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Effect of long term fertilization on soil fertility and yield of rice in Cauvery Delta Zone

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ABSTRACT

A long term fertility experiment was initiated in 1992 to study the effect of inorganic, organic fertilizers, agro chemicals and biofertilizers on productivity of a rice -rice system with respect to changes in soil fertility. Results of five years (2012-2017) experimentation revealed that the treatment receiving continuous application of NPK at 125:50:50 kg/ha in Kharif and 150:60:60 kg/ha in Rabi season along with green manure at 6.25 t/ha in Kharif and 12.5 t/ha of FYM in Rabi and gypsum at 500 kg ha $^{-1}$ both in Kharif an Rabi seasons respectively recorded significantly higher grain yield in both the seasons consecutively for five years. At the end of the 50th rice crop, the soil chemical properties like pH, EC, organic C, available N,P and K exhibited s significant differences due to various treatments imposed. The values of nutrient uptake by rice crop also showed significant differences among various treatments. The results suggest the need of integrated nutrient management practices to sustain in rice productivity in the heavy soils of Cauvery Delta Zone (CDZ).

Key words: *Permanent Manurial experiment, cropping systems, Soil fertility, crop uptake*

INTRODUCTION

Rice based cropping systems are the major production systems contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses of fertilizers *e.g.,* blanket fertilizer recommendations over large domains with least regard to the variability in soil fertility and productivity. Future gains in productivity and input use efficiency require soil and crop management technologies that are tailored to specific characteristics of individual farms or fields. To meet the food requirement of the growing population, the rice production has to be enhanced with good management practices with shrinking availability of land and water resources condition. A large part of the problems that have not been sufficiently clarified yet can be solved only by using long-term field experiments. The supply of soils with soil organic matter and the elaboration of suitable methods to determine optimal humus contents and the factors of the humus balance. Since many decades, we have optimal values for all macro- and micronutrients in the soil, we have also limit values for pollutants, however, we have no optimal values for the most important elements in soil, *i.e.,* carbon and nitrogen. The effect of crop rotations on the crop yields, soil health and chemical, physical and biological soil characteristics. We owe predominantly to the results of the long-term field experiments for the contemporary knowledge regarding the sustainable land use. Long-term field experiments will also be indispensable in future, as they cannot be replaced by new analytical techniques or models; on the contrary, they are an indispensable basis for the calibration and validation of these techniques. Cauvery Delta Zone is the potential tract in the traditional rice cultivated area of Tamil Nadu. Rice-Rice is the most common cropping system existing in Cauvery Delta Zone of Tamil Nadu. Therefore it was decided to study the effect of different treatment combinations on long term basis in rice-rice system to monitor rice productivity and soil fertility status.

MATERIALS AND METHODS

The Permanent manurial experiment (PME) in rice based cropping system *viz.,* rice - rice was started at Tamil Nadu Rice Research Institute, Aduthurai (110 N altitude, 790 31' E longitude, 19.4 MSL) during June, 1992 - 93. During normal years, the annual rainfall is 1200 mm of which around 70 % is received during September to October (North East monsoon). The climate of the experimental site (Cauvery Delta) is sub tropical monsoon type. Two rice crops, one during *kharif* transplanting in May - June and harvest in August-September and the second during *rabi* transplanting in October - November and harvest in January were grown under irrigated conditions every year. The soil of the experimental site is fine montmorillonitic, isohyperthermic, Udorthentic Chromusterts with heavy clay texture belonging to Kalathur soil series. Here, we are discussing the results of five consecutive years. The initial analytical data (2011-12) of the experimental soil are furnished in Table 1.

The Permanent Manurial Experiment with fixed plots has been laid out in a randomized block design with thirteen treatments and four replications. Treatments in the study involving various levels of chemical fertilizers and combination of fertilizers with organics, biofertilizers, herbicide and crop residues were compared (Table 2). A uniform plot size of 22.5 x 3.5 m (78.75 m2) was adopted.

Table 1. Initial soil properties of experimental plots of permanent manurial experiment.

	Treatment	pH	EC (dS m^{-1})	OC (%)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})
T_1	NP	8.07	0.47	0.98	232	59	204
T_2	NK	8.04	0.50	0.94	249	49	248
T_3	NPK	8.09	0.51	1.04	235	62	270
T_4	NPK	8.01	0.48	1.03	235	55	241
T_5	NPK+FYM	8.08	0.55	1.25	260	72	290
T_6	NPK+ FYM +BF	8.14	0.63	1.32	252	67	276
T_7	NPK+GYP+ FYM	8.06	0.62	1.17	255	74	284
T_8	NPK+ZnSO4	8.08	0.53	1.03	249	60	239
T_9	NPK+WC	8.15	0.48	1.05	252	57	254
T_{10}	NPK+GYP	7.92	0.48	1.05	260	53	242
T_{11}	NPK75%	8.15	0.48	1.13	227	57	245
T_{12}	NPK+CPC	8.09	0.51	1.15	260	60	268
T_{13}	Control	8.12	0.53	1.07	210	41	222
SEd		0.03	0.05	0.05	8	6	13
CD (p= 0.05)		0.06	0.10	0.10	17	12	27

FYM : Farmyard Manure- 12.5 t/ha ., GYP: Gypsum -500 kg/ ha., Weedicide : (Butachlor - 2.5 l/ha)., CPC - Composted Coirpith -12.5 t/ha., BGA :Blue Green Algae - 10 kg/ha., $ZnSO_4$: 25 kg/ha.

Nitrogen was applied in four equal splits for *kharif* (basal, 15, 30, 45 days after transplanting) and for *rabi* (basal, 20, 40 and 60 days after transplanting), respectively, while phosphorus and zinc were applied entirely as basal and potassium in two equal splits (as basal and at panicle initiation stage, 30 and 40 days after transplanting for *kharif* and *rabi* respectively). The fertilizers used were urea, single super phosphate, muriate of potash and zinc sulphate. For treatments of green manure (T_5, T_6 and T_7) Sesbania rostrata (3.23 % N, 0.32 % P and 4.30% K on dry weight basis) was incorporated @ 6.25 t ha^{-1} for *kharif* rice while *rabi* rice received farmyard manure (0.67 % N, 0.24 % P and 0.70 % K) @ 12.5 t ha^{-1} (T_5, T_6 and T_7). The phosphorus was skipped for T_4 during *rabi* season so as to study the residual effect of P applied during *kharif* on *rabi* rice and soil P status. In the case of T_{11}, only 75 % of the NPK was applied for *rabi* rice in order to assess the effect of reduced quantity of NPK. Most popular rice varieties of cauvery delta region *viz.,* ADT 43 and ADT 45 for short duration (*kharif*) and ADT 38 and ADT 39 for medium duration (*rabi*) were used in these experiments. Need based plant protection measures were taken up against pest and diseases.

At maturity, the plant height, number of panicles/m^2 and thousand grain weight were measured. Then the crop was harvested and the grain and straw yields were recorded from the net area of 5 m^2 in each plot. The grain yield was adjusted to 14 % moisture level. At the end of each year, representative post harvest soil samples (0-15 cm) were collected and analysed for pH and EC (1:2.5), organic carbon (Walkey and Black, 1943), available N (Jackson,1973), Bray P and 1 N NH_4OAC extractable K (Page et al., 1982). Likewise, the plant samples (grain and straw) were collected and analysed for N (Jackson, 1973) P and K (Jackson, 1973) and their uptake values were worked out. In order to compare the effect of various treatments on grain and straw yield, soil fertility and nutrient uptake, analysis of variance (ANOVA) was performed using

Table 2. Permanent Manurial Experiment - Treatment details.

T. No.	*Kharif*(kg ha^{-1})				*Rabi*(kg ha^{-1})			
	N	P_2O_5	K_2O		N	P_2O_5	K_2O	
T_1	125	50	0		150	60	0	
T_2	125	0	50		150	0	60	
T_3	125	50	50		150	60	60	
T_4	125	50	50		150	0	60	
T_5	125	50	50	GM	150	60	60	FYM
T_6	125	50	50	GM + Azos	150	60	60	FYM+BGA
T_7	125	50	50	GM+GYP	150	60	60	FYM+GYP
T_8	125	50	50	$ZnSO_4$	150	60	60	$ZnSO_4$
T_9	125	50	50	WC	150	60	60	WC
T_{10}	125	50	50	GYP	150	60	60	GYP
T_{11}	125	50	50		112.5	45	45	
T_{12}	125	50	50	CPC	150	60	60	CPC
T_{13}	Absolute control				Absolute control			

FYM : Farmyard Manure- 12.5 t/ha ., GM : Green Manure - 6.25 t/ha., GYP: Gypsum -500 kg/ha., Weedicide : (Butachlor - 2.5 l/ ha)., CPC - Composted Coirpith -12.5 t/ha., Azos : Azospirillum - 2 kg/ha., BGA :Blue Green Algae - 10 kg/ha., $ZnSO_4$: 25 kg/ha. 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.

standard statistical procedure for randomized block design.

RESULTS AND DISCUSSION

Growth Parameters

The mean plant height, number of panicles/m^2 and thousand grain weight are shown in table 3. The data showed that significnat growth parameters were recorded in treatment T_7 *viz.,* application of recommended dose of NPK + Green Mnaure @ 6.25 t/ha and Gypsum @ 500 kg/ha in *Kharif* and application of recommended dose of NPK + FYM @ 12.5 t/ha and Gypsum @ 500 kg/ha in *Rabi* followed by other treatments. Increase in growth parameters with increase in chemical fertilizers and organic manures might be due to the fact that higher nutrient supply rapidly converted the carbohydrates into proteins which in turn elaborated into protoplasm (Raman et al., 2012). The slow release of nitrogen from organic manures also increased the proportion of protoplasm to cell wall material and had several consequences one of them being an increase in size of cell, which expressed morphologically in increased plant height (Nambiar, 1994). 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 (Bari et al., 2006). 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. FYM provides better growing condition to plants by continuous supply of nutrients and improvement of soil propefrties (Urkarkur et al., 2010). This might have been attributed to increased photo-synthetically active leaf area with higher efficiency of CO_2 assimilating under increased supply of NPK. Nitrogen rich sources of nutrients required for good crop production because nitrogen is the main constituent of protoplasm, protein,chlorophyll, nucleotides, alkaloids, hormones and vitamins (Rayees and Sandeep, 2014). The absolute control recorded lower growth parameters.

Grain yield

The mean grain yields for all the tretaments over the crop seasons from 2012-2017 are shown in table 4. All the treatments with fertilizers either alone or in combination with organics/biofertilizers/herbicide/soil amendment under study showed significant increase in grain yields over absolute control. The results in table 4 revealed that during *Kharif* sesaon the treatement T_7 *viz.,* the application of NPK fertilizers at 125:50:50 kg/ha along with green manure (6.25 t ha^{-1}) and gypsum (500 kg ha^{-1}) recorded significnaly higher grain yield than the other treatments during all the five years. On an average, the treatment NPK+green manure+gypsum (T_7) was the most productive with yield increasing up

Table 3. Effect of treatments on growth parameters (Mean of five years).

Treatments	*Kharif*			Treatments	*Rabi*		
	Plant height (cm)	No. of panicles/ m^{-2}	1000 grain wt. (g)		Plant height (cm)	No. of panicles/ m^{-2}	1000 grain wt.(g)
NP	83.8	312	21.9	NP	83.4	338	22.9
NK	82.8	319	21.7	NK	82.3	339	22.4
NPK	81.2	325	21.3	NPK	82.2	340	22.1
NPKo	83.6	324	21.4	NPKo	84.1	336	22.9
NPK+GM	85.2	321	22.0	NPK+FYM	86.0	340	24.1
NPK +GM+ Azos	87.2	332	22.8	NPK+FYM+ BGA	88.9	344	24.7
NPK+GM+GYP	91.4	346	23.2	NPK+FYM + GYP	92.2	356	25.1
NPK +ZnSO4	85.8	330	22.6	NPK +ZnSO4	85.1	340	24.0
NPK +Herbicide	82.8	300	20.0	NPK +Herbicide	84.2	322	22.3
NPK + GYP	88.2	319	22.9	NPK + GYP	89.1	341	22.1
NPK	83.8	311	22.5	NPK -75%	84.1	340	22.4
NPK + CCP	84.3	325	22.9	NPK + CCP	82.3	334	24.0
Absolute Control	79.3	271	19.5	Absolute Control	73.1	285	21.2
SEd	1.0	4.3	1.1	SEd	0.6	5.2	1.3
CD(p=0.05)	2.8	10.1	2.6	CD(p=0.05)	2.9	11.1	2.9

FYM : Farmyard Manure- 12.5 t/ha ., GM : Green Manure - 6.25 t/ha., GYP: Gypsum -500 kg/ha., Weedicide : (Butachlor - 2.5 l/ha)., CPC - Composted Coirpith -12.5 t/ha., Azos : Azospirillum - 2 kg/ha., BGA :Blue Green Algae - 10 kg/ha., $ZnSO_4$: 25 kg/ha.

to 72% over control (T_{13}). This may be attributed to better utilization of applied nutrients through the activities of soil micro-organisms which involved in nutrient transformation and fixation and also the transport of nutrients from organic sources influences the nutrient availability to the crop plants as well as the potential for higher production (Mohandas et al., 2008). Moreover, organic manures has the essential plant nutrients and other growth promoting substances like enzymes and hormones, while no synthetic fertilizer can supply all together (Yadav et al., 2006). Similar results were reported by Kandeshwari et al. (2012). Hence, integrated use of organic and inorganic fertilizers can make important contribution for increasing and sustaining rice production. This was also evidenced by studies of Jayajothi, Nalliah Durai Raj (2015) and Nayak et al. (2012).

The table 4 also revealed that the combination of NPK+$ZnSO_4$ (T_8) brought out a significant increase in grain yield over NPK alone (T_3) indicating the importance of $ZnSO_4$ application for submerged rice grown in the heavy soils of Cauvery Delta Zone. Studies have proven that similar increase due to Zn application in dry matter and grain yields in different crops (Chamon et al., 2008). Similarly, the addition of gypsum (T_{10}) and coir pith compost (T_{12}) also showed significant difference in grain yield. On the contrary, addition of herbicide did not show significant influence on grain yield. Hence, the yield data suggested that the combination of inorganics and organics increases the yield (73 % in *kharif* and 69 % in *rabi*) and also the efficiency of NPK fertilizers is improved when used in conjunction with organics and gypsum for obtaining higher rice productivity. On perusal of yield data in *Rabi* seasons (Table 3), as in *Kharif* season experiments the treatment T_7 *viz.,* continuous application of 150:60:60 kg NPK along with FYM (12.5 t/ha) and gypsum (500 kg/ha) recorded significant higher grain yield in all the five years (2012-2017) than the other treatments. The overall increase due to the combination of NPK +FYM+gypsum was 69 % over control (T_{13}). 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 reduce 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 yield contributing characters of rice (Barik et al., 2008). Higher yield associated with higher level of inorganic fertilizers in combination with organic manures may be due to its greater availability and uptake of macro and micro-nutrients and active participation in carbon assimilation, photosynthesis, starch formation, translocation of protein and sugar, entry of water into plants root and development etc (Islam et al., 2013). It also enhances

Table 4. Effect of treatments on grian yield in Kharif and Rabi (mean of five years).

Treatments	*Kharif* grain Yield (kg/ha)		Treatments	*Rabi* grain yield (kg/ha)	
	Mean	% increase over control		Mean	% increase over control
NP	4604	40	NP	4373	27
NK	4643	41	NK	4495	31
NPK	4843	47	NPK	4733	38
NPKo	4625	41	NPKo	4612	34
NPK+GM	4958	51	NPK+FYM	4224	23
NPK +GM+Azos	5051	54	NPK +FYM+BGA	5126	49
NPK +GM+GYP	5671	72	NPK +FYM+GYP	5779	69
NPK +$ZnSO_4$	4890	49	NPK +$ZnSO_4$	5131	50
NPK +Herbicide	4821	47	NPK +Herbicide	4642	35
NPK + GYP	5448	66	NPK + GYP	5589	63
NPK -75%	4722	44	NPK -75%	4475	30
NPK + CCP	4998	52	NPK + CCP	5264	61
Absolute Control	3279		Absolute Control	3418	
SE (d)	113		SE (d)	114	
CD	235		CD	247	

FYM : Farmyard Manure- 12.5 t/ha ., GM : Green Manure - 6.25 t/ha., GYP: Gypsum -500 kg/ha., Weedicide : (Butachlor - 2.5 l/ha)., CPC - Composted Coirpith -12.5 t/ha., Azos : Azospirillum - 2 kg/ha., BGA :Blue Green Algae - 10 kg/ha., $ZnSO_4$: 25 kg/ha.

the process of tissue differentiation *i.e.,* from somatic to reproductive phase leading to higher grain and straw yield (Rahman et al., 2009). Accumulation of protein in grain under adequate N supply might be accounted to continuous availability of nitrogen for protein synthesis. This was also may be due to the higher yield attributes under this treatment. The results are also in conformity with findings of Hossaen et al. (2011) and Mohanty et al. (2013).

From the yield data it could be inferred that the addition of herbicide (T_9) did not influence the grain yield significantly. The reason may be that the herbicide could not bring any positive effect in terms of providing either nutrients or any other favour in controlling the weeds. It is of interest to note that skipping of P (T_4) in *Rabi* season did not reduce the grain yield as compared to NPK (T_3) indicating adequate supply of P from the soil for realizing similar grain yields. Similar trend was also noticed in respect of skipping of K (T_1) in both *Kharif* and *Rabi* seasons, when compared to NPK alone (T_3) and however the yield levels were low. Further, the application of lower quantity (75%) of NPK (T11) has brought out similar grain yields as did the 100 % NPK (T_3) which indicates the possibility of 25 % saving of NPK in the experimental site for realizing similar grain yields. It may be due to the fact that the experimental soil has the inherent capacity of supplying some amount of nutrients. From the yield data obtained both in *Kharif* and *Rabi* it is evident that the mean grain yields in control plot (T_{13}) are 3279 and 3418 kg/ha in both the seasons respectively. The reason for getting grain yield in unfertilized plots might due to continuous incorporation of rice stubbles and supply of naturally available N derived from mineralized soil N and biological N fixation by free living and plant associated microbes present in submerged rice soils (Stalin et al., 2006).

The grain yield data under the study emphasized the need of combination of organic manures (6.25 t/ha green manure in *Kharif* and 12.5 t/ha FYM in) with inorganic fertilizers (125:50:50 kg NPK/ha in *kharif* and 150:60:60 kg NPK/ha in *Rabi*), besides application of gypsum (500 kg/ha) 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 soils of Cauvery delta zone.

Soil fertility Status

The data on soil chemical properties at the end of the experiment (2017) are given in Table 5.

Soil pH

There is a slight significant variation in terms of increase in pH and EC due to the effect of treatments. Though there was some fluctuation in the pH values in the experiment are well in the neutral range of a rice system. However, the treatments which receive huge amounts of organic matter every season in the form of green manure @ 6.25tha^{-1} in *Kharif* and FYM @12.5 t ha^{-1} in *Rabi* registered a marginal increase in pH. This was supported by several workers (Parvathi et al., 2013 and Stalin et al., 2006).

Electrical conductivity

Electrical conductivity showed a slight significant increase among the treatments at the end of the 50th crop (Table 5), but the values are well below the normal soil. Although EC of the soil increased in different treatments but the actual values did not cross the critical limit of 4.0 dS m^{-1}. Such similar results have been reported in the literature (Sarwar et al., 2003 and Niklasch & Joergensen, 2001) which indicated that EC increased in acidic as well as alkaline soils when organic materials of different nature were applied to the soil. The decomposition of organic materials released acids or acid forming compounds that reacted with the sparingly soluble salts already present in the soil and either converted them into soluble salts or at least increased their solubility. Hence, the EC of soil was increased. However, the quantum of increase will depend how much quantity of the acids or acid forming substances was produced which will in turn relay upon the amount of the organic materials applied (Stalin et al., 2006).

Table 5. Effect of treatments on chemical properties of post harvest soil (2017).

Treatments	pH	EC (dS /m)	N (kg/ ha)	P (kg/ ha)	K (kg/ ha)	OC (%)
NP	8.06	0.48	233	64	219	0.91
NK	8.02	0.52	246	55	252	0.90
NPK	8.05	0.49	231	64	289	0.90
NPKo	8.01	0.50	232	57	267	0.92
NPK+FYM	8.04	0.58	248	77	319	1.28
NPK +FYM+BGA	8.11	0.60	240	72	292	1.38
NPK +FYM+GYP	8.06	0.61	250	78	314	1.21
NPK +ZnSO4	8.02	0.52	236	63	260	0.95
NPK +Herbicide	8.07	0.47	242	58	271	0.92
NPK + GYP	7.94	0.45	251	59	256	1.06
NPK -75%	8.08	0.48	224	61	262	0.91
NPK + CCP	8.06	0.53	243	63	284	1.21
Absolute Control	8.05	0.51	194	41	237	0.84
SEd	0.06	0.05	9	4	13	0.06
CD	1.2	0.08	16	7	27	0.12

FYM : Farmyard Manure- 12.5 t/ha ., GYP: Gypsum -500 kg/ ha., Weedicide : (Butachlor - 2.5 l/ha)., CPC - Composted Coirpith -12.5 t/ha., BGA :Blue Green Algae - 10 kg/ha., $ZnSO_4$: 25 kg/ha.

Available nitrogen

The data on available N showed that the treatmets receiving the combination of inorganics and organic registered higher available N levels when compared to control. The maximum available N was obtained (250 kg/ha) in the treatment *viz.,* Recommended NPK + FYM +GYP followed by Recommended NPK +FYM and Recommended NPK + BGA when compared to control. This may be attributed to the mineralization of N from organic manure during decomposition. Further increase in available N due to organic material application might also be attributed to the greater multiplication of microbes caused by the addition of organic materials for the conversion of organically bound N to inorganic form (Walia and Kler, 2006 and Patra et al., 2011). Addition of nitrogenous fertilizer along with FYM helps in narrowing down of C:N ratio and, thus, increased mineralization resulted in rapid conversion of organically bound N to inorganic forms (Sahu et al., 2014). Das et al. (2014) reported that increase in available N with farmyard manure application might be attributed to the direct addition of N through farmyard manure to the available pool of soil.

Available phosphorus

It is a well known fact that the crop uses only 25 to 30 per cent of applied phosphorus and the remaining part which is not readily available remains in the soil (Gudadhe et al., 2015). There was gradual increase in available phosphorus content of soil over the years and when compared to initial status of soil, increase was more under organic combination treatments (72 kg/ha to 78 kg/ha). Increase in available phosphorus with addition of organic sources might be due to additional application of phosphorus and mobilization of phosphorus from lower layers of the soil. Tolanur and Badanur (2003) also reported that FYM and green manure addition with inorganic fertilizers had the beneficial effect on increasing the available P status of soil. Therefore, combination of organic manure with chemical fertilizer and sole addition of chemical fertilizer also helped in increasing fixation of water soluble P, increased mineralization of organic P due to microbial action and enhanced availability of P (Varalakshmi et al., 2005). Further, it might be due to release of organic acid during microbial decomposition of organic matter which might have helped in the solubility of native phosphates thus increasing available phosphorus pool in the soil. In addition the organic anions compete with phosphate ions for the binding sites on the soil particles. The complex organic anions chelate Al^{+3}, Fe^{+3} and Ca^{+3} and thus decrease the phosphate precipitating power of these cations thereby increasing the phosphorus availability. (Nagar et al., 2016). Increase in available P with FYM application could be justified due to solubilization of the native P in the soil through release of various organic acids. The organic anions and hydroxyl acids, such as tartaric, citric, malonic and malic acids liberated during the decomposition of organic matter might complex or chelate Fe, Al and Ca and prevent them from reacting with phosphate. Such favourable effect of combined application of inorganic and organic source of nutrients in enhancing the availability of P was also noted by Prasad et al. (2010) and Bhattacharya et al. (2015).

Available potassium

Regarding available K, application of recommended dose of NPK+FYM recorded higher available K (319 kg/ha) than other treatments. The higher availability of potassium due to FYM may be ascribed to the reduction of K fixation and release of K due to the interaction of organic matter with clay (Rathore et al., 2011). This might be due to the reason that application of organic manure secreted organic acid during process of decomposition which led to mineralization of the fixed potassium and increased the availability of potassium. Moreover humus retains divalent cations (Ca^{++}, Mg^{++}) more strongly than the monovalent cations. Weaker retention of potassium relative to Ca and Mg may increase K availability. Integrated nutrient management showed higher value of available K content as compared to control and NPK alone. Beneficial effect of conjoint use of FYM along with inorganic fertilizer might be the reason of this increase. Application of organic matter improved the CEC of the soil and thus increased the retension of K in exchangeable form by a mass action effect. It might be ascribed to the reduction of K fixation and release of K in exchangeable site due to the interaction of organic matter with clay besides the direct addition of K to available pool of the soil. This is in agreement with the findings of Gogoi et al. (2010). The increase in available K content of soil with the application of recommended dose of NPK in addition to organic manure may be explained by mineralization of organic sources and solubilization from native sources during the decomposition (Mazmudar et al., 2014)

Organic carbon

The data on organic carbon status of 25th year (50th crop) showed a variation ranging from 0.90 to 1.38 %. The result showed that the treatments receiving the combination of organics and inorganics registered higher organic carbon content than other treatments. Continuous application of organic manures in combination with inorganic fertilizers showed the higher organic carbon content when compared to inorganic fertilization alone. The increase in organic carbon content in treatments with combination of both organic and inorganic sources may be attributed to higher biomass addition to soil through crop residues. Lowering of organic carbon content of soil was common in control and in treatments with only inorganic fertilizers (Nayak et al., 2012). This type of lowering of organic carbon content of soil may be due to its rapid mineralization resulting from intensive cropping and also as a result of attaining stable equilibrium with the changing soil crop environment (Singh et al., 2008 and Brar et al., 2015).

N, P and K uptake

The table 6 showed the effect of treatments on nitrogen, phosphorus and potassium uptake by grain and straw in both the seasons. The data showed that during *Kharif* the application of recommended dose of NPK + green manure + gypsum registered the highest NPK uptake in grain and straw followed by application of recommended dose of NPK + $ZnSO_4$ followed by recommended dose of NPK +Gypsum in both grain and straw. During *Rabi*, the application of recommended dose of NPK + FYM + gypsum registered the highest NPK uptake in grain and straw

Table 6 . Effect of treatments on N,P and K uptake of rice in both the seasons (mean of five years).

Treatments	*Kharif* Grain uptake (kg/ha) N	P	K	Straw uptake (kg/ha) N	P	K	Treatments	*Rabi* Grain uptake (kg/ha) N	P	K	Straw uptake (kg/ha) N	P	K
NP	46.8	9.7	10.3	32.7	5.1	69.6	NP	52.7	8.4	5.8	26.9	9.0	64.9
NK	50.6	10.5	10.6	32.3	5.1	69.4	NK	57.4	9.5	7.5	30.7	6.5	74.7
NPK	54.8	12.5	12.6	38.6	6.4	70.3	NPK	62.7	9.5	10.4	40.3	7.9	81.8
NPKo	50.8	10.2	10.7	35.7	5.8	71.3	NPKo	58.7	8.4	7.5	40.5	7.4	72.5
NPK+GM	58.5	12.3	12.9	33.5	5.7	85.3	NPK+FYM	67.7	11.2	9.6	43.1	8.5	80.4
NPK +GM+ Azos	55.9	11.2	11.2	38.4	5.3	84.7	NPK +FYM+BGA	69.4	10.7	9.4	41.8	9.3	83.7
NPK+GM+GYP	68.3	13.9	14.0	42.6	6.7	96.6	NPK +FYM+GYP	76.2	11.5	13.3	42.8	11.0	95.1
NPK +ZnSO	61.5	11.5	11.6	34.7	5.6	87.4	NPK +$ZnSO_4$	71.4	10.6	10.3	36.6	7.8	85.7
NPK +Herbicide	57.6	10.6	11	38.5	5.5	70.5	NPK +Herbicide	66.5	9.18	8.4	40.9	9.1	83.1
NPK + GYP	62.7	13.7	12.1	38.4	6.2	88.5	NPK + GYP	67.5	10.5	10.5	40.8	8.5	91.8
NPK	54.8	10.1	9.9	29.5	4.2	70.7	NPK -75%	58.7	7.8	8.2	36.2	8.1	79.8
NPK + CCP	52.2	10.4	10.5	32.4	5.5	71.6	NPK + CCP	63.1	9.1	10.7	36.9	6.8	69.8
Absolute Control	35.8	8.08	8.0	15.3	3.4	34.6	Absolute Control	28.2	5.3	4.5	16.8	4.7	40.4
SEd	3.8	0.86	1.4	6.52	0.44	3.88	SE (d)	2.76	0.66	1.78	2.77	0.84	5.04
CD(p=0.05)	7.4	1.64	2.72	4.72	0.88	8.3	CD(p=0.05)	5.3	1.62	3.2	3.5	1.52	10.54

FYM : Farmyard Manure- 12.5 t/ha., GM : Green Manure – 6.25 t/ha., GYP: Gypsum -500 kg/ha., Weedicide : (Butachlor – 2.5 l/ha)., CPC – Composted Coirpith -12.5 t/ha., Azos : Azospirillum – 2 kg/ha., BGA :Blue Green Algae – 10 kg/ha., $ZnSO_4$: 25 kg/ha.

followed by application of recommended dose of NPK + $ZnSO_4$ followed by recommended dose of NPK +FYM+BGA in both grain and straw. From this table it can be inferred that, combination of organics with inorganics registered higher nutrient uptake in both grain and straw than inorganics alone. The lowest uptake was noticed in control treatment.This result was similar to the result of Bhadoria and Prokash (2003). 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. Zhang et al. (1998) reported that organic manures increased labile, moderately stable and stable organic P contents in soil and uptake by plants. Sreelatha et al. (2006) who reported that application of organic manure and chemical fertilizers significantly increased the K uptake by rice. Ghosh et al. (2014) reported that integrated nutrient management increased N, P and K uptake by rice

CONCLUSION

From these experiments it can be concluded that during *Kharif* season, the treatments receiving green manure @ 6.25 t / ha and gypsum @ 500 kg / ha with NPK (125:50:50) and in *Rabi* season, the treatments receiving FYM @ 12.5 t / ha and gypsum @ 500 kg / ha with NPK (150:60:60) consistently registered higher yield, soil available N, P, K, organic carbon and N, P and K uptake.

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