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Sustaining paddy production through improved agronomic practices in the Gangetic alluvial zone of West Bengal

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A B S T R A C T

The article includes the research in Khevi region of Central Great Caucasus. Study area was divided by expositions (north and south), Excessive and imbalanced use of chemical fertilizer in modern agriculture has downgraded soil health. Farmers very often avoid organic fertilizer in crop production due to its unavailability. Stubble removal and other unscientific cultural practices are more likely to enhance soil degradation process and crop production in longer term. Here we undertook an experiment to identify suitable agronomic management practices for paddy cultivation in the Gangetic alluvial zone of West Bengal, India. Interactions between different cropping systems (Rice - Rapeseed - Fodder cowpea, Rice - Field pea - Fodder cowpea and Rice - Wheat - Fodder cowpea) and available nutrient sources through chemical fertilizer alone or in combination with organic fertilizers were studied. Crop uptake of nitrogen, phosphorous and potassium vis-a-vis different yield components as affected by management practices were investigated. Incorporation of leguminous crop (field pea) in the cropping sequence resulted in enhanced nutrient uptake and paddy production than other cropping systems. Application of organic manures mixed with chemical fertilizer has resulted into higher nutrient uptake and crop yield than chemical fertilizers alone. However, there was a significant difference with type of organic manure used. Application of farm yard manure and bio-gas slurry has resulted in maximum nutrient uptake and yield. Farm yard manure and bio-gas slurry being nitrogen poor, have the ability to supply nutrient for a longer time before exhaustion than nitrogen rich vermicompost and azolla. Our findings will be helpful to farmers for better use of their resources in agricultural management.

Keywords: Integrated nutrient management, Paddy cultivation, Cropping sequence, Crop nutrient uptake, Organic manure, Chemical fertilizer.

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Introduction

Paddy is the most important staple crop among cereals in south-west Asia. In India, paddy is cultivated throughout the country, except few dry areas, the Indo-Gangetic plain being most important among them. Muddy soils, which are capable of holding enough water, have advantage of cultivating paddy here over other areas. The use of chemical fertilizer for nitrogen, phosphorous and potassium (NPK) in Indian agriculture is increasing progressively since its introduction to agriculture. It has reached to about 26.5 million tons in 2009-10 from only 78 thousand tons during 1965-66 [1-4]. For a profitable return, farmers are applying chemical fertilizers at the rate higher than recommended dose causing soil health deterioration. Decreasing soil health and crop production in long run resulting from excessive use of imbalanced inorganic fertilizer has been reported elsewhere [5, and references therein]. Leaching and run-off loss of inorganic nutrients pose acute problem of water-body eutrophication [6-9].

Thus society faces both environmental and economic threat. However the farmers are unable to understand the negative impact these type of malpractice.

The integrated nutrient management (INM) aims to find a suitable management practice which should be profitable as well as sustainable for the environment [10-13]. It combines all possible sources of nutrient viz. organic, inorganic and bio-fertilizer and helps us to achieve our goal without environmental degradation [10, 13, 14,]. Organic source of nutrients such as farm yard manures (FYM), vermicomposts, azolla etc. are rich in carbon, nitrogen and other essential compounds [15]. They not only provide the crop nutrient, but also help in improving soil health [10, 16]. However their field requirement is quite high due to lesser concentration of nutrients as compared to inorganic fertilizers [17, 18]. The ability of organic fertilizers to supply nutrient is dependent on nature and composition of material, soil microbial diversity and climatic condition. Sources such as FYM, vermicompost, green manure, bio-gas slurry are all made up of different chemical composition [19]. Thus degradability and crop suitability of these materials are different. The inorganic fertilizers, on the other hand being very concentrated in nutrients are required in lesser quantity [20]. Though their requirement is less, they are found to aggravate soil health degradation [21,22]. Never the less, fertile soils are prerequisite for higher crop yield. Thus we have to find a possible proportion of organic as well as inorganic fertilizers which not only gives profitable return, but protects our soil form further degradation.

Legume crops are essentially beneficial to agriculture. They fix atmospheric inorganic nitrogen and release them in soil, cutting a significant proportion of inorganic nitrogenous fertilizer requirement [23,24]. However their cultivation in Gangetic alluvium belt has declined considerably [25-28]. Farmers prefer cereals and oil seeds over legumes for their daily requirement. Legumes, if incorporated in the cropping sequence increases the chance of further cut down on cost of cultivation, which is also environmentally sound and viable [23, 24].

There are several reports available on influence of organic fertilizer on plant nutrition and crop yield. Applications of farm yard manure, vermicompost, azolla, bio-gas slurry were found to have positive effect on nutrient uptake as well as soil health [10, 14, 20, 21, 29, 30]. However, only few reports [13, 31-33] are available on combined influence of various sources of nutrients (various chemical and organic fertilizers) and different cropping sequence in our study area. We tried to combine various possible nutrient sources and prevalent cropping pattern of the area and investigated interaction effect existed within them. This study will identify the best possible combination of nutrient source and cropping sequence for the whole Indo-Gangetic plain.

We hypothesized that agronomic cropping system and the source of nutrient applied would affect the nutrient supplying capacity of soil, hence crop yield. We considered Rice–Rapeseed–Fodder cowpea, Rice–Field pea–Fodder cowpea and Rice–Wheat–Fodder cowpea cropping sequence for alternative cropping system and FYM, vermicompost, biogas slurry and azolla as possible organic nutrient source besides chemical fertilizer suitable for this region. Our objective was to find out the effect of organic and inorganic sources of nutrients on crop nutrient uptake and productivity of paddy. We also tried to find out the suitability of organic fertilizers in rice cultivation and farming system which aims for sustainable paddy cultivation in the area.

2. Materials and methods

2.1 Site description and experimental design:

The field experiment was conducted during the period of July 2013 to June 2015 at Central Research Farm, Gayeshpur, Nadia, West Bengal (23°8'N and 88°E, 15 MSL), under new alluvial Zone. 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 initial soil characteristics were reported in Table 1. The experiment was laid out in strip plot design. All the nutritional management treatments were applied to rice, rapeseed, field pea and wheat, whereas fodder cowpea was grown in the residual fertility of the soil. The details of the treatments were listed in Table 2. Recommended cultural practices were followed for all the crops. The rice crop was harvested at 80 % physiological maturity and air dried for 3 days. After drying, the total plant was weighed, threshed and the grain yield was calculated. The straw yield was calculated by deducting grain yield from the total yield. The yield determining parameters of rice viz. number of panicle m^{-2}, number of filled grain panicle^{-1}, panicle weight (g), panicle length (cm) and test weight (g) were recorded after harvesting of the crop.

2.2 Nutrient analysis of soil and plant

The composite surface soil samples (top 15 cm) were collected from 25 different random locations of the experimental field and were mixed thoroughly. Total nitrogen (N) concentration was determined by modified Kjeldahl method [34], whereas hot alkaline $KMnO_4$ method [35] was followed for available N determination. Soil and plant phosphorus (P) concentration was determined by Olsen's method [36] and vanadomloybdo-phosphoric acid yellow color method by [37] respectively. Potassium (K) was determined flame photometry [34]. Crop nutrient uptake (kg ha^{-1}) 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}).

2.3 Statistical analysis

All the variables were subjected to ANOVA analysis meant for strip plot design [38] using SPSS (v21.0) software. The standard error of mean (S.Em±) and the value of critical difference (CD) at 5% level of significance were indicated in the tables to compare the difference between the mean values. Pearson correlations were calculated in Microsoft Excel (v2007). Figures were prepared using Sigmaplot (v10).

3. Results and discussion

3.1 Crop nutrient uptake as influenced by management practices:

We studied the changes in crop uptake of nitrogen, phosphorous and potassium (N, P and K) with different nutrient sources and management practice. There was significant variation in nutrient uptake by rice crop within different cropping sequence (C) and nutrient management (M). Generally C_2 cropping sequence reported higher nutrient uptake for N, P and K followed by C_1 and C_3. Though lesser amount of nutrient uptake was found for C_1 cropping sequence, the effect was statistically at par with C_2. The nutrient uptake in C_3 sequence was lowest and significantly differs from the rest. Paddy 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 %). Better nutrient uptake with combined application of inorganic and organic fertilizer was reported elsewhere [13, 18, 29, 32, 39]. Higher grain and straw yield was obtained from those plots where higher nutrient uptake was found, since minerals uptake by rice is associated with biomass production [40, 41].

The variation in N uptake with different treatments is reported in Table 3. 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}). Higher grain and straw N uptake (avg. 93.86 and 82.75 kg ha^{-1} respectively) was found when legume crop, field pea was introduced in the cropping sequence (C_2) as compared to conventional rapeseed (C_1; avg. 90.16 and 79.98 kg ha^{-1}) and wheat (C_3; 84.52 and 79.98 kg ha^{-1}) cultivation practice. However, effect of C_1 and C_2 cropping sequence was statistically at par. Nitrogen uptake in terms of nutrient management practice (M) was different when organic and chemical fertilizer was applied in different combination. Higher grain and straw uptake was found in case of M_1 (avg. 96.21 and 85.11 kg ha^{-1} respectively), M_2 (avg. 99.05 and 86.33 kg ha^{-1} respectively) and M_3 (avg. 98.72 and 88.13 kg ha^{-1} respectively) followed by M_4 (avg. 80.00 and 68.99 kg ha^{-1} respectively) and M_5 (avg. 73.59 and 65.05 kg ha^{-1} respectively). Farm yard manure (FYM) incorporation (M_2) had resulted highest grain uptake (avg. 99.05 kg ha^{-1}), whereas straw uptake was highest when biogas slurry (M_3; avg. 88.13 kg ha^{-1}) was applied. However the difference between M_1, M_2 and M_3 was statistically insignificant.

Significant variation in P uptake was observed (Table 3) in rice grain and straw due to the variation in nutritional management treatments during both the years of investigation. Phosphorous uptake closely followed N uptake trend. Highest grain P uptake was recorded in C_2 cropping sequence (19.78 kg ha^{-1}) followed by C_1 (18.11 kg ha^{-1}) and C_3 (16.72 kg ha^{-1}). Though C_1 and C_2 produced similar effect, it was significantly low in C_1. Similar variation was found for straw P uptake. Highest concentration was found in C_2 (9.81 kg ha^{-1}) followed by C_3 (8.02 kg ha^{-1}) and C_1 (7.95 kg ha^{-1}). Among different management practices, higher grain and straw P uptake was found in M_2 (22.72 and 11.20 kg ha^{-1} respectively) followed by M_3 (21.09 and 10.52 kg ha^{-1}) and M_1 (19.62 and 9.83 kg ha^{-1}). Lowest amount of grain and straw P uptake was found in M_4 (14.70 and 6.61 kg ha^{-1}) and M_5 (12.89 and 4.80

kg ha^{-1}). Statistical analysis revealed M_1, M_2 and M_3 yielded statistically similar P uptake, whereas M_4 and M_5 produced poor results.

Highest grain K uptake was found in C_2 (25.59 kg ha^{-1}) followed by C_1 (24.32 kg ha^{-1}), however there was no significant variation (Table 3). Least uptake was recorded in C_3 (23.03 kg ha^{-1}) where Rice - Wheat - Fodder cowpea sequence was followed. Higher straw uptake was found in C_2 (72.22 kg ha^{-1}) followed by C_3 (67.58 kg ha^{-1}) and C_1 (67.13 kg ha^{-1}). However their effect was statistically at per. When it comes to nutrient management, grain K uptake in M_2 (29.12 kg ha^{-1}) and M_3 (28.08 kg ha^{-1}) was higher than the rest M_1, M_4 and M_5 (25.33, 20.41 and 18.62 kg ha^{-1} respectively). Straw K uptake was found to be higher in M_3 (99.37 kg ha^{-1}) followed by M_2 (96.91 kg ha^{-1}) and M_1 (90.93 kg ha^{-1}). Straw K uptake in M_4 and M_5 (75.13 and 70.30 kg ha^{-1} respectively) was significantly lower than others.

Figure 1 shows the interaction effect between cropping sequence (C) and nutrient management (M) for N, P and K uptake. There was significant variation between treatments. Cropping sequence C_2 along with M_2 nutrient management yielded best result in nutrient uptake (205.21, 39.31 and 109.56 kg ha^{-1} respectively for N, P and K). Field pea and cowpea being a leguminous crop in cropping sequence helps in fixing atmospheric N, improving soil nutrient status. The effect was further amplified when FYM was incorporated in the nutrient management system (M_2). Farm yard manure being rich in carbonaceous and lignin compound helps in restoring soil health and better nutrient uptake [42 and references therein]. Application of both organic and inorganic fertilizer together helps in slow release of nutrient, thus enhanced nutrient use efficiency [16, 43]. They also stimulate soil microbial activity, crop root growth and reduced nutrient loss resulting better uptake of water and nutrient [44]. However the effect was statistically insignificant when compared to other nutrient management line except M_4 and M_5 (against C_2). Similarly, C_1 and C_3 yielded comparable results with M_1, M_2 and M_3. Several reports [30,45] were available showing positive influence of vermicompost (M_4) and azolla (M_5) on crop nutrient uptake and yield. However, we didn't find any significant impact of them on nutrient uptake. Azolla and vermicompost being N rich is preferentially decomposed and have quicker turnover rate relative to FYM [46]. Thus, vermicompost and azolla may act as source of nutrients, but it might not be able to supply nutrients during entire crop duration or would have to apply in higher amount to achieve desired crop production.

3.2 Influence of cultural management on paddy yield and yield components:

Our data revealed significant variation in panicle no m^{-2} with different treatments. Highest no (315 panicle m^{-2}) 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 M_1, M_2 and M_3 (264, 265 and 267 respectively; see Table 4). However, M_4 and M_5 reported lowest no of panicle m^{-2} (247 and 231 respectively). The Fig. 2a shows the interaction effect between cropping sequence and nutrient sources. Best result was found in C_2M_2, followed by C_2M_3 and C_2M_1 (283, 278 and 275 panicle m^{-2} respectively). Adequate and sustained nutrient supply during vegetative growth stage might have resulted higher panicle no m^{-2} in these treatments [40, 41]. Among the nutrient sources M_4 and M_5 yielded poor result with cropping sequence (C).

The no of filled grain $panicle^{-1}$ varied significantly among treatments. Best result was found in C_2 (163 grain $panicle^{-1}$; Table 4), i.e. when legume crop was incorporated in the cropping sequence. This was significantly higher than C_1 and C_3 (155 and 147 grain $panicle^{-1}$ respectively). Similar range of result was found when different sources of nutrients (168, 163 and 163 grain $panicle^{-1}$ for M_1, M_2 and M_3 respectively) were considered. However M_4 and M_5 yielded significantly lower no of filled grain $panicle^{-1}$ (145 and 134 grain $panicle^{-1}$ respectively). Figure 2b shows the interaction effect between cropping sequence and nutrient sources. The C_2M_2, like other parameter produced best result (189 grain $panicle^{-1}$), followed by C_2M_3 (175 grain $panicle^{-1}$). Legume crop incorporation and addition of organic fertilizer ensured sufficient nutrient supply during flowering to physiological maturity stage [41]. Reduced amount of N supply in M_4 and M_5 during this stage might have reduced no of filled grain $panicle^{-1}$.

Table 4 shows the variation in Panicle weight (g), panicle length (cm) and test weight. Highest panicle weight, panicle length and test weight was found in C_2 (2.65 g, 27.2 cm and 21.99 g respectively), followed by C_1 (2.55 g, 26.8 cm and

21.39 g respectively) and C_3 (2.47 g, 26.9 cm and 20.93 g respectively). Though the effect of C_1 was statistically at per C_2; C_3 produced significantly lower values. Among nutrient management, M_2 (2.66 g, 27.4 cm and 22.71gm respectively) proved to be superior to others. 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 Fig. 3. Except for panicle weight, C_2M_2 reported maximum values. However we didn't find any significant difference between treatment combinations for these components.

The grain yield, straw yield and harvest index were presented in Table 9. Highest grain yield of 4.74 t ha^{-1} was obtained in cropping sequence C_2 to which leguminous crop was incorporated, followed by C_1 (4.66 t ha^{-1}). The yield was significantly lower when wheat crop was grown after rice (C_3; 4.42 t ha^{-1}). Similarly higher yield was obtained from M_2 (5.08 t ha^{-1}) where FYM was a significant source component followed by M_3 and M_1 (5.01 and 4.84 t ha^{-1} respectively). However the yield was significantly lower when either vermicompost (M_4; 4.18 t ha^{-1}) or azolla (M_5; 3.91 t ha^{-1}) was used as organic source of nutrient besides inorganic sources. Similar results were recorded for straw yield. Cropping sequence C_2 resulted better straw yield followed by C_1 and C_3. Though M_2 was better in case of grain yield than M_3, latter performed better when straw yield was considered. However, the effect of M_3, M_2 and M_1 was statistically insignificant. Straw yield from M_4 and M_5 was significantly lower than the others. Grain harvest index of rice did not change significantly in different treatments. However, incorporation of leguminous crop (C_2) and use of FYM as nutrient source (M_2) yielded better results than others.

Figure 4 shows the interaction effect of cropping sequence and nutrient sources on paddy yield parameters. The treatment combination of C_1M_3 yielded highest grain and straw, followed by C_2M_2 and C_2M_3. Though C_1N_3 was found best, interaction effect between line C_1, C_2 and M_1, M_2, M_3 was statistically similar. However, the treatment combination between line M_4, M_5 and C_1, C_2, C_3 produced lowest grain and straw yield and was statistically significant compared to others.

We found strong to very strong correlation ($p<0.001$) between the nutrient uptake and paddy yield parameters (Table 5). 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 ($r=0.98$, $p<0.001$). This suggests primary role of N on growth and yield of crops. Researchers have found N in adequate account accounted 75 to 90% variation in yield component [41]. Association of number of panicle m^{-2}, number of filled grain $panicle^{-1}$ and panicle wt with N, P and K were mostly very strong ($r > 0.8$, $p< 0.001$). Though panicle length is known to be influenced by nutrient uptake [41], we found only moderate correlation ($r=0.62$ to 0.75, $p<0.001$). Very strong correlation ($r > 0.9$, $p<0.001$) between grain and straw yield and NPK indicates influence of nutrient uptake on dry matter accumulation and subsequent crop yield [39, 40, 44]. Researchers have found positive associations of harvest index with grain yield and nutrient uptake. However, we found weak correlation between them. Climatology, location, and ecology of the study area might be responsible for rendering their association. The plots where nutrient uptake was higher were found to produce higher yield. Improved soil health from balanced use of organic and inorganic fertilizers has resulted in enhanced and sustained nutrient uptake from soils during entire crop growth period, increased biomass production and crop yield [41].

4. Conclusion

We studied the influence of cropping system and nutrient sources on crop nutrient uptake and paddy yield. Few treatment combination produced better results in terms of nutrient uptake and yield and were statistically significant than others. Nutrients uptake and yield was highest when leguminous crop field pea was incorporated in the cropping system (C_2). Leguminous crops fixed atmospheric nitrogen to soil as plant available form, which in turn helped in better nutrient uptake and therefore crop yield. However, C_1 and C_3 produced statistically similar result to C_2. However their (C line) interaction with external nutrient source (M line) varied significantly in terms of nutrient uptake and crop 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 M_2)

was able to produce highest grain and straw yield in our study area. However, influence of chemical fertilizer alone or with biogas slurry (treatment M_1 and M_3 respectively) were statistically at par with M_2 in respect of nutrient uptake and yield. Though reports are available on positive influence of vermicompost and azolla (treatment M_4 and M_5 respectively), we found significantly less nutrient uptake and crop yield with their application. Azolla and vermicompost are nitrogen rich are preferentially degraded over carbon rich organic fertilizer such as FYM. Slow release of nutrient for longer time with FYM application might have out-performed nitrogen rich materials. Integration of these locally available fertilizer sources with dominant cropping system helped us to identify the best suitable cropping pattern and fertilizers to be applied for sustainable agriculture and net return. This study will also help policy makers to make certain to sustain agricultural production of India.

However, further study is required to understand possible nutrient dynamics and their uptake. Microbial diversity study and isotope tracing technique can help us to understand the changes going on in soil upon application of these fertilizers. These studies also make understand why some are out-performing others in terms of nutrient uptake and crop production. Studies may also be conducted with other available nutrient sources, such as sewage-sludge, fly ash from thermal power plant and their influence on crop production.

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Reference

[1] V.P. Sharma, H. Thaker, Demand for Fertiliser in India: Determinants and Outlook for 2020. Indian Institute of Management, 2011.

[2] W. Hopper, Indian Griculture and Fertilizer: An Outsider's Observations. In Keynote address to the FAI Seminar on Emerging Scenario in Fertilizer and Agriculture: Global Dimensions. New Delhi: FAI, 1993.

[3] P.K. Jaga, Y. Patel, An overview of fertilizers consumption in India: determinants and outlook for 2020-a review. International J. of Scientific Engineering and Technology, 1(6) (2012) 285-291.

[4] Fertiliser Association of India, Fertiliser Statistics 2009-10 and Earlier Issues. The Fertiliser Association of India, New Delhi, 2010.

[5] S. Savci, Investigation of effect of chemical fertilizers on environment. APCBEE Procedia, 1 (2012) 287-292.

[6] D.O. Hessen, A. Hindar, G. Holtan, The significance of nitrogen runoff for eutrophication of freshwater and marine recipients. Ambio (1997) 312-320.

[7] R. Bhateria, D. Jain, Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2(2) (2016) 161-173.

[8] B. Moss, Water pollution by agriculture. Philosophical Transactions of the Royal Society B: Biological Sciences, 363(1491) (2007) 659-666.

[9] G.D. Agrawal, Diffuse agricultural water pollution in India. Water science and technology, 39(3) (1999) 33-47.

[10] S.K. Zaman, M. Jahiruddin, G.M. Panaullahi, M.H. Mian, M.R. Islam, Integrated nutrient management for sustainable yield in rice-rice cropping system. In 17th World Congress of Soil Science, Bangkok (Thailand) (2002) 14-21 Aug.

[11] M. Arif, M. Tasneem, F. Bashir, G. Yaseen, R.M. Iqbal, Effect of integrated use of organic manures and inorganic fertilizers on yield and yield components of rice. J. of Agricultural Research, 52(2) (2014) 197-208.

[12] M.S. Aulakh, C. A. Grant, Integrated Nutrient Management for Sustainable Crop Production. The Haworth Press, Taylor and Francis Group: New York 2008.

[13] A.K. Patra, B. C. Nayak, M. M. Mishra, Integrated nutrient management in rice (Oryza sativa)-wheat (Triticum aestivum) cropping system. Indian J. of Agronomy, 45 (2000) 453-457.

[14] M.M. Islam, A. J. M. S. Karim, M., Jahiruddin, N. M. Majid, M. G. Miah, M. M. Ahmed, M. A. Hakim, Effects of organic manure and chemical fertilizers on crops in the Radish-Stem Amaranth-Indian spinach cropping pattern in homestead area. Australian J. of Crop Science, 5 (2011) 1370-1378.

[15] B. Gagnon, R. Lalande, S.H. Fahmy, Organic matter and aggregation in a degraded potato soil as affected by raw and composted pulp residue. Biology and fertility of soils, 34 (2001) 441-447.

[16] W. Mojeremane, M. Motladi, T. Mathowa, G.M. Legwaila, Effect of different application rates of organic fertilizer on growth, development and yield of rape (Brassica napus L.). International Journal of Innovative Research in Science, Engineering and Technology, 4(12) (2015) 11680-8.

[17] D. Alexander, S. Rajan, L. Rajamony, K. Ushakumari, S. Kurien, The adhoc Package of Practices recommendations for organic farming. Organic Farming, (2009).

[18] A.A. Ahmad, T.J. Radovich, H.V. Nguyen, J. Uyeda, A. Arakaki, J. Cadby, R. Paull, J. Sugano, G. Teves, Use of organic fertilizers to enhance soil fertility, plant growth, and yield in a tropical environment. In Organic Fertilizers-From Basic Concepts to Applied Outcomes. InTech, (2016).

[19] H.K. Murwira, P. Mutuo, N. Nhamo, A.E. Marandu, R. Rabeson, M. Mwale, C.A. Palm, Fertilizer equivalency value of organic materials of different quality. In B. D. Vanlauwe, Integrated plant nutrient management in Sub-Saharan Africa: From concept to practice. Trowbridge, UK: CAB International, (2002) 113 – 122.

[20] J.H. Chen, The combined use of chemical and organic fertilizers and/or biofertilizer for crop growth and soil fertility. In International workshop on sustained management of the soil-rhizosphere system for efficient crop production and fertilizer use. Land Development Department Bangkok Thailand, 16 (2006) 20.

[21] M.S. Khan, N.C. Shil, S. Noor, Integrated Nutrient Management for sustainable yield of major vegetable crops in Bangladesh. Bangladesh J. of Agriculture and Environment, 4 (2008) 81-94.

[22] S. Savci, An agricultural pollutant: chemical fertilizer. International J. of Environmental Science and Development, 3(1) (2012) 77-80.

[23] W.R. Stern, Nitrogen fixation and transfer in intercrop systems. Field crops research, 34 (1993) 335-356.

[24] P. Singh, B. Shahi, K.M. Singh, Enhancing Pulses Production in India for Improved Livelihood and Nutritional Security: An Analysis of Constraints and Strategies, (2016) DOI: http://dx. doi. org/10.13140/RG, 2(30789.24805).

[25] C. Johansen, J.M. Duxbury, S.M. Virmani, C.L.L. Gowda, S. Pande, P.K. Joshi, Legumes in rice and wheat cropping systems of the Indo-Gangetic Plain-Constraints and opportunities. International Crops Research Institute for the Semi-Arid Tropics, 2000.

[26] A. Ramakrishna, C.L.L. Gowda, C. Johansen, Management factors affecting legumes production in the Indo-Gangetic Plain. (2000) 156-165.

[27] A.K. Singh, S.S. Singh, V. Prakash, S. Kumar, S.K. Dwivedi, Pulses production in India: present status, bottleneck and way forward. J. of AgriSearch, 2(2) (2015) 75-83.

[28] M. Ali, P. K. Joshi, S. Pande, M. Asokan, S. M. Virmani, Ravi Kumar, B. K. Kandpal, Legumes in the Indo-Gangetic Plain of India. (2000) 35-70.

[29] P.K. Saha, M. Ishaque, M.A. Saleque, M.A.M. Miah, G.M. Panaullah, N.I. Bhuiyan, Long-Term Integrated Nutrient Management for Rice-Based Cropping Pattern: Effect on Growth, Yield, Nutrient Uptake, Nutrient Balance Sheet, and Soil Fertility. Communications in Soil Science and Plant Analysis, 38 (2007) 579-610.

[30] S.I. Hyder, S.A. Tariq Sultan, T. Tabssam, A. Ali, M.A. Ullah, Optimizing Yield and Nutrients Content in Peas by Integrated Use of Bio-Organic and Chemical Fertilizers. International Journal, 37 (2016).

[31] S.S. Tomar, A. Singh, A. Dwivedi, R. Sharma, R.K. Naresh, V. Kumar, S. Tyagi, A.S. Rahul, B.P. Singh, Effect of integrated nutrient management for sustainable production system of maize (Zea mays L.) in indo-gangetic plain zone of India. International J. of Chemical Studies, 5(2) (2017) 310-316.

[32] S.K. Kakraliya, R.D. Jat, S. Kumar, K.K. Choudhary, J. Prakash, L.K. Singh, Integrated nutrient management for improving, fertilizer use efficiency, soil biodiversity and productivity of wheat in irrigated rice wheat cropping system in Indo-Gangatic plains of India. International J. of Current Microbiology and Applied Sciences, 6(3) (2017) 152-63.

[33] B. Biswas, D.C. Ghosh, M.K. Dasgupta, N. Trivedi, J. Timsina, A. Dobermann, Integrated

assessment of cropping systems in the Eastern Indo-Gangetic plain. Field crops research. 99(1) (2006) 35-47.

[34] M.L. Jackson, Soil Chemical Analysis, Prentice Hall of India Pvt. Ltd. New Delhi, India, 1973.

[35] B.V. Subbiah, G.L. Asija, A rapid method for the estimation of nitrogen in soils. Current Science, 26 (1956) 259-260.

[36] S.R. Olsen, C.V. Cole, F.S. Watanabe, L.A. Dean, Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture Circular, 939 (1954) 1-19.

[37] R. Koenig, C. Johnson, Colorimetric determination of phosphorus in biological materials. Industrial and Engineering Chemistry Analytical Edition, 14 (1942), 155-156.

[38] K.A. Gomez, A.A. Gomez, Statistical Procedures for Agricultural Research. John Wiley and Sons, New York, 1984.

[39] S. Dasgupta, A. Sarkar, A.K. Chaitanya, A. Saha, A. Dey, R. Mondal, Response of Potato Crop to Integrated Nutrient Management in the Indo-Gangetic Alluvial Soils of West Bengal, India. J. of Experimental Agriculture International, 16 (2017) 1-10.

[40] S. Matsushima, Nitrogen requirements at different stages of growth. In The Minerals Nutrition of the Rice Plant; John Hopkins University Press: Baltimore, MD, (1964) 199–218.

[41] N.K. Fageria. Mineral Nutrition of Rice. CRC Press, Taylor & Francis Group, (2014) 541.

[42] P.K. Bandyopadhyay, S. Saha, S. Mallick, Comparison of Soil Physical Properties betweena Permanent Fallow and a Long-Term Rice–Wheat Cropping with Inorganic and Organic Inputsin the Humid Subtropics of Eastern India. Communications in Soil Science and Plant Analysis, 42 (2011) 435-449.

[43] G.B. Singh, P.P. Biswas, Balanced and integrated nutrient management for sustainable crop production. Indian J. of Fertilizers, 45 (2000) 55-60.

[44] K.N. Devi, M.S. Singh, N.G. Singh, H.S. Athokpam, Effect of integrated nutrient management on growth and yield of wheat (Triticum aestivum L.). J. of Crop and Weed, 7(2) (2011) 23-27.

[45] R. Kumar, B.C. Deka, M. Kumar, S.V. Ngachan, Productivity, Quality and Soil Health as Influenced by Organic, Inorganic and Biofertilizer on Field Pea in Eastern Himalaya. J. of Plant Nutrition, 38 (2015) 2006-2027.

[46] A.S. Grandy, G.P. Robertson, Land use intensity effects on soil C accumulation rates and mechanisms. Ecosystems, 10(1) (2007) 58-73.

Table 1. *Initial physico-chemical properties of the experimental soil*

Particulars	
Sand (%)	36.8
Silt (%)	28.0
Clay (%)	35.2
Textural class	Clay-loam
Bulk density (g cm^{-3})	1.53
Soil pH	6.84
EC	0.24
Organic carbon (%)	0.66
Available N (kg ha^{-1})	147.84
Available P_2O_5 (kg ha^{-1})	18.24
Available K_2O (kg ha^{-1})	125.25

Table 2. *Details of the treatments employed in the experiment*

Vertical strips (Cropping system; C):	
C_1	Rice –Rapeseed – Fodder cowpea
C_2	Rice – Field pea – Fodder cowpea
C_3	Rice – Wheat – Fodder cowpea
Horizontal strips (Nutrient management; M):	
M_1	100% Recommended dose of Fertilizers (RDF) through chemical fertilizer (CF)
M_2	75% RDN through CF +25% N through FYM+ 100% RD of PK through CF
M_3	75% RDN through CF +25% N through Biogas Slurry + 100% RD of PK through CF
M_4	75% RDN through CF +25% N through Vermicompost + 100% RD of PK through CF
M_5	75% RDN through CF +25% N through Azolla+ 100% RD of PK through CF

Table 3. *Changes in nitrogen (N), phosphorus (P) and potassium (K) uptake with different agronomic practices (two years pooled data)*

Treatments	N 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
CD (p=0.05)	4.93	6.18	1.12	0.64	1.64	5.86
Nutrient management						
M1	96.21	85.11	19.62	9.83	25.33	74.05
M2	99.05	86.33	22.72	11.20	29.12	76.93
M3	98.72	88.13	21.09	10.52	28.08	76.81
M4	80.00	68.99	14.70	6.61	20.41	62.39
M5	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
CD (p=0.05)	11.07	6.41	2.48	1.06	2.83	7.39

Table.4. *Variation in paddy yield parameter as influenced by various agronomic practices (two years pooled data)*

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 ±	3.1	1.3	0.03	0.07	0.05	0.07	0.28
CD (p=0.05)	10.2	4.3	0.11	0.24	0.15	0.24	NS
Nutrient management							
M1	264	168	2.63	27.2	4.84	6.96	40.89
M2	265	163	2.66	27.4	5.08	7.07	41.69
M3	267	163	2.66	27.2	5.01	7.15	41.08
M4	247	145	2.52	26.8	4.18	6.01	41.02
M5	231	134	2.33	26.3	3.91	5.77	40.33
SEm ±	4.9	3.4	0.05	0.17	0.17	0.12	0.53
CD (p=0.05)	14.7	8.6	0.16	0.50	0.50	0.37	NS

Table.5. *Correlation between NPK uptake and yield parameters*

	N Uptake	*P Uptake*	*K Uptake*	*Panicle m^{-2}*	*Filled grain $panicle^{-1}$*	*Panicle wt (g)*	*Panicle length (cm)*	*Test Weight (g)*	*Grain yield (t ha^{-1})*	*Straw yield (t ha^{-1})*	*Harvest Index*
N Uptake	1.00										
P Uptake	0.94[a]	1.00									
K Uptake	0.95[a]	0.93[a]	1.00								
Panicle m^{-2}	0.85[a]	0.86[a]	0.82[a]	1.00							
Filled grain $panicle^{-1}$	0.83[a]	0.85[a]	0.73[a]	0.84[a]	1.00						
Panicle wt (g)	0.75[a]	0.76[a]	0.64[a]	0.80[a]	0.80[a]	1.00					
Panicle length (cm)	0.63[a]	0.69[a]	0.70[a]	0.80[a]	0.54[b]	0.42	1.00				
Test Weight (g)	0.76[a]	0.86[a]	0.75[a]	0.69[a]	0.71[a]	0.71[a]	0.53[b]	1.00			
Grain yield (t ha^{-1})	0.98[a]	0.93[a]	0.96[a]	0.79[a]	0.77[a]	0.71[a]	0.62[a]	0.74[a]	1.00		
Straw yield (t ha^{-1})	0.98[a]	0.93[a]	0.95[a]	0.80[a]	0.77[a]	0.72[a]	0.57[a]	0.74[a]	0.98[a]	1.00	
Harvest Index	0.48[b]	0.49[b]	0.49[b]	0.42	0.40	0.32	0.58[a]	0.38	0.57[a]	0.39	1.00

'a' and 'b' indicates significance level at $p < 0.001$ and 0.01 respectively (n= 30)

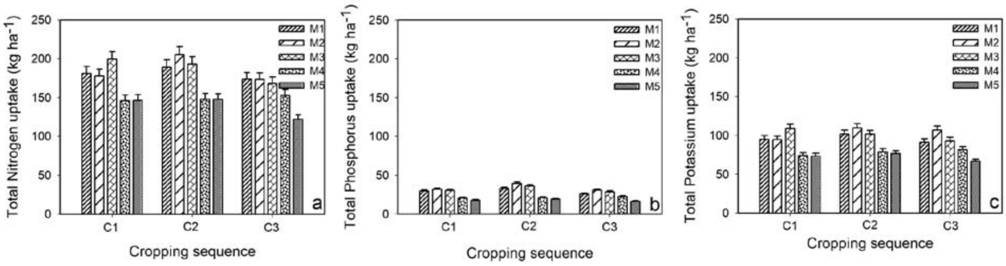

Fig. 1a, b, c. *Interaction effect between cropping sequence (C) and nutrient management (M) for N, P and K uptake respectively*

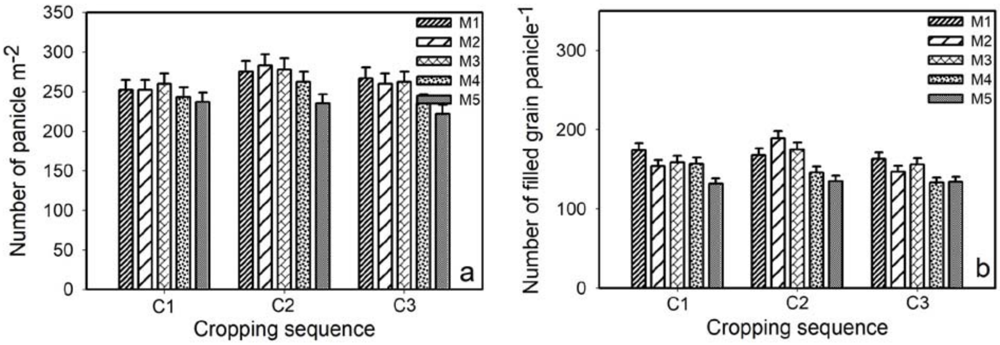

Fig. 2a, b. *Interaction effect between cropping sequence (C) and nutrient management (M) for number of panicle m^{-2} and number of filled grain panicle^{-1} respectively*

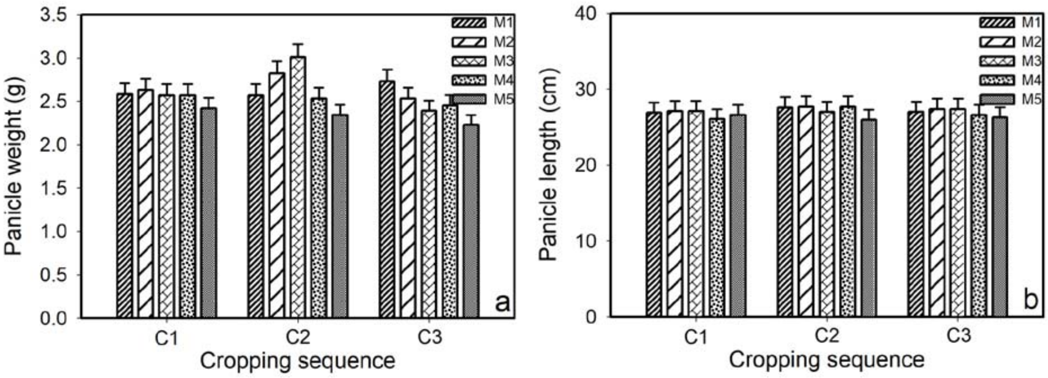

Fig. 3a, b. *Interaction effect between cropping sequence (C) and nutrient management (M) for panicle weight (g) and panicle length (cm) respectively*

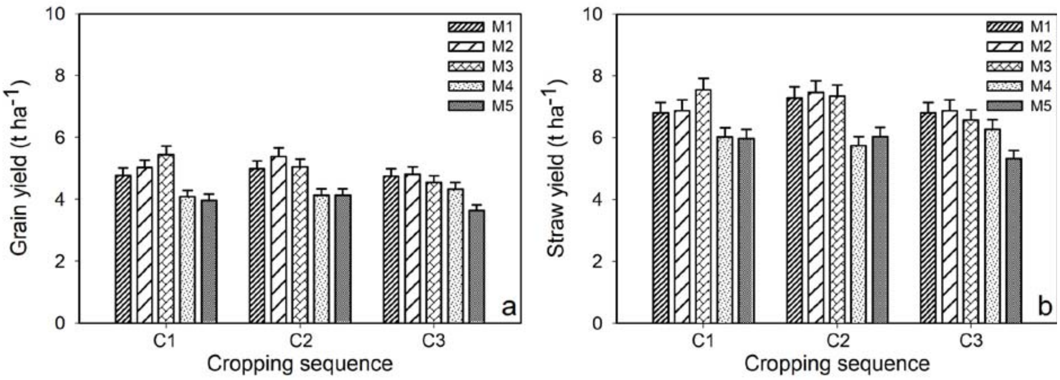

Fig. 4a, b. *Interaction effect between cropping sequence (C) and nutrient management (M) for grain yield and straw yield respectively*