filled Grains panicle^{-1}	Unfilled grains panicle^{-1}	Sterility (%)	Test Weight (g)
T_1	266.67	22.31	158.13	124.60	33.87	21.38	21.25
T_2	277.50	23.29	162.8	132.63	30.17	18.53	21.61
T_3	272.50	22.67	160.97	129.20	31.77	19.72	21.38
T_4	293.33	23.81	170.80	144.03	26.77	15.67	21.80
T_5	280.83	23.52	164.07	135.13	28.93	17.65	21.77
T_6	306.67	24.30	176.03	154.03	22.00	12.51	22.13
T_7	295.83	23.88	171.27	145.53	25.73	15.04	21.91
T_8	313.33	24.46	179.77	159.67	20.10	11.19	22.78
T_9	297.50	23.97	172.00	147.03	24.97	14.53	21.99
T_{10}	172.50	20.37	152.07	112.83	39.23	25.83	20.10
SE m (±)	5.98	0.49	3.51	2.94	0.63	0.38	0.32
CD at 5%	17.04	1.39	10.00	8.39	1.81	1.09	0.91

Notations- T_1- 50% RDF NPK+FYM 5 t ha^{-1}, T_2- 75% RDF NPK+FYM 5 t ha^{-1}, T_3- 50% RDF NPK+ FYM 7 t ha^{-1}, T_4- 75% RDF NPK+FYM 7 t ha^{-1}, T_5- 50% RDF NPK+Vermicompost 2 t ha^{-1}, T_6- 75% RDF NPK+Vermicompost 2 t ha^{-1}, T_7- 50% RDF NPK+Vermicompost 3 t ha^{-1}, T_8- 75% RDF NPK+Vermicompost 3 t ha^{-1}, T_9- 100% RDF NPK (120:60:60) kg ha^{-1} and T_{10}- Control plot.

3.2. Yield

The grain yield of rice expressed in terms of t ha^{-1} as influenced by various nutrient management. The result of rice in terms of ton-ha indicated significant variation due to different treatments employed. The table 2 indicates that the grain yield obtained under 75% RDF of NPK+Vermicompost 3 t ha^{-1} surpassed the yields obtained under different nutrient application treatments. The yield obtained under 75% RDF+Vermicompost 3 t ha^{-1}-(6.07) t ha^{-1} showed significant higher yield over other nutrient management treatments and the control plot T_{10} showed lowest grain yield of (2.94) t ha^{-1}. Application of organic and inorganic in combination enhances the physical, chemical and biological condition of soil healthy on the other hand supplying nutrients to the crop progressively but in a steady way. Synthetic fertilizers combined with organic manures provided best yield as inorganic fertilizers enables macro and micronutrient absorption and processes like carbon assimilation, photo-synthesis, starch formation, transfer of protein and sugar, water entry into crop for root development. Similar finding was observed by (Senthamizhkumaran *et al.*, 2021; Kundu, 2012; Chowdhury, 2015 and Pradhan, 2019) [35, 21, 10, 29].

The straw yield expressed in t ha^{-1} revealed that integrated nutrient management practices showed good influence on straw yield in respect to different doses of nutrient application. From the table 2 it is clearly observed that the treatment with T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1}) showed highest straw yield of (7.65) t ha^{-1} while the control plot revealed lowest straw yield of T_{10}-(Control plot)-(4.22) t ha^{-1} due to balanced application of NPK to the rice crops. Organic manures improved physical and chemical properties of soil contributing towards utilization of nutrients more efficiently by the crops. Such observation was recorded by (Swarup and Yaduvanshi, 2006; Rani and Srivastava, 1997; Narwal and Chaudhary, 2006; Bhandari *et al.*,1992 and Kadiyala *et al.*, 2012) [39, 30, 4, 18].

From the data of table 2 it was revealed that T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(13.71) t ha^{-1} showed highest biological yield followed by 75% RDF of NPK+ Vermicompost 2 t ha^{-1}-(13.38) t ha^{-1} and 100% RDF of NPK-(12.86) t ha^{-1}. The lowest biological yield was observed in T_{10}-(Control plot)-(7.16) t ha^{-1}. Such increase in biological yield was due to integration of chemical fertilizer with other integrated nutrient management practices which might helped in luxuriant growth of crop and enhanced yield production of crop and increasing the efficiency of the rice crop for optimal nutrient usage, the combination of which ascribed to enhanced biological yield. Certain reduced quantity of biological yield under other treatments may be accounted for reduction in dry matter and economical yield of grain. The combined product of which resulted in decreased biological yield. Similar results could be corroborated with that of (Barik *et al.*, 2011; Singh *et al.*, 2011; Balasubramanian and Wahab, 2012; Singh and Dhar, 2011 and Polthanee *et al.*, 2008) [3, 38, 1, 38, 28].

As per the result it was observed from table 2 that T_8-(75% RDF of NPK+Vermicompost 3 t ha^{-1})-(44.24)% revealed best result among all other treatments followed by 75% RDF of NPK+Vermicompost 2 t ha^{-1}-(43.71)% and 100% RDF of NPK-(43.27)%. The treatment with 50% RDF of NPK either with 7 t or 5 t FYM ha^{-1} showed least harvest index with lowest harvest index in T_{10}-(Control plot)-(41.05)%. The application of integrated nutrient management enhanced the available soil nutrients for the uptake by rice crop to produce healthy grains and overall yield through different physio-chemical and biological process that resulted in attaining highest harvest index in treatment with 75% RDF of NPK+Vermicompost 3 t ha^{-1}. Similar findings were observed by (Chandrika *et al.*, 2024; Khairnar *et al.*, 2011; Khursheed *et al.*, 2013 and Swarup and Yaduvanshi *et al.*, 2013) [19, 20, 40].

Table 2: Effect of organic and inorganic nutrient management on yield of transplanted *boro* rice (2 years Pooled value):

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest Index
T_1	4.68	6.56	11.24	41.60
T_2	4.99	6.84	11.83	42.20
T_3	4.86	6.73	11.59	41.90
T_4	5.45	7.19	12.64	43.12
T_5	5.09	6.92	12.01	42.44
T_6	5.85	7.53	13.38	43.71
T_7	5.51	7.24	12.74	43.22
T_8	6.07	7.65	13.71	44.24
T_9	5.57	7.29	12.86	43.27

T_{10}	2.94	4.22	7.16	41.05
SE m (±)	0.11	0.15	0.25	0.35
CD at 5%	0.31	0.42	0.73	0.99

Notations- T_1- 50% RDF NPK+FYM 5 t ha^{-1}, T_2- 75% RDF NPK+FYM 5 t ha^{-1}, T_3- 50% RDF NPK+ FYM 7 t ha^{-1}, T_4- 75% RDF NPK+FYM 7 t ha^{-1}, T_5- 50% RDF NPK+Vermicompost 2 t ha^{-1}, T_6- 75% RDF NPK+Vermicompost 2 t ha^{-1}, T_7- 50% RDF NPK + Vermicompost 3 t ha^{-1}, T_8- 75% RDF NPK+Vermicompost 3 t ha^{-1}, T_9- 100% RDF NPK (120:60:60) kg ha^{-1} and T_{10}- Control plot.

4. Conclusion

75% RDF of NPK+Vermicompost 3 t ha^{-1} manifested to be most effective in attaining best yield attributes and yield in transplanted boro rice through supply of proportionate amount of plant nutrients to the rice crop. Other treatment such as 75% RDF of NPK+Vermicompost 2 t ha^{-1} and 100% RDF of NPK also showed better result in all aspects compared to 75% RDF of NPK+Vermicompost 3 t ha^{-1}. The integrated nutrient practices could sustain crop productivity and maintain soil health through restoring the fertility level leading to sustainable crop production.

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