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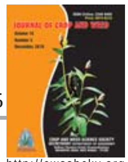

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Enhancement in rice production as influenced by cropping systems and integrated nutrient management in New Alluvial Zone of West Bengal

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ABSTRACT

An experiment was conducted at Central Research Farm, BCKV, Nadia during 2017 and 2018 with three cropping systems- i) Rice -Rapeseed - Fodder cowpea (C1), ii) Rice - Field pea - Fodder cowpea (C2); iii) Rice - Wheat - Fodder cowpea (C3) and five integrated nutrient managements i) 100% Recommended dose of Fertilizers (RDF) through chemical fertilizer (CF) (N1), ii) 75% RDN through CF +25% N through FYM+ 100% RD of PK through CF (N2), iii) 75% RDN through CF +25% N through Biogas Slurry + 100% RD of PK through CF (N3), iv) 75% RDN through CF +25% N through Vermicompost + 100% RD of PK through CF (N4) and v) 75% RDN through CF +25% N through Azolla+ 100% RD of PK through CF (N5).The experiment was designed in strip plot design with three replications and nutrition wasgiven to rice, rapeseed, field pea and wheat, whereas fodder cowpea was grown in the residual fertility. Nutrients uptake and yield was highest when leguminous crop field pea was incorporated in the cropping system (C2) and use of FYM (N2) alongside chemical fertilizer gave higher number of panicles, grains panicle^{-1} and grain yield (5.08 t ha^{-1}).Influence of chemical fertilizer alone or with biogas slurry were statistically at par with N2 whereas least performance was recorded in vermicompost and azolla.Regarding the interaction effect, better performance was obtained in treatment combination C2N2in respect of nutrient uptake and yield.

***Keywords*: Cropping system, INM, organic manure, rice**

Rice is the main staple crop among cereals in south-west Asia. In India, it is cultivated throughout the country, except few dry areas. However the Indo-Gangetic plain holds the title as most important rice growing belt. The muddy soils capable of holding enough water hold the advantage of cultivating rice over other areas. During rainy season rice is cultivated in 433.88 lakh ha areas and consume around 1.227 MT of chemical fertilizer in West Bengal during 2015-16. The use of chemical fertilizer in Indian agriculture is increasing progressively since its inception. For a profitable return, farmers are applying chemical fertilizers at the rate far beyond its recommended dose. However they are unable to understand the negative impact these type of malpractice. Decreasing soil health and crop production in the long run resulting from inorganic fertilizer was reported by various scientists viz. Barak *et al*., (1997); Guo *et al*. (2010) and Savci, (2012). Leaching and run-off loss of inorganic nutrients pose acute problem of water-body eutrophication (Hessen *et al*., 1997). Thus society faces both environmental and economic threat.

The integrated nutrient management of crops helps us to find a suitable management practice which is profitable as well as sustainable for the environment (Nambiar, 1997; Zaman *et al*., 2002). It combines all possible sources of nutrient viz. organic, inorganic and biofertilizer and helps us to achieve our goal in a sustainable manner (Islam *et al*., 2011; Sood, 2007; Mahendran and Chandramani, 1998; Singh and Lal, 2006). The organic source of nutrients such as farm yard manures (FYM), vermicomposts, green manures etc. are rich in carbonaceous compounds (Gagnon *et al*., 2001andNemati *et al*., 2000). They not only provide the nutrient, but also play an important role in soil health improvement (Bhuyian *et al*., 1994; Zamanet al., 2002; Ghosh *et al*., 2007; Kumar *et al*., 2005). However their field requirement is quite high due to lower concentration of nutrients as compared to inorganic fertilizers. The inorganic fertilizers, being very concentrated in nutrients are required in lesser quantity (Chen, 2006). Though their requirement is less, negative impact from excessive use of inorganic fertilizer has been reported elsewhere (Khan *et al*., 2008). Fertile soils are prerequisite for higher crop yield. Thus we have to find a possible proportion of organic as well as inorganic which not only gives profitable return, but protects out soil form further degradation.

Legume crops are beneficial to agriculture. They fix atmospheric inorganic nitrogen and release them in soil (Crews *et al.*, 2004 and references therein), thus cutting a significant proportion of nitrogenous fertilizer application (Stern, 1993). However their cultivation in Gangetic alluvium belt has been declined considerably (Johansen *et al.*, 2000). Farmers prefer cereals and oil seeds over legumes to maintain their lifestyle. However, if incorporated in the cropping sequence there is a chance further to cut down the cost inorganic fertilizer requirement, which is environmentally sound and viable

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(Stern, 1993). Keeping these in mind, we carried out an experiment with INM and cropping sequence to find out an alternative farming system which aims for sustainable rice cultivation. We chose Rice-Rapeseed-Fodder cowpea, Rice-Field pea-Fodder cowpea and Rice-Wheat-Fodder cowpea cropping sequence for this experiment and FYM, vermicompost, biogas slurry and azolla as organic nutrient source besides chemical fertilizer. Our objective was to assess the influence of organic and inorganic sources of nutrients on the productivity and grain quality of rice.

MATERIALS AND METHODS

An experiment was conducted during 2017 and 2018 at Central Research Farm, Gayeshpur, Nadia (23°8´N, 88°E and 15 MSL) in New Alluvial Zone of West Bengal. The field was medium in slope having well irrigation facility. The site receives an average annual rainfall of 1460 mm and the annual temperature varies from 10°C (in January) to 37°C (in April). The type of soil of the experiment field was clay-loam in texture having moderate water holding capacity. The PH of the soil is 6.84, organic carbon 0.66%, available N, P2O5, K2O are 147.84, 18.24, 125.25 kg ha^{-1} respectively. The experiment was laid out in strip plot design. All nutritional management treatments were applied in rice, rapeseed, field pea and wheat, whereas fodder cowpea was grown in the residual fertility of the soil.

Different cropping system *viz*. i) Rice -Rapeseed - Fodder cowpea (C1), ii) Rice - Field pea - Fodder cowpea (C2) and iii) Rice - Wheat - Fodder cowpea (C3) with external nutrient sources *viz*. i) 100% Recommended dose of Fertilizers (RDF) through chemical fertilizer CF (N1), ii) 75% RDN through CF +25% N through Farm Yard Manure+ 100% RD of PK through CF (N2), iii) 75% RDN through CF +25% N through Biogas Slurry + 100% RD of PK through CF (N3), iv) 75% RDN through CF +25% N through Vermicompost + 100% RD of PK through CF (N4) and v) 75% RDN through CF +25% N through Azolla+ 100% RD of PK through CF (N5).

The soil samples of 25 different spots of the experimental field were collected up to a depth of 15 cm and were mixed thoroughly for a composite sample. Total nitrogen (N) concentration was determined by modified Kjeldahl method (Jackson, 1973), whereas hot alkaline KMnO4 method (Subbiah and Asija, 1956) was followed for available N determination. Phosphorus concentration of soil and plant was determined by Olsens method (Olsen *et.al*., 1954) and vanadomloybdo-phosphoric acid yellow color method by Koening and Johnson (1942) respectively. Potassium was determined flame photometry (Jackson, 1973). Nutrient uptake (kg ha^{-1}) of crop was calculated by multiplying the % concentration of nutrients to the crop yield (kg ha^{-1}) using the following formula,

Nutrient uptake (kg ha^{-1}) = Nutrient concentration (%) × yield (kg ha^{-1}).

Recorded data were analyzed with the help of ANOVA analysis meant for strip plot design (Gomez and Gomez, 1976) in SPSS software and standard error of mean (S.Em±) along with the value of Critical difference (CD) at 5% level of significance were indicated in the tables of the results to compare the difference between the mean Values. Pearson correlations were calculated in Microsoft Excel (2007).

RESULTS AND DISCUSSION

Nutrient uptake as influenced by management practice

We studied the changes in crop nutrient uptake (N, P and K) with different nutrient sources and management practice. We found significant variation in nutrient uptake by rice crop within different cropping sequence (C) and management practice (N). Generally C2 cropping sequence reported higher nutrient uptake for N, P and K followed by C1 and C3. Though lesser amount of nutrient uptake was found for C1 cropping sequence, the effect was statistically at par to C2. The nutrient uptake in C3 sequence was lowest and statistically significant from the rest. Rice grain was enriched in N and P (53 and 68 % respectively) than straw (47 and 32 % respectively) except K, where straw retained higher K (77 %) against grain (27 %). Similar observation was reported elsewhere (Yoshida 1981; Mohapatra *et al*., 1993; Dobermann *et al*., 1996; Dobermann *et al*., 1998 and Saha *et al*., 2007). Higher grain and straws yield was obtained from those plots where higher nutrient uptake was reported (Matsushima 1964, Saha *et al*., 2007). Minerals uptake by rice is closely related with biomass production (Matsushima, 1964).

The variation in nitrogen uptake with different treatments is reported in table 1. The pooled data showed total N uptake (grain + straw) varied from 121.95 to 205.21 kg ha^{-1} among treatments. The grain nitrogen uptake (avg. 89.51 kg ha^{-1}) was more than straw (avg. 78.72 kg ha^{-1}) and more enriched. Higher grain and straw N uptake (avg. 93.86 and 82.75 kg ha^{-1} respectively) was recorded when legume crop field pea was introduced in the cropping sequence (C2) compared to conventional rapeseed (C1; avg. 90.16 and 79.98 kg ha^{-1}) and wheat (C3; 84.52 and 79.98 kg ha^{-1}) cultivation practice. However, the effect of C1 and C2 was statistically at par. The N uptake in terms of nutrient management practice (N) was different when organic and chemical fertilizer was applied in different combination. Higher grain and straw uptake was found in case of N1 (avg.

96.21 and 85.11 kg ha^{-1}respectively), N2 (avg. 99.05 and 86.33 kg ha-1respectively) and N3 (avg. 98.72 and 88.13 kg ha^{-1}respectively) followed by N4 (avg. 80.00 and 68.99 kg ha^{-1}respectively) and N5 (avg. 73.59 and 65.05 kg ha^{-1}respectively). The FYM incorporation (N2) had resulted highest grain uptake (avg. 99.05 kg ha^{-1}), whereas straw uptake was highest when biogas slurry (N3; avg. 88.13 kg ha^{-1}) was applied. However,statistically insignificant result was observed between the difference between N1, N2 and that of N3.

Significant variation in phosphorus uptake was observed (Table 1) in rice grain and straw due to the variation in nutritional management treatments in both the years of investigation. The phosphorus uptake closely followed N uptake trend. Highest grain P uptake was recorded in C2 cropping sequence (19.78 kg ha^{-1}) followed by C1 (18.11 kg ha^{-1}) and C3 (16.72 kg ha^{-1}). Though C1 and C2 produced similar effect, it was significantly less in C1. There was similar trend in straw P uptake and the higher uptake was found in C2 (9.81 kg ha-1) followed by C3 (8.02 kg ha^{-1}) and C1 (7.95 kg ha^{-1}). Among different management practices, higher grain and straw P uptake was found in N2 (22.72 and 11.20 kg ha^{-1}respectively) followed by N3 (21.09 and 10.52 kg ha^{-1}) and N1 (19.62 and 9.83 kg ha^{-1}). The N4 (14.70 and 6.61 kg ha^{-1}) and N5 (12.89 and 4.80 kg ha-1) recorded the lowest amount of grain and straw P uptake. Statistical analysis showed N1, N2 and N3 was similar in P uptake, whereas N4 and N5 produced poor results.

Highest grain K uptake was found in C2 (25.59 kg ha^{-1}) followed by C1 (24.32 kg ha^{-1}), however there was no significant variation (Table 1). Least uptake was found in C3 (23.03 kg ha^{-1}) where Rice - Wheat - Fodder cowpea sequence was followed. Higher straw uptake was found in C2 (72.22 kg ha^{-1}) followed by C3 (67.58 kg ha^{-1}) and C2 (67.13 kg ha^{-1}). However no significant difference was found between them. When it comes to nutrient management, grain K uptake in N2 (29.12 kg ha^{-1}) and N3 (28.08 kg ha^{-1}) was very superior to rest N1,N4 and N5(25.33,20.41and18.62 kg ha^{-1}respectively). K uptake of straw was found to be higher in N3 (99.37 kg ha^{-1}) followed by N2 (96.91 kg ha^{-1}) and N1 (90.93 kg ha^{-1}). K uptake of straw in N4 and N5 (75.13 and 70.30 kg ha^{-1}respectively) was significantly lower than others.

Figure 1shows the interaction effect between cropping sequence (C) and nutrient management (N) on N, P and K uptake and a significant variation between treatmentswere observed. Cropping sequence C2 along with N2 nutrient management reported best result for nutrient uptake (205.21, 39.31 and 109.56 kg ha^{-1} respectively for N, P and K). The filed pea and cowpea being a leguminous crop in cropping sequence helps in fixing atmospheric N (9-125 kg ha^{-1}), improving soil nutrient status (Lindemann and Glover, 2003). The effect was further amplified when FYM was incorporated in the nutrient management system (N2). FYM being rich in carbonaceous and lignin compound (Bandyopadhyay *et al*., 2011 and references therein) helps in restoring soil health and better nutrient uptake (Baskar, 2003; Patil *et al*., 2005). Application of organic manures and inorganic fertilizer together helped in slow release of nutrient thus enhanced nutrient use efficiency (Singh and Biswas, 2000). However the effect was statistically insignificant when compared to other nutrient management line except N4 and N5 (against C2). Similarly, C1 and C3 yielded comparable results with N1, N2 and N3. Several reports (Kandan and Subbulakshmi, 2015; Kumar *et al*., 2015; Hyder *et al*., 2016) were available showing positive influence of vermicompost (N4) and azolla (N5) on crop nutrient uptake and yield. However, we didn't find any significant impact of them on nutrient uptake. Vermicompost being N rich (Ravimycin, 2016) are preferentially decomposed and have quicker turnover rate relative to FYM (Grandy and Robertson, 2007). Thus, though vermicompost may act as source of nutrients, it and might not be able to supply the nutrient during the entire crop duration or have to apply in higher amount for sufficient nutrient supply.

Influence of INM on rice growth and yield parameters

Number of panicle m^{-2}

Our data revealed significant variation in panicle no. m-2 with different treatments. Highest no. of panicle m-2(315) was found under legume cropping sequence, where as other cropping sequence resulted similar panicle initiation (249 panicle m^{-2}). However, when compared within different nutrient sources, no significant difference was found within N1, N2 and N3 (264, 265 and 267 respectively; see Table 2). However, N4 and N5 reported lowest no of panicle m-2 (247 and 231 respectively). Fig. 2a shows the interaction effect between cropping sequence and nutrient sources. Best result was found in C2N2, followed by C2N3 and C2N1 (283, 278 and 275 respectively). Among the nutrient sources N4 and N5 yielded poor result with cropping sequence (C).

Number of filled grain panicle^{-1}

The number of filled grain varied significantly among treatments. Best result was found in C2 (163 grain panicle^{-1}; Table 2), *i.e*. when legume crop was incorporated in the cropping sequence. This was significantly higher than C1 and C3 (155 and 147 grain

Table 1: Changes in nitrogen (N), phosphorus (P) and potassium (K) uptake with different agronomic practices

Treatments	Nitrogen uptake		P uptake		K uptake	
	Grain N (kg ha^{-1})	Straw N (kg ha^{-1})	Grain P (kg ha^{-1})	Straw P (kg ha^{-1})	Grain K (kg ha^{-1})	Straw K (kg ha^{-1})
Cropping system						
C1	90.16	79.98	18.11	7.95	24.32	67.13
C2	93.86	82.75	19.78	9.81	25.59	72.22
C3	84.52	73.45	16.72	8.02	23.03	67.58
SEm (±)	**1.51**	**1.89**	**0.34**	**0.20**	**0.50**	**1.80**
LSD(0.05)	**4.93**	**6.18**	**1.12**	**0.64**	**1.64**	**5.86**
Nutrient management						
N1	96.21	85.11	19.62	9.83	25.33	74.05
N2	99.05	86.33	22.72	11.20	29.12	76.93
N3	98.72	88.13	21.09	10.52	28.08	76.81
N4	80.00	68.99	14.70	6.61	20.41	62.39
N5	73.59	65.05	12.89	4.80	18.62	54.69
SEm(±)	**3.69**	**2.14**	**0.83**	**0.35**	**0.94**	**2.47**
LSD (0.05)	**11.07**	**6.41**	**2.48**	**1.06**	**2.83**	**7.39**

Table 2: Variation in paddy yield parameter as influenced by various agronomic practices

Treatments	Number of panicle m^{-2}	Number of filled grain panicle^{-1}	Panicle weight (g)	Panicle length (cm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Cropping system							
C1	249	155	2.55	26.8	4.66	6.64	41.08
C2	267	163	2.65	27.2	4.74	6.77	41.10
C3	249	147	2.47	26.9	4.42	6.37	40.82
SEm(±)	**3.10**	**1.30**	**0.03**	**0.07**	**0.05**	**0.07**	**0.28**
LSD (0.05)	**10.20**	**4.30**	**0.11**	**0.24**	**0.15**	**0.24**	**NS**
Nutrient management							
N1	264	168	2.63	27.2	4.84	6.96	40.89
N2	265	163	2.66	27.4	5.08	7.07	41.69
N3	267	163	2.66	27.2	5.01	7.15	41.08
N4	247	145	2.52	26.8	4.18	6.01	41.02
N5	231	134	2.33	26.3	3.91	5.77	40.33
SEm(±)	**4.90**	**3.40**	**0.05**	**0.17**	**0.17**	**0.12**	**0.53**
LSD (0.05)	**14.70**	**8.60**	**0.16**	**0.50**	**0.50**	**0.37**	**NS**

panicle-1respectively). Similar range of result was found when different sources of nutrients (168, 163 and 163 grain panicle-1 for N1, N2 and N3 respectively) were considered. However N4 and N5 yielded significantly lower no. of filled grain panicle^{-1} (145 and 134, respectively). Figure 2b shows the interaction effect between cropping sequence and nutrient sources. The C2N2, like other parameter produced best result (189 grain panicle^{-1}), followed by C2N3 (175 grain panicle^{-1}).

Panicle weight and panicle length

Table 4 shows the variation in Panicle weight (g), panicle length (cm) as well as test weight and the highest values were found in C2 (2.65 g, 27.2 cm and 21.99 g respectively), followed by C1 (2.55 g, 26.8 cm and 21.39 g respectively) and C3 (2.47 g, 26.9 cm and 20.93 g respectively). Though the effect of C1 was statistically at par C2; C3 produced significantly lower values. Among nutrient management, N2 (2.66 g, 27.4 cm and 22.71g respectively) proved to be superior to others.

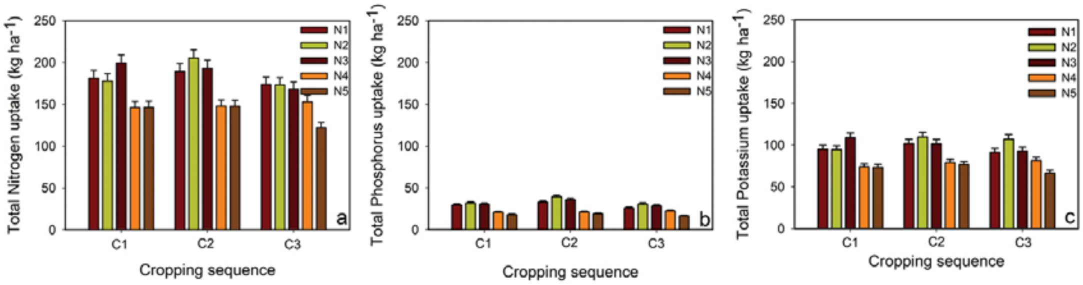

Fig. 1a, b, c: Interaction effect between cropping sequence (C) and nutrient management (N) for N, P and K uptake respectively

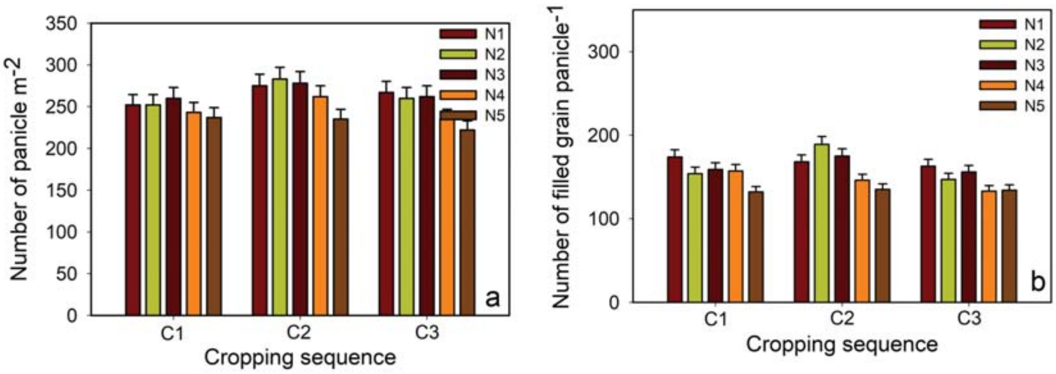

Fig. 2a, b: Interaction effect between cropping sequence (C) and nutrient management (N) for Number of panicle m^{-2} and Number of filled grain $panicle^{-1}$ respectively

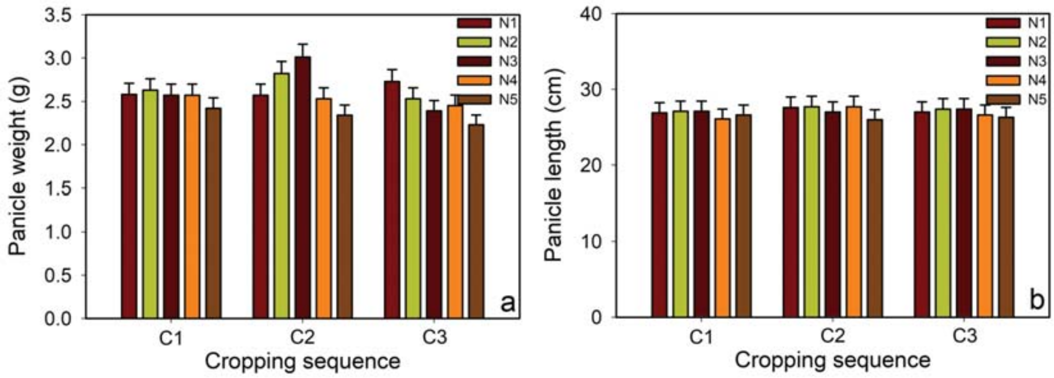

Fig. 3a, b : Interaction effect between cropping sequence (C) and nutrient management (N) for Panicle weight (g) and panicle length (cm) respectively

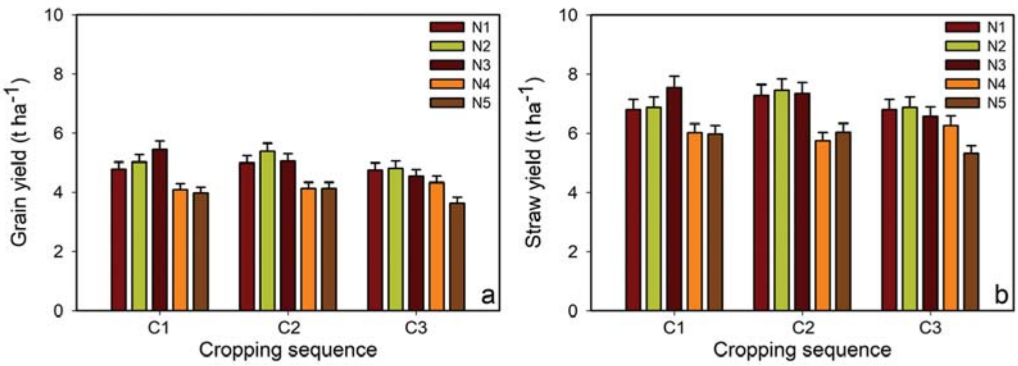

Fig. 4a, b: Interaction effect between cropping sequence (C) and nutrient management (N) for grain yield and straw yield respectively

Table 3: Correlation between NPK uptake and yield parameters

	Total N	*Total P*	*Total K*	*Grain yield*	*Straw yield*	*panicle sq.m*	*filled grain panicle^{-1}*	*Panicle wt.*	*Panicle length*
Total N	1.00								
Total P	0.94	1.00							
Total K	0.95	0.93	1.00						
Grain yield (t ha^{-1})	0.98	0.93	0.96	1.00					
Straw yield (t ha^{-1})	0.98	0.93	0.95	0.98	1.00				
No of panicle sqm^{-1}	0.85	0.86	0.82	0.79	0.80	1.00			
No of filled grain panicle^{-1}	0.83	0.85	0.73	0.77	0.77	0.84	1.00		
Panicle weight	0.75	0.76	0.64	0.71	0.72	0.80	0.80	1.00	
Panicle length	0.63	0.69	0.70	0.62	0.57	0.80	0.54	0.42	1.00

However there were no significant difference in terms of panicle weight, panicle length and test weight among various nutrient sources. The interaction effect between the cropping sequence and nutrient sources were presented in Figure 3. Except for panicle weight, C2N2 reported maximum values. However we didn't find any significant difference between treatment combinations for these parameters.

Grain and straw yield

Highest grain yield of 4.74 t ha^{-1} was obtained in cropping sequence C2 to which leguminous crop was incorporated, followed by C1 (4.66 t ha^{-1}). The yield was significantly lower when wheat crop was grown after rice (C3; 4.42 t ha^{-1}). Similarly higher yield was obtained from N2 (5.08 t ha-1) where FYM was a significant source component followed by N3 and N1 (5.01 and 4.84 t ha^{-1} respectively). However the yield was significantly lower when either vermicompost (N4; 4.18 t ha^{-1}) or azolla (N5; 3.91 t ha^{-1}) was used as organic source of nutrient besides inorganic sources (Table 2). Similar results were recorded for straw yield. Cropping sequence (C2) resulted better straw yield followed by C1 and C3. Though N2 was better in case of grain yield than N3, the later performed better when straw yield was considered. However, the effect of N3, N2 and N1 was statistically insignificant. Straw yield from N4 and N5 was significantly lower than the others.

Regarding the interaction effect on rice yield parameters, treatment combination of C1N3 yielded highest grain and straw, followed by C2N2 and C2N3. Though C1N3 was found best, interaction effect between line C1, C2 and N1, N2, N3 was statistically similar. However, the treatment combination between line N4, N5 and C1, C2, C3 produced lowest grain and straw yield and was statistically significant compared to others (Fig. 4).

We found strong to very strong correlation ($p<0.001$) between the nutrient uptake and rice yield parameters (Table 3). Very strong correlation between N, P and K indicates co-adsorption of nutrients by plants. Though all the nutrients (N, P and K) were strongly correlated with other yield parameters, the association of N was strongest. Association of number of panicle^{m-2} and number of filled grain panicle^{-1}with N, P and K were mostly very strong ($r > 0.8$, $p< 0.001$). However the correlation strength was relatively weaker ($r=0.62$ to 0.75, $p<0.001$) in case of panicle weight and length. Very strong correlation ($r > 0.9$, $p<0.001$) between grain and straw yield and NPK indicates influence of nutrient uptake on crop grain and straw yield (Dasgupta *et al*., 2017). The plots where nutrient uptake was higher were found to produce higher yield.

From the two years field experiments it had been found that few treatment combination produced better results in terms of nutrient uptake and yield and were statistically significant than others. Grain yield of rice and nutrients uptake were highest when leguminous crop field pea was incorporated in the cropping system (C2). Leguminous crops incorporated atmospheric N2 in soil as plant available form, which in turn helped in better nutrient uptake and therefore crop yield. However, C1 and C3 also produced statistically similar result to C2. However their (C line) interaction with external nutrient source (N line) varied significantly regarding nutrients uptake and yield. Though their effect was similar on nutrient uptake and yield, their effect on soil environment might be different. Among different external nutrient sources, use of farm yard manure (FYM) alongside chemical fertilizer was found to be superior. Organic carbon rich FYM was able to sustain the crop nutrient supply during the entire crop duration. Higher nutrient uptake due to FYM application (in N2) was able to produce highest grain and straw yield in the alluvial zone of West Bengal. However, influence of chemical fertilizer alone or with biogas slurry (N1 and N3 respectively) were statistically at par with N2 in respect of nutrient uptake and yield. Though reports are available on positive influence of vermicompost and azolla (N4and N5 respectively), we found significantly less nutrient uptake and crop yield from their application.

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