



# Long term effect of fertilization on rice (*Oryza sativa*) yield, nutrient uptake, economics and soil fertility under 25 years old rice-rice cropping system in vertisol of Tamil Nadu

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## Abstract

The continuous use of fertilizers on yield, nutrient uptake, economics and soil fertility was studied under 25 years old rice-rice cropping system in Vertisol of sub tropical India. Significant increase in grain and straw yield and nutrients (N,P and K) uptake in grain and straw was observed in Integrated Nutrient Management (INM) practices. A strong negative correlation occurred between organic carbon and sand and bulk density of soil. Correlation between organic carbon and silt, clay, pore space, infiltration rate and water holding capacity are significantly positive. The INM treatment recorded higher yield resulting in higher economic returns, additional net income and benefit: cost ratio. Application of RDF with organic manures in rice is socially acceptable, economically viable and environmentally sustainable way of nutrient application which helps in sustainable crop production, greater profit and maintaining soil quality.

**Keywords:** Rice-rice cropping system, integrated nutrient management, soil fertility, net income, partial budgeting

## Introduction

Generally in field experiments, when fertilizers are once applied to a particular unit they are not fully utilized on that particular unit. The treatment may leave residual effect on the succeeding crop. Among the nutrients, nitrogen shows a fair response in the same crop season when it is applied while, response of phosphorous and potash is generally visible in the second and third year of experimentation (Liu *et al.*, 2014). The soil gets exhausted due to increase in plant growth inspite of continuous application of nitrogen, phosphorus and potassium. To formulate fertilizer recommendations to crops, it is therefore, essential that the experiment should be repeated over time at the same site, because, the effects of climate, soil, fertilizer, agronomic practices get stabilized only after a period of years and responses to fertilizer treatments also become more stable and reliable (Kidd *et al.*, 2017). Long term field experiments, therefore, form one of the most useful tools for technical advances and are indispensable for framing empirical rules for the conduct of practical agriculture. These experiments can be used for precise monitoring of changes in soil fertility and soil productivity.

Rice is the most important and staple food crop for more than two third of population of India. The slogan "RICE IS LIFE" is most appropriate for India as this crop plays

vital role in our national food security and a mean of live hood for millions of rural households. India is the second largest rice producing country in the world after China. Cauvery Delta Zone is the potential tract in the traditional rice cultivated area of Tamil Nadu. Rice-Rice cropping system is the most prevailing system in this zone (Stalin *et al.* 2006). It is being increasingly realized that when crops are grown in system, the fertilizer requirement of the cropping system as a whole is important than individual crop (Sharma and Subehia, 2003). There is a need to revive the age old practice of application of organic manures to maintain soil fertility and also to supplement many essential plant nutrients for crop productivity. The use of inorganic fertilizers in combination with organic manures has been found more advantageous than either of them alone for sustainable agriculture on long term basis (Kumara *et al.*, 2018). However, long term fertilization of inorganic fertilizers with organic fertilizers, farm chemicals and biofertilizers in rice - rice cropping system is very limited. Keeping these points in mind, a Permanent Manurial Experiment (PME) was started to study the continuous use of inorganic fertilizes with organic fertilizers, farm chemicals and biofertilizers on soil fertility and rice productivity in 1992 in Tamil Nadu Rice Research Institute, Aduthurai, Thanjavur district, Tamil Nadu, India.



## Statistical Analysis

The data for the crop and soil properties were analysed by analysis of variance as outlined by Gomez and Gomez (1984). The significance of the treatment effect was

determined using F-test and to determine the significance of the difference between the means of the two treatments, least significant differences (LSD) at 5% probability level. Correlations and regressions were determined using the data analysis tool pack of MS Excel (2003).

**Table 1 Treatment details**

T. No.	<i>Kharif</i> (kg ha <sup>-1</sup> )				<i>Rabi</i> (kg ha <sup>-1</sup> )			
	N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	
1	125	50	0		150	60	0	
2	125	0	50		150	0	60	
3	125	50	50		150	60	60	
4	125	50	50		150	0	60	
5	125	50	50	GM	150	60	60	FYM
6	125	50	50	GM + Azos	150	60	60	FYM+BGA
7	125	50	50	GM+GYP	150	60	60	FYM+GYP
8	125	50	50	ZnSO <sub>4</sub>	150	60	60	ZnSO <sub>4</sub>
9	125	50	50	WC	150	60	60	WC
10	125	50	50	GYP	150	60	60	GYP
11	125	50	50		112.5	45	45	
12	125	50	50	CPC	150	60	60	CPC
13	Absolute control				Absolute control			

FYM: Farm yard manure – 12.5 t ha<sup>-1</sup>; GM:Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>; BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>

For *Kharif* N splits: 4 splits: Basal, 15 DAT, 30 DAT, 45 DAT – 25 % each ; For *Rabi* N splits: 4 splits: Basal, 20 DAT, 40 DAT, 60 DAT – 25 % each

## Results and Discussion

### Grain and straw yield

All the treatments with fertilizers either alone or in combination with organics/biofertilizer/herbicide/soil amendment under study showed significant increase in yield over control (Table 2). During both the seasons, the application of NPK fertilizer at 125:50:50 kg ha<sup>-1</sup> along with green manure @ 6.25 t ha<sup>-1</sup> and gypsum @ 500 kg ha<sup>-1</sup> (T<sub>7</sub>) recorded significantly higher grain yield than other treatments. On an average, the treatment NPK + green manure +gypsum (T<sub>7</sub>) was the most productive with yields increasing up to 81% over control (T<sub>13</sub>), 66% over NPK + Gypsum (T10), 62% over NPK +Green Manure + Azospirillum (T6) and 59% over NPK + Green Manure, respectively. The grain yield data under

the study emphasized the need for conjunctive use of organic manures with inorganic NPK fertilizers. Besides application of gypsum might have provided sulphur nutrient for rice and also eliminated ill-effects of toxicity of ferrous and manganese ions due to continuous submergence. Therefore, the combined use of organics, inorganics and specific amendment could sustain the productivity of rice in heavy soil of Cauvery Delta Zone. Organic manures acting as slow release source of N are expected to more closely match with N and supply of other nutrients with demand of rice crop and this could have reduced the N losses and also improved the nutrient use efficiency particularly of nitrogen. Therefore, inorganic fertilizers in combination with organic manures caused the greater translocation of photosynthates from source to sink site that resulted higher grain yield of rice (Naveen kumar *et al.*, 2019).

**Table 2 Effect of treatments on grain yield (kg ha<sup>-1</sup>)**

Treatments	Kharif season		Treatments	Rabi season	
	Grain Yield	% increase over control		Grain Yield	% increase over control
NP	4809	47	NP	5932	43
NK	4782	46	NK	5693	37
NPK	4958	51	NPK	5938	43
NPK	4932	50	NK	5341	30
NPK+GM	5216	59	NPK+FYM	6099	47
NPK +GM+Azos	5316	62	NPK +FYM+BGA	6262	51
NPK +GM+GYP	5942	81	NPK +FYM+GYP	6603	59
NPK +ZnSO <sub>4</sub>	5054	54	NPK +ZnSO <sub>4</sub>	6149	48
NPK +Herbicide	5092	55	NPK +Herbicide	6089	47
NPK + GYP	5442	66	NPK + GYP	6391	54
NPK	4888	49	NPK -75%	5828	40
NPK + CPC	5180	58	NPK + CPC	6056	46
Absolute Control	3269		Absolute Control	4141	
CD	216*		CD (p=0.05)	225*	

\* = Significant at  $p \leq 0.05$

FYM :Farm yard manure – 12.5 t ha<sup>-1</sup>; GM:Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>; BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>

The same trend was observed in straw yield (Table 3) also. Increase in straw yield might be attributed to increase in photosynthetic area and dry matter accumulation. Slow available nitrogen from organic manure is known to enhance the formation of new cells, promotes root and shoot growth. It is also associated with the vital oxidation reduction reactions of various physiological processes

determining the supply of photosynthates to proliferating shoots and other parts. Thus, readily available N in organic and inorganic sources of nutrients might have helped in production of large number of shoots and finally their conversion into dry matter accumulation and straw yield per unit area. (Indoria *et al.*, 2018; Moe *et al.*, 2019).

**Table 3 Effect of treatments on straw yield (kg ha<sup>-1</sup>)**

Treatments	Kharif season		Treatments	Rabi season	
	Straw yield	% increase over control		Straw yield	% increase over control
NP	5815	44	NP	6533	24
NK	5859	45	NK	6124	16
NPK	6091	51	NPK	6598	26
NPK	6087	50	NK	6023	15
NPK+GM	6337	57	NPK+FYM	7093	35
NPK +GM+Azos	6450	59	NPK +FYM+BGA	7236	38
NPK +GM+GYP	6906	71	NPK +FYM+GYP	7653	46
NPK +ZnSO <sub>4</sub>	6398	58	NPK +ZnSO <sub>4</sub>	7195	37
NPK +Herbicide	6279	55	NPK +Herbicide	6945	32
NPK + GYP	5484	60	NPK + GYP	7212	37
NPK	6054	50	NPK -75%	6523	24
NPK + CPC	6384	58	NPK + CPC	7023	34
Absolute Control	4032		Absolute Control	5236	
CD	312*		CD (p=0.05)	392*	

\* = Significant at  $p \leq 0.05$

FYM : Farm yard manure – 12.5 t ha<sup>-1</sup>; GM:Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>; BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>



## Nutrient uptake by grain and straw

The data (Table 4) showed that, the treatments were statistically significant in case of grain and straw uptake for all the three (N, P and K) nutrients. The integrated nutrient management treatments had a favourable effect on the uptake of nutrients (N, P and K) than that of inorganic treatments and control. In both the seasons, the absolute control ( $T_{13}$ ) recorded lower N, P and K uptake values which are again the reflection of the lowest yield recorded in the absolute control plots. The higher NPK uptake may be due to higher yield received in this treatment (Arunkumar *et al.*, 2014; Gill and Aulakh, 2018).

Generally, application of recommended dose of NPK along with organics increased the N, P and K uptake by rice. Jacqueline *et al.*, (2008) reported that the N uptake by rice grain and straw increased significantly with the combined application of organic manure and chemical fertilizers. Niederberger *et al.*, (2019) reported that organic manures increased labile, moderately stable and stable organic P contents in soil and uptake by plants. Basak *et al.*, (2016) reported that application of organic manure and chemical fertilizers significantly increased the K uptake by rice.

**Table 4 Effect of treatments on nutrient uptake in grain and straw (kg ha<sup>-1</sup>)**

Treatments	Kharif season						Treatments	Rabi season					
	Grain			Straw				Grain			Straw		
	N	P	k	N	P	k		N	P	k	N	P	k
NP	50.0	9.5	10.5	35.0	6.0	67.8	NP	57.3	11.9	10.9	29.2	8.6	63.7
NK	51.1	9.0	12.5	34.9	5.5	83.6	NK	60.4	11.1	14.8	30.7	6.3	74.4
NPK	57.7	10.7	14.5	42.3	7.3	93.7	NPK	63.3	13.4	15.8	37.0	8.4	78.5
NPK	55.2	9.4	12.6	40.4	6.1	90.3	NK	60.2	11.6	15.3	34.3	7.6	75.0
NPK+GM	61.1	10.5	14.6	45.3	7.1	103.4	NPK+FYM	68.7	14.1	17.5	39.6	8.7	81.5
NPK +GM+ Azos	56.8	10.6	14.5	42.7	6.7	65.9	NPK +FYM+BGA	69.2	13.6	17.5	38.8	9.1	82.4
NPK+GM+GYP	71.0	11.2	17.8	53.7	8.1	115.9	NPK +FYM+GYP	73.9	14.8	19.1	41.1	9.9	90.2
NPK +ZnSO	61.7	10.5	14.5	41.3	6.8	96.0	NPK +ZnSO <sub>4</sub>	66.2	13	16.1	34.4	7.8	80.4
NPK +Herbicide	59.7	9.7	13.2	42.1	6.2	89.6	NPK +Herbicide	64.4	12.6	15.6	35.8	8.8	81.7
NPK + GYP	64.2	11.5	15.7	45.5	7.1	104.2	NPK + GYP	64.9	13.5	16.2	37.8	8.3	83.8
NPK	55.0	9.5	13.0	37.2	6.2	87.1	NPK -75%	61.0	11.8	14.2	33.4	8.2	77.2
NPK + CPC	59.1	10.8	14.5	41.5	7.2	96.6	NPK + CPC	63.0	13.0	17.4	36.3	7.6	78.7
Absolute Control	32.1	6.0	7.0	16.7	3.5	37.3	Absolute Control	33.4	7.0	7.7	15.4	4.6	40.4
CD(p=0.05)	7.5*	1.5*	2.3*	4.6*	0.88*	8.1*	CD(p=0.05)	5.3*	1.5*	3.3*	3.6*	1.3*	10.5*

\*= Significant at  $p \leq 0.05$

FYM: Farm yard manure – 12.5 t ha<sup>-1</sup>; GM: Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>;

BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>

## Soil Correlation studies

Simple Correlation Coefficients (r) between soil physical parameters and organic carbon were studied at the end of 25<sup>th</sup> year. When soil organic carbon increases, sand content decreases. A high degree negative correlation of organic carbon was observed with sand content ( $r = - 0.806$ ). But when organic carbon increases, the silt and clay content were increased. So a positive correlation of organic carbon was observed with silt ( $r = 0.629$ ) and clay content ( $r = 0.411$ ) of soil samples (Fig.1-3). Organic carbon and bulk density of soils showed strong negative correlation between them.

Similar results were obtained as strong negative correlation ( $r = - 0.7536$ ) between organic matter and bulk density (Fig. 4) which is required for the proper growth of the plants. But there was a strong positive correlation between organic carbon and pore space ( $r = 0.609$ ), infiltration rate ( $r = 0.895$ ) and water holding capacity ( $r = 0.655$ ) (Fig.5-7). The table 5 gives the correlation coefficient between organic carbon and other soil properties in nutshell. Bindhu and Sujata (2017) stated a reverse correlation between organic carbon and bulk density. Similar result was obtained by Sakin (2012).

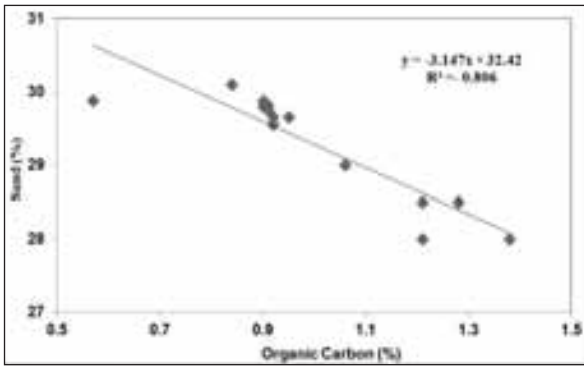


Fig.1. Relationship of organic carbon (%) with sand (%)

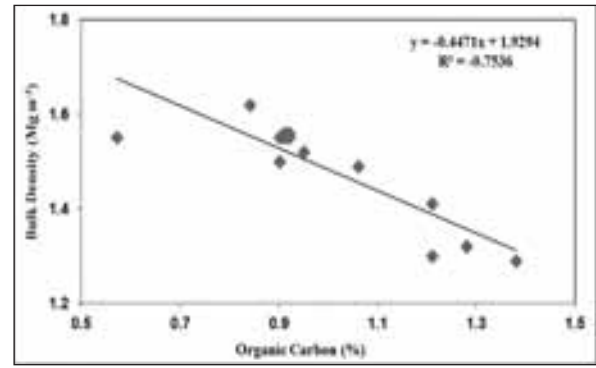


Fig.4. The relationship of organic carbon (%) with Bulk density (Mgm-3)

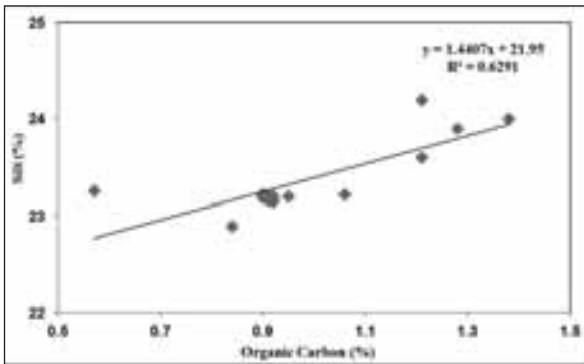


Fig.2. The relationship of organic carbon (%) with silt

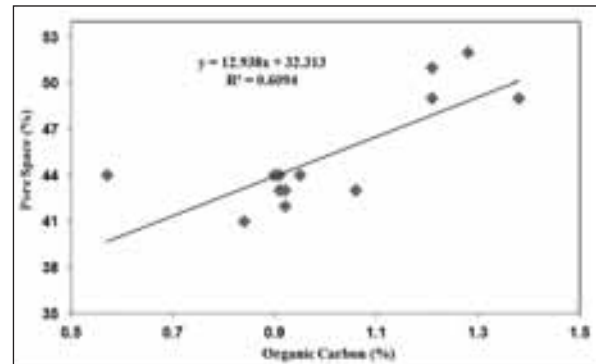


Fig.5. The relationship of organic carbon (%) with pore space (%)

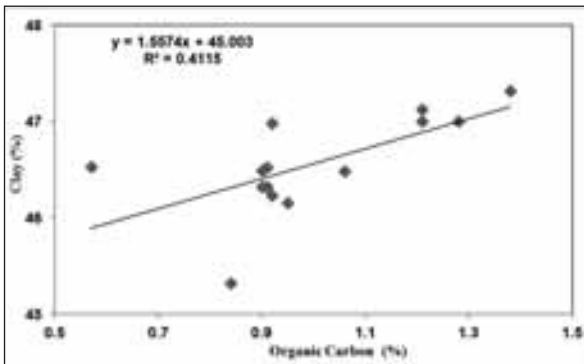


Fig.3. The relationship of organic carbon (%) with clay (%)

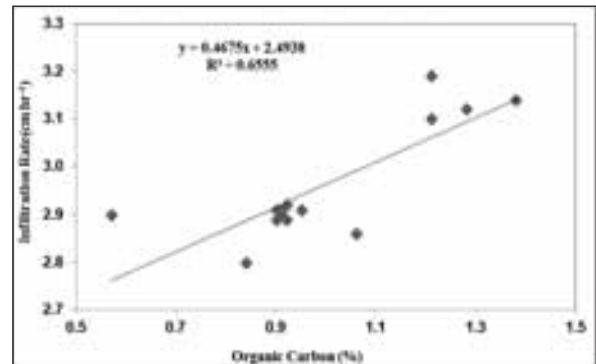


Fig.6. The relationship of organic carbon (%) with infiltration rate (cm hr<sup>-1</sup>)

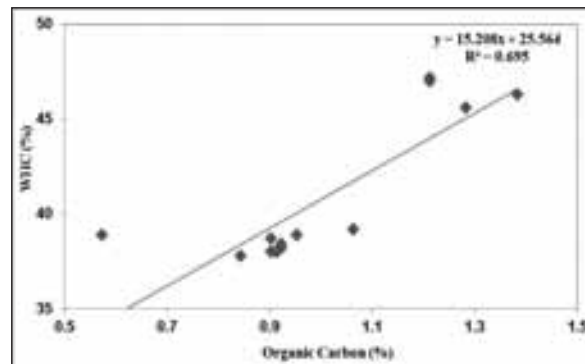


Fig. 7 The relationship of organic carbon (%) with water holding capacity (%)





**Table 5 Simple correlation coefficient between soil properties**

Related soil parameters	Correlation Coefficient (r)	Level of significance
Organic Carbon – Sand %	- 0.806	Strong negative
Organic Carbon – Silt %	0.629	Significant positive
Organic Carbon – Clay %	0.411	Significant positive
Organic Carbon – BD	- 0.754	Strong negative
Organic Carbon – Pore Space	0.609	Significant positive
Organic Carbon – Infiltration Rate	0.895	Strong positive
Organic Carbon – Water Holding Capacity	0.695	Significant positive

### Economics

Net return and B: C ratio was calculated in both the seasons in rice crop fertilized with organic and inorganic fertilizers (Table 6). Gross return was calculated as the total value of grain and straw yield of rice. The highest net return of Rs.60, 230 was obtained in the treatment T<sub>7</sub> during *kharif* season and the same treatment recorded the highest Benefit Cost ratio of 2.96. In *rabi*, the same treatment (T<sub>7</sub>) recorded the highest net return of Rs.62, 231 and the Benefit Cost ratio of 2.98. In both seasons, the treatment T<sub>7</sub> was followed by T<sub>6</sub> with respect to maximum net returns and B:C ratio. The minimum net return and benefit cost ratio was obtained in control (T<sub>13</sub>) in both the seasons. The treatment T<sub>7</sub> recorded the highest additional net income (Rs.31, 808

in *kharif* and Rs.33, 935 in *Rabi*) than other treatments in both the seasons (Table 7). Hence, it can be reasonably concluded that integrating organic manures along with inorganic fertilizers would be the best. Combined use of organic manures with inorganic fertilizers could save part of the money that would have been paid for the greater doses of the chemical fertilizer and is socially acceptable. The higher yield realized under the INM treatment would be the reason for more economic return as against the cost of cultivation with higher net gain, additional net income and benefit: cost ratio. The result was in conformity with the findings of Jat *et al.*, (2018), who also realized higher economic return due to integrated nutrient management practices.

**Table 6 Effect of continuous application of fertilizers on net returns (Rs.) and B:C ratio**

Treatments	<i>Kharif</i> season		Treatments	<i>Rabi</i> season	
	Net Returns (Rs.)	B:C ratio		Net Returns (Rs.)	B:C ratio
NP	34,890	1.71	NP	35,982	1.71
NK	33,980	1.76	NK	35,432	1.78
NPK	36,262	1.79	NPK	37,122	1.79
NPK	35,170	1.79	NK	36,152	1.79
NPK+GM	38,094	1.96	NPK+FYM	40,194	1.96
NPK +GM+Azos	57,526	2.54	NPK +FYM+BGA	53,556	2.24
NPK +GM+GYP	60,230	2.96	NPK +FYM+GYP	62,231	2.98
NPK +ZnSO <sub>4</sub>	47,090	1.87	NPK +ZnSO <sub>4</sub>	49,234	1.88
NPK +Herbicide	43,740	1.80	NPK +Herbicide	42,134	1.80
NPK + GYP	43,990	1.80	NPK + GYP	45,236	1.89
NPK	44,470	1.83	NPK -75%	44,723	1.83
NPK + CPC	41,134	1.70	NPK + CPC	42,351	1.72
Absolute Control	-912	1.01	Absolute Control	-1125	1.02

FYM :Farm yard manure – 12.5 t ha<sup>-1</sup>; GM:Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>; BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>

**Table 7 Effect of continuous application of fertilizers on change in net income (Partial Budgeting)**

<i>Kharif</i> season		<i>Rabi</i> season	
Treatments	Change in Net Income (Rs.)	Treatments	Change in Net Income (Rs.)
NP	18414	NP	17090
NK	18365	NK	15880
NPK	18375	NPK	17905
NPK	17489	NK	19509
NPK+GM	17372	NPK+FYM	15940
NPK +GM+Azos	20853	NPK +FYM+BGA	22562
NPK +GM+GYP	31808	NPK +FYM+GYP	33935
NPK +ZnSO <sub>4</sub>	20169	NPK +ZnSO <sub>4</sub>	22113
NPK +Herbicide	20370	NPK +Herbicide	18341
NPK + GYP	25011	NPK + GYP	23681
NPK	17848	NPK -75%	20239
NPK + CPC	17657	NPK + CPC	22411
Absolute Control	18414	Absolute Control	17090

FYM : Farm yard manure – 12.5 t ha<sup>-1</sup>; GM:Green manure – 6.25 t ha<sup>-1</sup>; GYP: Gypsum – 500 kg ha<sup>-1</sup>; WC: Herbicide (Butachlor 2.5 lit ha<sup>-1</sup>); CPC : Coirpith compost – 12.5 t ha<sup>-1</sup>; Azos: Azospirillum – 2 kg ha<sup>-1</sup>; BGA: Blue Green Algae – 10 kg ha<sup>-1</sup>; Zn SO<sub>4</sub> @ 25 kg ha<sup>-1</sup>

Therefore, taking the findings of the present study into consideration, it may be concluded that application of recommended dose of NPK (125:50:50) along with Green Manure @ 6.25 t/ha and gypsum 500 kg/ha in *kharif* and in *rabi* recommended dose of NPK (150:60:60) along with FYM @ 12.5 t/ha and gypsum 500 kg/ha improved rice productivity, maintained soil quality with economic gain in rice cultivation. Application of RDF with organic manures in rice is socially acceptable, economically viable and environmentally sustainable source of nutrient application which helps in sustainable crop production, providing greater profit and maintaining soil quality.

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