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EVALUATION OF LONG TERM DIFFERENT NUTRIENT MANAGEMENT PRACTICES ON CROP PRODUCTIVITY AND SOIL QUALITY IN RICE (*ORYZA SATIVA*)-POTATO (*SOLANUM TUBEROSUM*)-GROUNDNUT (*ARACHIS HYPOGAEA*) CROPPING SYSTEM IN NEW ALLUVIAL SOIL ZONE OF WEST BENGAL, INDIA

P. Bose[1*], M. Roy[2] and P.K Patra[3]

[1*] Department of Environmental Studies, Visva-Bharati, Santiniketan, West Bengal, India
[2] Department of Agronomy, BCKV, Mohanpur, Nadia, West Bengal, India
[3] Department of Environmental Studies, Visva-Bharati, Santiniketan, West Bengal, India
Email:[1*]boseenvs2010@gmail.com, [2]manabbckv@gmail.com, [3]pulakpatra@visva-bharati.ac.in

ABSTRACT

We analyzed data from a long-term rice-potato-groundnut cropping sequence to evaluate the effects of different nutrient management practices on yield trends, economics and soil fertility of the system. In this study, most of the organic and integrated treatments showed significantly higher mean system yield in terms of rice-equivalent yield (REY) of the 13th and 14th crop cyclethan that of with purely inorganic source. Highest mean rice-equivalent system yieldwas obtained in the treatment with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (14.96 t ha^{-1}). In contrast with the yield result, purely inorganic treatment showed better performance compare to all other organic and integrated treatments from the economical point of view during last two 13th and 14 th cropping year. The organic nutrient-management packages increased the mean soil organic carbon and soil macronutrients (available N, P and K) at the end of 13th and 14 th cropping system cycle over the control (fallow land) and the buildup was maximum in the soil, applied with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (0.98%, 301.8, 61.1 and 173.3 kg/ha for organic carbon, N, P and K). The mean microbial population after thirteenth and fourteenth cropping year in terms of colony forming units increased in a higher rate in soils with organic nutrient supply system (bacteria 3.7 to 14.5 cfu g^{-1}, fungi 3 to 12.3 cfu g^{-1}) compared to the control as against the respective increases of 1.2 cfu g^{-1} and 1.8 cfu g^{-1} in the soils receiving nutrients through chemical fertilizers. Application of 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB was the best organic nutrient management practice compare to other studied management practices for rice–potato–groundnut cropping system in new alluvial zone of West Bengal for improving soil health and productivity. However, this system can be profitable under organic farming only when on-farm generated organic manures are used.

Keyword: Integrated nutrient management, Cropping system, Yield, Soil health

Introduction

Agriculture is the most important sector of the Indian Economy, where 50% of the population depends on agriculture but the shrinking of net cultivation area in recent few decades poses a serious challenge to the sustainability and profitability of farming sector. In view of the declining rate in per capita availability of land, it is necessary to develop strategies and agricultural technologies that conserve environmental sustainability and enable adequate employment and income generation in long term basis, especially for small and marginal farmers who constitute more than 80% of the farming community in India. At the early stage, Green revolution leads to high yields in agricultural sector and addressed the issue of food security. Gradually the agricultural productivity became at optimum level but to cope up with increasing food demand generated from population explosion, high yielding trend and market competition all the technologies and manmade supplements has been used contentiously and excessively to increase the yield without considering the quality of the product and Environmental health. Thus conventional agricultural system became absolutely dependent on the extensive and unscientific application of chemical fertilizers, pesticides and herbicides etc., whereas the continuous and unscientific use of chemical fertilizers and pesticides ultimately affect the soil health adversely as well as leads to decrease product quality. Chemical fertilizers may be helpful for achieving the high yield level in short term but soil physiochemical and biological environments may be deteriorated due to low organic matter content in soil and finally have negative impact on soil productivity as well as soil health in long term basis. In the past, scientists have expressed concerns on the risk about the indiscriminate and blind dependency on chemicals in the agricultural sector as it finally leads to hasty deterioration soil health and both stability and sustainability of the productivity. (Attanayake *et al*., 2010; Rajnish and Subhash, 2011; Muhibbullah *et al*., 2005). It leads to decline the profit and income security of the farmers especially in long term basis. About 75% of the adversely affected households belong to rural communities of developing countries whose livelihood is directly or indirectly dependent on agriculture and allied activities, unable to generate remunerative employment and about 40% families are forced to live in poverty. Finally they compelled to migrate to cities for another source of income, keeping their agricultural lands fallow, may become a major national challenge (FAO, 2009).

Organic farming has expanded rapidly in recent years and is seen as a sustainable alternative to chemical-based agricultural systems (Avery, 2007; Biao *et al*., 2003; Stockdale *et al*., 2001) as it has several environmental benefits compared to conventional agricultural system. It reduces chemical use and increase species abundance, richness (Bengtsson *et al*., 2005; Hole *et al*., 2005), improve soil structure (Schrama *et al*., 2018), increase soil fertility (Leifeld and Fuhrer, 2010), use less energy and reduce agricultural greenhouse gas emissions (Gomiero *et al*., 2008) in one hand and also provide substantially to farmers' food security and improve farmers' livelihoods on the other hand (Scialabba and Hattam, 2002; Parrott *et al*., 2006) Though Organic agriculture generally conserve resources and soil quality through increasing the nutrient availability by controlling the net mineralization-immobilization patterns, a 100 percent conversion to organic agriculture could decrease global yields. According to various studies, this yield reduction could be 30 to 40 percent in intensively farmed regions under the best geo-climate conditions.

In this context there is another sustainable alternative of chemical fertilizer based agriculture on the environment and economic point of view, called Integrated Nutrient Management (INM). Due to more exhaustion of soil nutrients, no single source of nutrients is capable of retain plant nutrients in adequate and balanced proportion. There should be joint role of organic and inorganic fertilizers to sustain productivity and biological health of soil (Babu *et al*., 2007). There are several researchers shows that integrated nutrient management have sustained the soil fertility and crop yield on long term basis (Urkurkar *et al*., 2010). To build environment friendly and economically viable agricultural system, INM is a better option as this approach balancing the soil fertility and plant nutrient supply to an optimum level through the efficient use of available organic and inorganic nutrients. In this approach all the organic and inorganic source of plant nutrients are applied efficiently based on economic consideration and the balance required for the crop. The combined use of organic and inorganic sources of plant nutrients not only increases the production and profitability of field crops, but also it helps in maintaining the fertility status of the soil (Kannan *et al*., 2013).

It is highly desirable to make massive efforts to adopt organic sources as a source of plant nutrients in the developing countries, India in particular. Introduction of Organic source in agricultural system needed not only for Environment and agricultural product quality improvement but also recycling and conservation of natural resources. Keeping this points in view, present investigation was conducted to find out best nutrient management Practice of rice-potato-ground nut system for higher productivity and income level in sustainable manner and for improving soil and environmental qualities.

Scented rice–potato–groundnut is an important cropping system in alluvial soil of sub-humid tropical climate of Indo-Gangetic plain, mostly cultivated by chemically. Organically grown scented rice and potato can be sold with premium price that will make the organic farming profitable. Groundnut is very much helpful for improving soil fertility which ultimately boosting organic farming. In view of the above an experiment with different sources of organic nutrient has been planned in scented rice- potato-groundnut cropping system.

Materials and Methods

The long-term experiment was started from 2004-05 with Rice-Potato-Groundnut cropping system at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal. The experimental sight was located at 22°58´20´´N latitude and 88°30´11´´E longitudes, and 9.75 m above mean sea level under the new alluvial soil zone of West Bengal. The zone falls under hot, humid subtropical climate having average annual rainfall of approximately 1,480 mm and mean annual minimum and maximum temperatures of 12.5 and 36.2 C, respectively. The soil of the experimental area was sandy clay loam in texture with good drainage facilities and having medium to high soil fertility with (7.17-7.63) pH, (0.16-0.21 µs) E.C, (0.72-0.86%) organic carbon respectively. In the experimental site scented rice-potato-groundnut cropping system has been continuing for the last fourteen (14) years with six (6) different nutrient management practices (Detailed in table 1), out of which 4 treatments consist of different sources of organic nutrients and one treatment is integrated nutrient management and other one is purely inorganic. The present investigation was carried out in last thirteenth (2016-17) and fourteenth (2017-18) crop cycleon those six (6) different nutrient management practices with one fallow plot in the experimental site, takenas a control of soil quality. The experiment was fitted in randomized complete block design with three replications and plot size was 10 m × 8 m.

In this experiment farm yard manure (FYM)(0.57% N), Vermicompost (1.04% N), Neem cake (5.11% N), and Dhainchagreen manure was added as organic source of nutrients and *Rhizobium, Azospirillum* and *Azotobacter* are used as bio fertilizers, whereas N, P, K and Zn containing fertilizers was used as inorganic. The recommended doses of inorganic nutrients (RDN) for different crops in the cropping system was as follows: scented rice 60-30-30 ($N\text{-}P_2O_5\text{-}K_2O$ kg ha^{-1}), potato 200-150-150 ($N\text{-}P_2O_5\text{-}K_2O$ kg ha^{-1}) and groundnut 20-60-40 ($N\text{-}P_2O_5\text{-}K_2O$ kg ha^{-1}). In case of organic nutrient management, all manures were applied before final land preparation for transplanting of rice and at planting of potato and Groundnut in furrows. In case of inorganic nutrient management, full quantity of P and K were applied as basal in all the crops and N was applied in split doses. Rice (*Oryza sativa* L.) is grown during rainy (*kharif*) season as scented rice (var. *Gobindobhog*); potato (*Solanum tuberosum*) (var. *KufriJyoti*) is grown in winter (*rabi*) season and groundnuts (*Arachis hypogaea*) (var.*TAG-24*) is grown in summer season sequentially in a single crop calendar year. In this present experiment, 1st crop cycle refers to June 2016 to May 2017 (2016-17), similarly June 2017 to May 2018 (2017-18) indicate 2nd cycles.

Grain yield (kg h^{-1}) of rice, tuber yield of potato (kg h^{-1}) and pod yield of groundnut (kg h^{-1}) was recorded at the time of harvest. Organic yield from purely organic treatment sold in high premium price in market compare to the yield from inorganic treatment. For proper and scientific comparison of productivity and economics between all the different nutrient management practices, yield of all crops under all the nutrient management practices should be in a uniform stage (Equivalent yield). Thus, Yield of all crops (Rice, Potato and Groundnut) under purely organic farming, converted to equivalent yield on organic product premium market price and normal market price basis and used for computing System Rice Equivalent Yield and other economic analysis instead of original yield of rice, potato and groundnut. Yield of all crops (Rice, Potato and Groundnut) under purely organic farming, converted to equivalent yield using this formulae (EY of crop a) = $Ya(Pa/Pb)$, Where, EY is equivalent yield of rice or potato or groundnut, Ya is the organic yield of rice or potato or groundnut under purely organic farming in kg ha^{-1}, Pa is the premium market price of organic product(rice or potato or groundnut) and Pb is the normal market price of rice or potato or groundnut. Whereas equivalent yield of all crops (Rice, Potato and Groundnut) under purely inorganic and integrated farming were same as their original yield, because their price is same as normal market price of rice or potato or groundnut. Rice equivalent yield (REY) of potato and groundnut for all the treatments was calculated by converting the equivalent yield of potato and groundnut into rice equivalent yield on a price basis, using the formula: REY (of crop x) = $Yx(Px/Py)$, Where, REY is rice equivalent yield of potato or groundnut. Yx is the yield of potato or groundnut in kg ha^{-1}, Px is the price of potato or groundnut and Py is the price of rice. Then, System Rice Equivalent Yield (SREY) for whole system of rice-potato-groundnut was calculated by summing up of equivalent rice yield, REY of potato and groundnut in all 6treatments. Ultimately, SREY was used to compare among different treatments. For economic analysis Cost of cultivation, Gross return, Net return, return per rupee investment and Benefit: Cost ratio were computed by standard methods. Economic Efficiency was calculated by dividing the net returns of each treatment with the total days per year during both the years.

Soil samples were drawn at initial and at the end of each cropping cycle (viz. 2016-17 and 2017-18) from a depth of 0–15 cm from each treatment randomly in a zigzag manner of a few meters apart and pooled together to make a composite sample. Soil pH and Electrical Conductivity (EC) was analyzed by standard method whereas, Soil organic carbon (SOC), N, P and K content were analysed using standard procedures (Jackson *et al.*, 1973). For determining the microbiological analysis, the fresh soil samples was crushed and passed through 2.0 mm sieve and stored at 4°C in freeze until the completion of all the analyses. Enumeration of microbial population (Total bacterial count, Phosphate solubilizing bacteria, Cellulose degrading bacteria) and fungal population was done by standard method.

The analysis of variance (ANOVA) was conducted using randomized block design which was performed by Microsoft excel version-2013. The detail of the ANOVA procedure for randomized block design can be found in Gomez and Gomez, 1984(Gomez and Gomez, 1984).

Table 1: Different nutrient management practices that was followed in this experiment are as follows

Treatment	Scentedrice	Potato	Groundnut
T_1	50% RDN in inorganic form + 50% recommended N from FYM + 10 kg ha^{-1} $ZnSO_4$.	50% RDN in inorganic form + 50% recommended N from FYM.	50% RDN in inorganic form + 50% recommended N from FYM.
T_2	33% of recommended N each from FYM, Vermicompost and Neem cake.	33% of recommended N each from FYM, Vermicompost and Neem cake.	33% of recommended N each from FYM, Vermicompost and Neem cake.
T_3	T_2 + Dhainchagreen manure	T_2	T_2
T_4	50% N from FYM + Rock phosphate + *Azospirillum* (4.5 kg culture ha^{-1}) and PSB (4.5 kg culture ha^{-1}).	50% N from FYM + Rock phosphate + *Azotobacter* (4.5 kg culture ha^{-1}) and PSB (4.5 kg culture ha^{-1}).	50% N from FYM + Rock phosphate + *Rhizobium* (4.5 kg culture ha^{-1}) and PSB (4.5 kg culture ha^{-1}).
T_5	T_2 + Biofertilizers same as T_4.	T_2 + Biofertilizers same as T_4.	T_2 + Biofertilizers same as T_4.
T_6	100% RDN in inorganic form + 10 kg ha^{-1} $ZnSO_4$.	100% RDN in inorganic form.	100% RDN in inorganic form.
T_7 (Fallow land)	Fallow land		

(RDN= recommended dose of nutrient; FYM= farmyard manure; PSB=phosphate solubulizing bacteria)

Results and Discussion

Crop yield and system yield

The individual crop yields in all the two cropping system cycle (thirteenth and fourteenth) were highest with 50% of the RDF + 50% of N as FYM (T1) (1.78 and1.8 t ha^{-1} for rice, 16.8 and 16.9 t ha^{-1} for potato and 1.72,1.82 t ha^{-1} for groundnut), which was closely followed by the treatment received 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) in Rice and Groundnut (1.65 and 1.66t ha^{-1} for rice and 1.58, 1.61t ha^{-1} for groundnut) and Recommended dose of nutrient with $ZnSO_4$ particularly for rice (T6) in Potato (16.4 and 15.4 t ha^{-1}) respectively. Application of recommended dose of inorganic nutrient with $ZnSo_4$ particularly for rice (T6) recorded the lowest yield during all the two years in Rice (1.47 and 1.42 t ha^{-1}) whereas the treatment with 50% N from

FYM + rock phosphate + *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T4) showed lowest yield in other two crops, Potato and groundnut (11.3 and 10.6 t ha^{-1} for potato and 1.33 and 1.38 t ha^{-1} for groundnut). If we closely see, all the organic and integrated treatments showed increase in all the individual crop yield from thirteenth to fourteenth crop cycle except 50% N from FYM + rock phosphate + *Azospirillum* and PSB (T4) for potato. Maximum increase of yield of rice potato and groundnut in 2^{nd} cropping cycle (fourteenth) compare to 1^{st} cropping cycle (thirteenth) was 4.6, 4.9 and 6.1 % in 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhainchagreen manure for rice only (T3), 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) and 50% of the RDN + 50% of N as FYM (T1) respectively. Recommended dose of nutrient with $ZnSO_4$ particularly for rice (T6) showed decreases in yield of 3.2, 6.0 and 2.9% in rice, potato and groundnut cropping system during this two studied cropping years. The result showed clear statistically significant difference between the six studied treatments at 0.01% level of significance in all the individual crop yield during two consecutive studied year (2016-17 and 2017-18). Mean yield of thirteenth and fourteenth cropping year of all the crops also showed statistically significant difference (C.D value 0.03 for rice yield, 0.13 for potato yield and 0.04 for groundnut yield) between the six compared studied treatments at 0.01% level of significance. Analysis of data indicated that the effect of different nutrient management practices on yield of rice followed by potato and groundnut is more pronounced in the 1^{st} year than 2^{nd} year which is evidenced by higher CV values (Table 2). We can also interpret that the integrated application of organic and inorganic nutrient showed highest yield compared to all other inorganic and organic treatments. The result previously supported by many researchers indicated that INM practice can be an effective practice and eco-friendly approach to produce greater yield production and maintain satisfactory stable profitability to farmers (Selim, 2018; Parmar and Sharma, 2002; Cheuk *et al*., 2003; Sarwar *et al*., 2007; Sarwar *et al*., 2008; Abedi *et al*., 2010; Ghosh *et al*., 2010; Diacono and Montemurro, 2011). Whereas among all the organic treatment 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) showed highest yield in all the cropping system. Though all the organic nutrient management practice showed higher yield compare to inorganic in rice cropping system but in potato the result became inverted. This might be related to high requirement of nutrients for potato cropping system.

Table 2: Effect of nutrient management packages on crop yield (t/ha) in rice-potato-groundnut cropping system

Treatment	Grain yield of Rice ($t\ ha^{-1}$)			Tuber yield of Potato ($t\ ha^{-1}$)			Pod yield of Groundnut ($t\ ha^{-1}$)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
T_1	1.783	1.795	1.789	16.8	16.918	16.859	1.72	1.825	1.772
T_2	1.617	1.63	1.624	12.8	12.885	12.843	1.35	1.396	1.373
T_3	1.567	1.638	1.603	13.433	13.89	13.662	1.363	1.409	1.386
T_4	1.533	1.578	1.556	11.333	10.625	10.979	1.333	1.383	1.358
T_5	1.65	1.661	1.656	14.3	15	14.65	1.581	1.612	1.597
T_6	1.467	1.42	1.444	16.4	15.415	15.908	1.488	1.444	1.466
S.E(m)	0	0.02	0.01	0.04	0.08	0.04	0.02	0.018	0.01
S.E(d)	0	0.03	0.01	0.06	0.11	0.06	0.03	0.025	0.02
C.D	0.01	0.06	0.03	0.12	0.24	0.13	0.07	0.053	0.04
C.V (%)	0.3	2.51	1.8	0.56	1.13	0.89	3.15	2.347	2.77
P value	0.006	0.004	0.005	0.005	0.006	0.006	0.004	0.005	0.007

Details of the treatments is given in Table 1, S.E(m)= standard error for mean, S.E(d)= standard error for deviation, C.D= critical difference, C.V= coefficient of variation,

On the other hand mean equivalent individual crop yield of thirteenth and fourteenth cropping system and system yield in terms of rice-equivalent yield (REY) showed a different picture in terms of individual original yield as it computed by considering the organic prime product price. Mean system yield in terms of rice-equivalent yield (REY) in the two consecutive cropping system cycle were highest in the treatment with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) (14.96 t ha^{-1}), which was followed by 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhainchagreen manure for rice only (T3) (13.81 t ha^{-1}). Application of 50% N from FYM + rock phosphate + *Azospirillum* and PSB recorded the lowest mean systemrice-equivalent yield of two consecutive cropping cycle (11.95 t ha^{-1}) which was almost same with recommended dose of nutrient with $ZnSo_4$ particularly for rice (T6). All the organic nutrient-management practices except one (50% N from FYM + rock phosphate + *Azospirillum* and PSB) (T4) showed higher mean system yields over the inorganic treatment (Table: 3). Significantly all the treatments showed slight increase in system yield during thirteenth to fourteenth cropping cycle except 50% N from FYM + rock phosphate + *Azospirillum* and PSB (T4) and recommended dose of inorganic nutrient with $ZnSo_4$ particularly for rice (T6) which might be the interpretation of single or small number of organic source and purely inorganic source could not improve the yield of the crops; rather it reduced the system yield, especially in long term basis (Patra *et al*., 2016). However, continue application of organic matter gradually improved the physico-chemical properties of soil and increasing the availability of plant nutrients by reducing nutrient loss from the soil which might have resulted in increased productivity (Chaudhary and Thakur, 2007). Furthermore, as the productivity hugely depend on proper supply of macro- and micronutrients, organic matter maintained this supply in optimal congruence with crop demand which might have improved its yield attributes and yield (Sharma and Subehia, 2014).

Table 3: Effect of nutrient management packages on Mean equivalent yield and System rice equivalent yield (t/ha) in rice-potato-groundnut cropping system

Treatment	Mean Equivalent Yield of thirteenth and fourteenth cropping system (t ha^{-1})			System Rice Equivalent Yield (t ha^{-1})		
	Rice	Potato	Groundnut	2017	2018	Mean
T1	1.789	16.859	1.772	12.939	13.674	13.307
T2	2.033	16.52	1.711	13.059	13.487	13.273
T3	2.007	17.571	1.728	13.428	14.186	13.807
T4	1.948	14.127	1.693	11.977	11.914	11.945
T5	2.073	18.841	1.99	14.544	15.38	14.962
T6	1.444	15.908	1.466	12.037	11.865	11.951

Details of treatments is given in Table 1

System economics

Mean System gross return, System net return, System Benefit: Cost ratio and Return per rupee investment of two consecutive year 2016-17 and 2017-18 showed statistically significant difference (C.D value 2514.845 for Gross return, 2514.845 for Net return, 0.01for B:C ratio and 0.01for SRPRI) between the six studied treatments at 0.01% level of significance. Among the all treatments, application of 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) recorded the highest mean (two consecutive cropping system cycles) gross return 314307 ₹/ha (Table: 4) followed by another purely organic treatment received 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhainchagreen manure for rice only (T3) 290136 ₹/ha. On the other hand purely inorganic system (recommended dose of inorganic nutrient with $ZnSO_4$ particularly for rice) (T6)scored lowest mean gross return 251002 ₹/ha. However, the highest mean system net returns 121099 ₹/ha with highest mean benefit: cost ratio (1.9), meansystem economic efficiency (331.8 ₹/ha/Day) and mean system return per rupee investments (0.93) of two studied cropping year 2016-17 and 2017-18 were realized with application of purely inorganic nutrient treatment (T6). This was due to higher cost of cultivation in case of organic treatment which also include transportation cost of huge quantity of organic manure. The results clearly identifying the purely inorganic cropping system as more beneficial from organic and integrated nutrient management practice from economical perspective as previous researchers showed in their research (Patra *et al.*, 2017).

Table 4: Mean economics of two consecutive cropping year 2016-17 and 2017-18 for rice-potato-groundnut cropping system

Treatment	System GR (₹ ha^{-1})	System total cost (₹ ha^{-1})	System NR (₹ ha^{-1})	System B:C	SRPRI	System EE (₹/ha/Day)
T_1	279987.7	178590.7	101397	1.567	0.567	277.8
T_2	278966.2	214426.8	64539.42	1.3	0.3	176.82
T_3	290135.9	218076.8	72059.17	1.33	0.33	197.422
T_4	251074.9	161631.8	89443.16	1.554	0.554	245.05
T_5	314307.1	217464.3	96842.8	1.445	0.445	265.323
T_6	251001.6	129902.8	121098.8	1.932	0.932	331.778
S.E(m)	870.7279	-	870.7279	0.00	0.00	-
S.E(d)	1231.395	-	1231.395	0.01	0.01	-
C.D	2514.845	-	2514.845	0.01	0.01	-
C.V (%)	0.88724	-	2.709438	0.90	2.62	-
P value	0.007	-	0.004	0.005	0.005	-

GR=gross return, NR=net return, B:C=benefit cost ratio, EE=economic efficiency, SRPRI=system return per rupee investment, Details of treatments is given in Table 1, S.E(m)= standard error for mean, S.E(d)= standard error for deviation, C.D= critical difference, C.V= coefficient of variation

Soil pH, EC and organic carbon

The meansoil pH after thirteenth and fourteenth cropping year under different nutrient management treatments was almost neutral ranging from 7.1 to 7.6 (Table: 5). There were little changes in pH value even after continued addition of fertilizer compare to initial. The mean soil pH after thirteenth and fourteenth cropping year decreased maximum in purely inorganic treatment (T6) (4%) compare to initial. This decline in soil pH may be ascribed to the formation of organic acids due to the decomposition of inorganic fertilizers. Mean soil electrical conductivity after consecutive last two cropping year (2016-17 and 2017-18) decreased in the range of 0.04-0.1 µs in all the treatment compare to initial. The initial status of soil organic carbon (SOC) of the experimental site was medium to high (0.72 to 0.86%) whereas after thirteenth and fourteenth cropping year (2016-17 and 2017-18) the mean soil organic carbon ranged between 0.58 to 0.98% (Table: 5).The result of the compared seven treatments for organic carbon showed statistically significant at 0.01% level of significance in both the consecutive years, 2016-17 and 2017-18. And their corresponding C.D value was 0.08. Addition of organic inputs over the years resulted the increase in mean soil organic carbon after thirteenth and fourteenth cropping year over initial value and the maximum buildup was highest with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) (0.98%), which was followed by another organic treatment received 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhaincha green manure for rice only (T3) (0.97%). Continuous application of organic manure stimulated the activity of soil microorganisms and may be attributed to slower break down rate and constant mineralization rate and increased above and below ground organic residues due to enhanced crop growth (Moharana *et al*., 2012; Prasad *et al*., 2010). Maximum increase of mean soil organic carbon of thirteenth and fourteenth cropping year shown under treatment received 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhaincha green manure for rice only (T3) (24.4%) over initial value. Themean result of soil organic after thirteenth and fourteenth cropping year (2016-17 and 2017 18) categorically showed highest organic carbon content in organic treatment followed by integrated, purely inorganic and fallow land. Many researchers showed the same trend in their research especially after the conversion period in long term basis (Patra *et al*., 2016; Patra *et al*., 2017). The addition of organic complemented with N–P–K increased the organic carbon content of soil over that achieved with N–P–K alone, due to additive effect of N–P–K and organics and interaction between them. This was partially due to addition of carbon and partially due to integration of organic and inorganic fertilizers, resulting in good crop growth, which in turn results in more plant residue addition and helped to build up the soil organic carbon. Results were in accordance with findings of Kumar and Sharma, (2015) who reported an increase in organic carbon content of soil with the addition of organic manures and biofertilizers. The treatments which received only inorganic fertilizers showed lower organic carbon values when compared to initial level which could be due to no addition of organic manures as well as intensive oxidation process aided by degradation and decomposition of organic matter. Treatments receiving super optimum dose of inorganic fertilizers and integration treatments, will produce more biomass, so more amount of stubbles are produced thereby resulting in increase in soil organic carbon after incorporation. The SOC content improved in the fertilized plots compared with the unfertilized plots due to carbon addition through the roots, crop residues and rhizodeposition. These results corroborate the findings of Kundu *et al*. (2002). Many long-term experiments have shown that both chemical fertilizer and manure application increased the SOC content over purely inorganic treatment in the soil, but the increases in SOC were much higher with organic manure (Rudrappa *et al*., 2006; Yadav *et al*., 2000; Bharambe and Tomar, 2004; Aoyama and Kumakura, 2001).

Table 5: Changes in soil pH, EC and Organic carbon under different nutrient management practices in rice-potato-groundnut cropping system (after thirteenth and fourteenth cropping system cycle)

Treatment	pH				EC(µs)				Organic carbon (%)			
	Initial	2017	2018	Mean	Initial	2017	2018	Mean	Initial	2017	2018	Mean
T_1	7.17	7.45	7.44	7.445	0.16	0.112	0.121	0.117	0.72	0.81	0.83	0.82
T_2	7.24	7.583	7.5	7.542	0.19	0.116	0.134	0.125	0.74	0.86	0.97	0.915
T_3	7.43	7.613	7.597	7.605	0.18	0.119	0.13	0.124	0.78	0.95	0.99	0.97
T_4	7.63	7.64	7.603	7.622	0.21	0.097	0.121	0.109	0.84	0.94	0.95	0.945
T_5	7.33	7.52	7.467	7.493	0.18	0.122	0.126	0.124	0.86	0.97	0.98	0.975
T_6	7.6	7.397	7.19	7.293	0.17	0.109	0.117	0.113	0.72	0.66	0.61	0.635
Fallow Land	-	7.147	7.11	7.128	-	0.119	0.115	0.117	-	0.6	0.56	0.58
S.E(m)	-	0.07	0.05	0.043	-	0.01	0.01	0.007	-	0.03	0.03	0.019
S.E(d)	-	0.099	0.071	0.061	-	0.015	0.014	0.01	-	0.04	0.04	0.026
C.D	-	0.216	0.154	0.126	-	0.032		0.021	-	0.08	0.08	0.054
C.V (%)	-	1.626	1.165	1.416	-	15.81	14.29	15.02	-	5.66	5.21	5.436
P value	-	0.001	0.002	0.005	-	0.055	0.08	0.085	-	0	0	0.002

Details of treatments is given in Table 1, S.E(m)= standard error for mean, S.E(d)= standard error for deviation, C.D= critical difference, C.V= coefficient of variation

Available N, P and K

The average mean after thirteenth and fourteenth two consecutive cropping year of available N, P and K of the soil were ranged from (225.9-301.8), (41.1-61.1) and (132.3-173.3) kg/ha, respectively (Table: 6). The highest average mean after two consecutive cropping cycle of available N, P and K of the soil showed in organic treatment T5, 301.8, 61.1 and 173.3 kg/ha respectively whereas the lowest value recorded in fallow land, 208.4, 32.2 and 128.6 kg/ha respectively. All the organically treated (T2-T5) and integrated (T1) treatments showed higher mean available N, P and K content compare to fully inorganic (T6) and fallow land (T7). The mean soil N, P and K after last two consecutive cropping year (2016-17 and 2017-18) increased under organic inputs was to the tune of 6.4 to 33.6%, 1.6 to 8.4% and 8.4 to 31.0%, respectively over the purely inorganic treatment (T6). On the other hand integrated treatment received with 50% of the RDN + 50% of N as FYM (T1)showed significant increase of N(21.4%), P (24.1%) and K (14.2%) over the soils under inorganic inputs (T6). Both soil N and P showed statistically significant difference between seven studied treatments in the two individual studied year at 0.01% level of significance. The mean value soil N and P concentration of the two studied years also revealed a significant difference (C.D value 32.7414 for N and 3.21148 for P) among seven studied treatments at 0.01% level of significance. Whereas in soil K content the result was non-significant at 0.05% level of significance among the seven treatments for both the studied years but there was a significant difference at 0.01% level of significance when both the years was pooled. Maximum increase of mean available N of two studied cropping year 2016-17 and 2017-18 was recorded in the treatment with33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) (44.8%) followed by another organic treatment with 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhaincha green manure for rice only (T3) (41.4%) and integrated treatment with 50% of the RDN + 50% of N as FYM (T1) (31.5%) over the control system (T6) (fallow land). Similar trend was followed in different researches, where application of maximum combination of organic sources with bio fertilizers showed higher nutrient availability especially for long term basis (Patra *et al.*, 2016; Patra *et al.*, 2017). The higher available nitrogen content in organic treated plots might be due to high organic carbon content,slow N mineralization from FYM and N fixation by bio fertilizers (Yadav *et al.*, 2000; Gami *et al.*, 2001). Whereas in Integrated application of organic and inorganic sources, N mineralization from FYM and direct inclusion of N through inorganics resulted increase in soil N over purely inorganic and fallow land. In addition, integration of organic and inorganic treated plots produced more biomass and, therefore, possibly had more extensive root systems that may have contributed to increased N levels. Anwar *et al.* (2005) studied the effect of integrated application of inorganic and organic fertilizers on soil health. They found that soils treated with organic manures +inorganic fertilizers had more positive impact on available nitrogen than soils received with inorganic fertilizers alone. The lower nutrient content in soils under inorganic treatment was a result of mining of available N with continuous cropping over a long period of time. Maximum mean build-up of available P after two studied cropping year 2016-17 and 2017-18 shown in soils under purely organic treatment with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) (30.8 kg-ha) followed by another two purely organic treatment with 33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhaincha green manure for rice only (T3) (29.7kg-ha) and 33% of recommended N each from FYM, Vermicompost and Neem cake (T2) (22.3 kg-ha) over control treatment (T7). This might be due to the continuous application of organics released phosphorus by solubilize native phosphorus through organic acids and reduced the activity of polyvalent cations thereby reducing the P-fixation (Gupta *et al.*, 1988; Urkurkar *et al.*, 2010). In case of soil K, treatment received with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5) reported maximum increase of mean available K after two studied cropping year (34.8 %) followed by the treatment received with33% of recommended N each from FYM, Vermicompost and Neem cake along with Dhaincha green manure for rice only (T3) (28.9 %) and 33% of recommended N each from FYM, Vermicompost and Neem cake (T2) (19 %) over the control (T7). Many researchers reported similar results and they revealed that, application of organic manure reduced the leaching loss of K and lead to increase K concentration in soil (Mairan *et al.*, 2005; Manuja *et al.*, 2013). Its favorable effect is evident in enhancing the solubility of insoluble K compounds during the decomposition process and increasing cation-exchange capacity, which ultimately attributed the increased soil k content.

Table 6: Status of soil available N, P and K under different nutrient management practices in rice-potato-groundnut cropping system (after thirteenth and fourteenth cropping system cycle 2016-17 & 2017-18)

Treatment	Available Nitrogen (kg ha^{-1})			Available Phosphorus (kg ha^{-1})			Available Potassium (kg ha^{-1})		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
T_1	260.773	287.467	274.12	49.867	52.067	50.967	149.82	152.313	151.067
T_2	270.267	273.093	271.68	54.133	55	54.567	150.993	154.99	152.992
T_3	281.307	308	294.653	60.867	63.067	61.967	162.837	168.703	165.77
T_4	234.08	246.4	240.24	46.133	46.933	46.533	141.643	145.2	143.422
T_5	293.627	310.053	301.84	61.6	64.533	63.067	170.353	176.257	173.305
T_6	217.653	234.08	225.867	39.6	42.533	41.067	134.237	130.313	132.275
Fallow Land	205.333	211.493	208.413	33.733	30.8	32.267	131.817	125.363	128.59
S.E(m)	14.293	17.293	11.217	1.502	1.608	1.1	14.656	14.513	10.313
S.E(d)	20.213	24.456	15.864	2.124	2.274	1.556	20.726	20.524	14.584
C.D	44.04	53.285	32.741	4.628	4.956	3.212	-	-	30.101
C.V (%)	9.829	11.209	10.587	5.264	5.494	5.384	16.872	16.892	16.882
P value	0.002	0.004	0.002	0.005	0.002	0.001	0.06	0.065	0.003

Details of treatments is given in Table 1, S.E(m)= standard error for mean, S.E(d)= standard error for deviation, C.D= critical difference, C.V= coefficient of variation

Soil biological properties

The Soil biological properties was significantly influenced by different nutrient management practices in the average mean after thirteenth and fourteenth two consecutive cropping year (2016-17 & 2017-18) (Table: 7). Both the soil biological properties (total bacteria and fungi) resulted a statistical significant difference among the seven treatments under study for the two consecutive year. Similarly, the pooled value of the two years also shown a significant difference among the seven treatments at 0.01% level of significance with the corresponding C.D value 1.690174 and 1.57275 respectively. The microbial and fungal population of the experimental soil showed maximum accelerated upon receiving nutrients either through organic manure or organic and inorganic integrated sources as compared to control (fallow land). Organics supplied the nutrients by decomposition and mineralization of nutrients and in addition with bio fertilizers in soil creating a favorable condition for the proliferation of microbes in the soil (Table: 7). Organic manure addition with inorganic fertilizer showed a profound increase in the microbial population in comparison to chemical fertilizer used alone. The highest average mean population of soil bacteria and fungi of two consecutive cropping cycle showed in organic treatment received with 33% of recommended N each from FYM, vermicompost and Neem cake along with *Azospirillum*, *Azotobacter*, *Rhizobium* and PSB (T5), 24.5×10^6 cfu g^{-1} soil and 20.2×10^4 cfu g^{-1} soil respectively and the lowest value recorded in control (T7) (fallow land) 10×10^6 cfu g^{-1} soil and 7.8×10^4 cfu g^{-1} soil respectively. This might be due to synergistic effect of bio fertilizers with added three organic manure components, which in turn, induced high degree of mineralization. The mean soil total bacterial and fungal population after thirteenth and fourteenth cropping year was increased by 3.7 to 14.5× 10^6 cfu g^{-1} soil and 3to 12.3 × 10^4cfu g^{-1} soil respectively under organic treatments over the control as against the respective increases of 1.2× 10^6 cfu g^{-1} soil and1.8 × 10^4 cfu g^{-1} soil in the soils receiving nutrients through chemical fertilizers (Table: 7). The bacterial count noticeably increased with application of different organic N sources compared to control. Kumari *et al*. (2017) justified the finding of present experimentation. On the other hand the application of organics along with chemical fertilizers also registered a significant increase in bacterial population over control. The long term application of various organic manure leads to increase soil organic carbon, which generally served as a source of energy for biological activity, thereby enhancing the density of microbes in organic applied treatments (Moharana *et al*., 2012). Kuttimani *et al*. (2017) revealed that the fungal population had a positive correlation with addition of organic sources of nutrients in the treatments. Overall, most of the soil microorganisms are chemo-autotrophs, which require organic source of carbon as food and oxidation of organic substances provides energy which might be the reason in improving microbial population in soils applied with organics (Ingle *et al*., 2014).

Table 7: Status of Total soil bacteria and fungi (cfu g^{-1}) under different nutrient management practices in rice-potato-groundnut cropping system (after thirteenth and fourteenth cropping system cycle)

Treatment	Total soil bacteria (10^6 g^{-1} soil)			Fungi (10^4 g^{-1} soil)		
	2017	2018	Mean	2017	2018	Mean
T_1	14.33	15	14.67	20	20.33	20.17
T_2	16.67	17	16.84	14	14.67	14.34
T_3	13.33	14	13.67	13	14.33	13.67
T_4	20.33	21.67	21	10.33	11.33	10.83
T_5	23.33	25.67	24.5	19.33	21	20.17
T_6	12.33	10	11.17	10	9.33	9.665
Fallow Land	10.33	9.67	10	7.67	8	7.835
S.E(m)	0.845	0.792	0.579	0.77	0.754	0.539
S.E(d)	1.195	1.12	0.819	1.089	1.067	0.762
C.D	2.604	2.44	1.69	2.372	2.324	1.573
C.V (%)	9.259	8.496	8.878	9.894	9.236	9.558
P value	0.002	0.004	0.002	0.001	0.003	0.002

Details of treatments is given in Table 1, S.E(m)= standard error for mean, S.E(d)= standard error for deviation, C.D= critical difference, C.V= coefficient of variation

Conclusion

From this study, it can be concluded that continuous application of different organic manure with or with out biofertilizers can maintain the soil health and also useful for good productivity especially for long term basis. The same systems can be profitable under organic farming only when on-farm generated organic manures are used. System with Integration of inorganic fertilizer with organic manure may also strengthening yield capacity compare to purely inorganic system and also can maintain positive balance of N, P, K and Organic carbon in the soil.

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