International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(5): 255-258

Received: 19-07-2018
Accepted: 23-08-2018

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Influence of long term fertiliser experiment on soil organic carbon, available nutrients and microbial population in an acid inceptisols of tropical India

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Abstract
A study was conducted to determine soil organic carbon and nutrient content in soil in a long term fertiliser experiment in relation to inorganic and integrated application of organic manure in rice-rice system on an acidic sandy loam soil. The fertilizer treatment included balanced, imbalanced fertilisation and integration of organic manure like FYM along with soil conditioner and absolute control. The results showed that N alone or N and P and K did not have any significant effect on soil organic carbon and N but significantly higher than absolute control. The available N was 32.25% higher in NPK+FYM than in 100%NPK in comparison to 10.24% increase with super optimal dose of fertiliser. Only FYM along with NPK registered a buildup of available P in soil compared to other treatments. Buildup of available K in soil over a period 11 years was observed. The FYM along with lime treated plot showed higher microbial population. The grain yields were significantly influenced by the treatments. Integration of inorganic along with organic manure proved superior for better crop growth and yield.

Keywords: long term, rice, soil organic carbon, available nutrients, yield

Introduction
Soil is a natural body with biological activity, and the level of soil fertility is the basic condition to determine soil productivity. Soil and crop management practices such as fertilization, crop rotation and land-use change exert a considerable influence on soil chemical and biological properties over time. Routine applications of inorganic fertilizer and manure are an essential component of soil management in arable crop production systems. These amendments are used primarily to increase nutrient availability to plants, but they can also affect soil microorganisms.

Since 1980s, amount of chemical fertilizers increased rapidly, while the amount of organic fertilizers decreased gradually. The application of chemical fertilizers became the most important measure of increasing grain yields. The utilization of chemical fertilizers not only increases crop yields, but also changes soil physicochemical properties. Soil microorganisms and the processes that they control are essential for the long-term sustainability of agricultural systems (Wardle *et al*., 1999) [20] and are important factors in soil formation and nutrient cycling. It has been frequently reported that soil microbial biomass and activity is an important aspect of soil quality (Schloter, *et al*., 2003) [13].

Application of organic manures improves the physical and microbial condition of the soil and enhances fertilizer use efficiency when applied in conjunction with mineral fertilizer (Babu *et al*. 2007) [1]. Soil productivity and sustainability are intimately linked to soil biological properties, which provide resiliency and buffering capacity of soil to alleviate stress.

Materials and Methods
The long-term fertilizer experiment of All India Coordinated Research Project (AICRP) of ICAR at OUAT, Bhubaneswar, India (20°17′ N, 85°49′ E and 30 m above mean sea level) since 2005-06 was selected for this study. The location of the experimental site is characterized as sub-humid subtropical climate with dry season from October to June and wet season from July to September. The soil of the experimental site was sandy loam in texture, acidic (pH 5.8) and udic Ustochrept type. Rice cultivar Swarna and Lalata were grown under flooded condition in both *kharif* and *rabi* season of every year. Among twelve Seven

treatments *viz*., 100% N at 80 kg ha^{-1} of N in the form of urea, 100% NP at 80 kg ha^{-1} of N and 40 kg ha^{-1} of P_2O_5 in the form of DAP and urea, 100% NPK at 80:40:40 kg ha^{-1} of $N:P_2O_5:K_2O$ in the form of DAP, urea and MOP; 150% NPK; 100% NPK+ FYM; 100% NPK+ Lime+ FYM, FYM at 5 t ha^{-1} Lime as $CaCO_3$ @ 1t ha^{-1} and an unfertilized control were evaluated for the study. Nitrogen was applied in three splits *i.e*. 25% as basal, 50% at 18 days after transplanting and 25% at panicle initiation stage. Total P was applied as basal and K was applied 50% as basal and 50% at panicle initiation stage. Rice seedlings were transplanted at a spacing of 20 cm × 10 cm with 2-3 seedlings per hill. Necessary intercultural, water management and plant protection measures were undertaken in general until the crop was matured for harvesting. The experiment was laid out in randomized block design (RBD) and replicated in quadruplicate.

Surface soil samples (0-15 cm depth) were collected during fallow period after harvest of *rabi* rice 2016 from each treatment plot. Each soil sample was separated into two parts. One part was air-dried and stored at room temperature for determining soil chemical properties. The other part was passed through a 2-mm sieve, moistened to 60% of their water holding capacity, and immediately stored at 4 °C for the measurement of soil microbial and biochemical properties. Soil pH was determined with a glass electrode pH meter (Jackson 1973) [6]. Available N was determined by Kjeldahl method (Subbiah and Asija 1956) [17]. Available P was extracted with Olsen reagent (0.5 *M* NaHCO3 at pH 8.5 (Olsen *et al*. 1954) [10] at soil extractant ratio of 1:20, shaken for 30 min and quantified by molybdenum-blue colour method using a spectrophotometer. Available K was extracted with neutral normal ammonium acetate (pH 7.0) shaken for 5 min and measured by flame photometer (Jackson 1973) [6]. The SOC was determined by dichromate oxidation (Walkley and Black 1934) [19]. Microbial habitat groups in soil such as bacteria, fungi and actinomycetes were enumerated using nutrient agar, rose Bengal agar and Kenknight's agar as growth medium, respectively, following dilution plating viable count method (Weaver *et al.* 1994) [21]. After the required incubation period, the colony forming units (cfu) were counted and expressed as cfu g^{-1} of soil. All the data were subjected to statistical analysis as per the methods suggested by Gomez and Gomez (1984) [5] at 5% significance level.

Table 1: Changes in nutrient availability as influenced by manurial treatments

Treatments	pH_w (1:2.5)	SOC (g /kg)	Available macro-nutrients (kg /ha)		
			N	P	K
100%NPK	4.97	5.20	314	7.57	111
150%NPK	5.28	5.92	371	9.67	150
100%NPK+FYM	5.48	6.90	409	49.15	152
100%NPK+LIME+FYM	5.70	6.80	372	52.57	159
100%N	4.81	5.12	297	6.45	93
100%NP	5.13	5.75	316	10.15	104
Control	5.06	3.02	203	5.85	82
CD (P=0.05)	0.15	1.09	38.65	3.14	14.6
CV (%)	1.97	13.58	8.28	13.86	8.49
Initial	5.8	4.3	187	19.7	43.40

Results and Discussions

Soil reaction

The data on soil pH revealed that there was general decrease in pH from initial value of 5.80 in all treatments. This result was in contrast with Devi (2002) [3] reported that there was no significant effect on soil pH within 13 years of cropping on a *vertic Haplaquept*. Among all the treatments Lime and FYM along with balanced fertilization recorded highest pH. This indicates that continuous application of lime with FYM along with optimum dose of NPK maintained the pH at a slightly higher level than no lime treatments. There was a maximum drop of 0.83 unit in the plot treated with optimum dose of fertilizer (100%NPK). Nambiar (1994) [9] also reported that the soil pH decreased by 0.9-1.0 units from the initial value on two *Alfisols* (acidic pH) at Ranchi and Palampur.

Soil organic carbon (SOC)

Soil organic carbon of surface soil (0-15 cm) measured by Walkley and Black method varied from a lowest of 3.02g/kg in un manures control plot to a highest of 6.80 g/kg in 100% NPK+FYM+Lime treatment (Table 1). It maintained a higher level of SOC than other treatments and soils of all the manured treatments had significantly higher content of SOC than control. There is an increase in SOC in the plot with 100%NPK+Lime+FYM by 32.69% over control. Results from a few long term experiments also showed similar build up of SOC due to application of manure with balanced fertilization (Tripathy *et al*., 2014) [18]. The results revealed that cultivation over the years caused an increase in the soil organic carbon content in all the treatments except control. Manna *et al*. (2007) [8] observed that application of fertilizer NPK, either alone or in combination with FYM sequestered more C and improved soil qualities and crop productivity. The magnitude of decrease in case of control was 29% from the initial value of 4.3 g/kg. In recent study, Elayarajan *et al.*, (2015) [4] have reported an increase in SOC of surface soil due to continuous application of fertilizers. Balanced fertilization, super-optimal dose of NPK on the other hand increased the content by 72% and 96% over the control respectively. Addition of extra dose of NPK (150% NPK) however, recorded significantly higher SOC in soils. This might be due to more root biomass accumulation in soil than 100% NPK treatment. Imbalance fertilization did not show any significant difference in SOC content than that of balanced fertilization.

Available nutrients

There was an increase in available nitrogen content of soil in all the treatments over 11 years (Table 1). In all fertilized plots increase in available N content is due to addition of more roots and stubbles and accumulation of more organic matter in soil. Available nitrogen varied from 203 kg/ha in control to 409 kg/ha in 100% NPK + FYM applied plot. The treatment adding more residues accumulate more organic matter and available N. In FYM amended treatment, N mineralization is more due to better biological activity (Bhattacharyya *et al.*, 2015) [2]. 100% NPK showed 54%

increase over control and 150%NPK showed 18% higher nitrogen content over balanced fertilization.

Results presented in Table 1 revealed that the manurial treatments had significant effect on available P content of surface soil. Available Phosphorus varied widely from 5.85 kg/ha in control to 52.57 kg/ha in 100%NPK+Lime+FYM treated plot. Addition of FYM to 100%NPK measured the next best value for Olsen P. Higher amount of available P measured in FYM amended treatment is due to addition of FYM, reduced or no fixation by Al/Fe with increase in pH, more solubility of inorganically bound P and mineralization of organic P (Khiari, 2005) [7].

Available potassium is varied from 82kg/ha in control to 159 kg/ha in plot receiving 100% NPK+ Lime+ FYM. Positive effect of FYM on crop also been reported by Pattanaik (2012) [11].Release of various types of organic acids by microorganisms also help in solubilizing the insoluble K to available form of K (Sheng and He, 2006) [15]. 100% NPK+FYM was at par with 100%NPK+Lime+FYM. There was an increase in potassium content in all the treatments over the initial K content i.e.43.4kg. All the treatments varied significantly with the control plot. There was an increase of 35% and 82% in 100%NPK and 150% NPK treatment over the control. Higher content of available K in 150%NPK treatment is due to addition of more organic biomass through roots and stubbles.

Table 2: Effect of manurial treatments on fungi, bacteria and actinomycetes population (cfu g^{-1} soil)

Treatments	Fungus ($\times 10^4$)	Bacteria ($\times 10^6$)	Actinomycetes ($\times 10^6$)
100%NPK	13.37	12.62	0.263
150%NPK	15.25	17.87	0.275
100%NPK+FYM	33.62	17.12	0.327
100%NPK+LIME+FYM	21.75	23.75	0.334
100%N	14.12	13.00	0.224
100%NP	15.00	15.25	0.232
Control	10.75	5.12	0.205
CD (0.05)	3.51	3.93	0.04
CV (%)	14.47	17.69	9.52

Biological activity

Microbial Population

Results presented in table 2 revealed that the soil fungal population varied from 10.75×10^4 cfu/g to 33.62×10^4 cfu/g. All other treatments recorded significantly lower population than the 100%NPK+FYM treated plot. Second highest population was observed in 100%NPK+Lime+FYM treated plot. Integrated use of 5t FYM and 100%NPK showed highest fungal population which was 212% more than that of control. Integration of FYM to inorganic fertilizer maintained much higher population than other treatments which might be due to favorable effect of FYM on bacterial population (Devi, 2002) [3].

Bacterial population measured varied from 5.12×10^6 cfu/g to 23.75×10^6 cfu/g. The treatment with 100%NPK+Lime+FYM recorded significantly highest bacterial population Application of Lime increased bacterial population by 57% over the balanced fertilization which is due to the favorable effects of pH on bacterial population due to rise in pH from 5.06 in control to 5.70 and 5.56 in 100%NPK+Lime+FYM and 100%NPK+Lime treated plot respectively (Paul and Clark, 1989) [12].

Actinomycetes population varied from 5.37×10^6 cfu/g to 1.62×10^6 cfu/g. Application of FYM with or without Lime showed highest actinomycetes population. Lime application caused an increase in actinomycetes population. This is supported with the fact that the increased organic carbon in limed plots might have been conducive for the actinomycetes growth (Shah *et al.*, 1990) [14].

Table 3: Effect of manorial treatments on grain and straw yield (q/ha)

Treatments	Grain yield	Straw yield	Total biomass
100%NPK	32.52	41.97	74.50
150%NPK	39.71	45.39	85.11
100%NPK+FYM	49.04	55.04	104.08
100%NPK+LIME+FYM	45.33	52.08	97.41
100%N	15.85	19.75	35.61
100%NP	30.21	31.87	62.09
Control	10.60	16.33	26.94
CD (P=0.05)	5.89	9.75	14.4
CV (%)	12.58	17.57	14.07

Yield

Results on grain yield showed (table 3) that highest yield of 49.04 q/ha was obtained in 100%NPK+FYM treatment which was at par with 100%NPK+Lime+FYM treatment (45.33q/ha) and it was significantly higher than all other treatments. Combination of FYM to 100% NPK resulted in significant increase in grain yield in all the years. There was 22.10% yield increase in 150%NPK over 100%NPK. In a study conducted on typic *Ustochrept* on a clayey soil of Andhra Pradesh (Srilatha *et al.*, 2014) [16] however, reported more yield with 150%NPK than 100%NPK +FYM. Grain yield was significantly lower in control plot than all other treatments. Straw yield followed the same trend as grain yield with highest in 100%NPK+FYM treatment and lowest in control.

Conclusion

Within eleven years the treatments showed that combination of FYM 5t /ha with recommended doses of NPK fertilizers however, resisted the drop in pH. Eleven years of continuous cropping with fertilizers increased the SOC content, available N and available K. In contrast there was a drop in available P in all treatments except the 100% NPK + FYM treatment. All fertilized treatments recorded significantly higher biological activity than control. Grain yield of all fertilized plots that received 100%NPK or higher NPK or combination of other nutrients or FYM produced significantly higher yield with highest yield measured in 100% NPK + FYM treatment.

Acknowledgements

Authors are grateful to AICRP on LTFE under ICAR for financial and technical support to conduct the experiment.

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