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Long Term Integrated Nutrient Management in Rice-Maize Cropping System

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Abstract: *Continuous growing of rice –ricemono-cropping over the years and excessive dependence on chemical fertilizers alone has led to decrease insoil fertility and productivity. A long term field study was initiated in 1989 at Agricultural Research Station, Kathalagere, University of Agricultural Sciences, Bangalore to study the effect of combination of organic and inorganic fertilizers on yield, fertility status and uptake pattern of nutrients in rice-maize cropping system. The results of 5years(2008-09 to 2012-13) of the experiment revealed that treatments receiving both organic and inorganic fertilizers in kharif season, followed by only inorganic fertilizers during summer season have improved the soil fertility level. Higher rice grain yields were observed in kharif season in $T_9$by receiving 25 per cent "N" through paddy straw and 75 per cent NPK through inorganic fertilizers, while least was obtained in control. Similarly, higher maize yields were observed in T_6which received 50 per cent "N" through FYM and 50 per cent NPK through inorganic fertilizers in kharif followed by 75 per cent NPK through inorganic fertilizers with minimum yield in control. The uptake pattern of nutrients in the both of the crops followed the same trend. Adoption of INM practices and inclusion of light irrigated croplike maize after rice in summer season to avoid shortage of water and saved 25 per cent of recommendeddose of nitrogen with incorporation of paddy straw as organic source of nutrient in rice-maize cropping system.*

Key words*: INM, Rice –Maize cropping system, INM in cropping system.*

I. Introduction

Organic materials particularly farm yard manure and green manures have traditionally been used in rice cultivation. However, after the industrial revolution widespread introduction of inorganic fertilizers led to decline in the use of organic material in cropping system (RosegrantandRoumasset, 1998). The impact of increased use ofinorganic fertilizer in crop production has been large and important (Hossain and Singh, 2000). It has been estimated that fertilizer use growth contributed to about 25% of the total increase in rice production in Asia between 1965 and 1980 (Barker *etal*., 1985). However, in recent years there has been serious concern about long-term adverse effect of continuous and indiscriminate use of inorganic fertilizers on deterioration of soil structure, soil health and environmental pollution (Ghosh and Bhatt, 1998). The fact that use of green manure and other organic matter can improves soil structure, nutrient exchange and maintains soil health has again raised interest in organic farming (Ayoub, 1999; Becker *et al.*, 1995). Use of organic manure aloneas a substitute to chemical fertilizers is not profitable and will not be enough to maintain the present level of crop productivity of high yielding varieties (Garrity and Flinn, 1998). Therefore, integrated nutrient management in which both organic and inorganic fertilizers are used simultaneously is probably the most effective methods to maintain healthy sustainable soil system while, increasing crop productivity (Janssen, 1993).

Rice - rice based cropping system are of prime importance in global food production especially in south-east Asia. There has been a decline in productivity of rice in India; this decline has been attributed to continuous mono-cropping of rice and excessive dependence on chemical fertilizers that has led to decrease in soil "N" and degradation of soil. This problem can be partly solved by switching on to growing rice-legume cropping systems rather than continuous rice production systems. Integrating chemical fertilizers with organic manures was quite promising, not only in maintaining higher productivity but also in providing greater stability in crop production (Nazirkar*et al.*,2010). The crop residue and green manuring are also known to serve as a good source of organic manures. The information on the effect of all these organics in conjunction with inorganic fertilizer is limiting. Rice-rice is the predominant cropping sequence under the Bhadra command area followed by rice-maize. Hence, an experiment was conducted to study the efficacy of combination of inorganic fertilizers with paddy crop residue and *in-situ* green manuring on the productivity and economic feasibility over longer period in rice-maize cropping system.

II. Methodology

A long term field experiment was conducted from 1989 to 2012 at Agricultural Research Station, Kathalagere ($13^0 2^1$ L,$76^0 15^1$ E and 561.6 m MSL) under Bhadra command area to study the effect of integrated nutrient management on soil fertility status and productivity of rice-maize sequence under permanent plot experiment in moderately shallow, dark reddish brown, sandy clay soils (Alfisols). The initial soil fertility levels were (pH - 6.40, EC - 0.13 dsm^{-1}, organic carbon - 0.68 %, available Nitrogen -288.0 kg/ha, available phosphorus - 12.3 kg/ha, available potash -211.4 kg/ha) (Table-1) and the climate is semi-arid with an average annual rainfall of 655 mm major distribution between May to October. Mean maximum and minimum temperatures are 34^0C and 10^0C, respectively during the months of March to January taken as reference.All chemicals and reagents were procured from Merck ^{R} India Ltd. Double distillation water was used throughout the analysis.

The experiment was laid out in a randomized block design with twelve treatments with different organic sources of nutrients (Treatment details are given in Table 2) with four replications. The organic sources of nitrogen used were FYM (Farm yard manure), paddy straw and Glyricidia with nitrogen content of 0.5 per cent, 0.4 per cent and 0.8 per cent on dry weight basis respectively. Nutrient equivalent basis of organic sources to meet the required quantity of N were incorporated in the soil 15 days before planting of kharif paddy. Entire doseof P, K and 50 per cent of inorganic N were applied at the time of planting in the form of Single Super Phosphate, Muriate of Potash and Urea respectively. The remaining dose of nitrogenous fertilizer was top dressed in equal splits at 30 and 60 days after transplanting in the form of Urea. Twenty-five days old seedlings were transplanted in rows of 22.5 cm apart with 10cm spacing between hills. For the summer crop of maize, 50 per cent N and full dose of P and K were applied at different levels based on the treatments at the time of sowing and remaining 50 per cent N was applied at 30 days after sowing. Seeding was done in rows of 60 cm apart with 30 cm spacing between maize seeds. Intercultural operations were done before top dressing of nitrogen. Plant protection measures were adopted for both the crops as and when pest and diseases were noticed. Yield data on paddy crop during *kharif* followed by maize crop during *summer* has been considered for the statistical analysis. Soil samples were collected after the harvest of *summer* maize crop and analyzed for different parameters like pH, electrical conductivity, organic carbon, available phosphorus and available potash content by following the standard methods to study the changes in the soil fertility levels. The plant samples (grain and straw samples separately) of both the seasons were collected after the harvest of crop and analyzed for uptake of nitrogen, phosphorus and potassium content by following standard methods and plant uptake of nutrients was calibrated using grain and straw yields data. All the results were subjected for statistical analysis for drawing conclusions using standard statistical analysis tools.

Organic carbon (Walkley and Black method,1934) and nitrogen content of soil were estimated by using (Olsen *et al.*, 1954). Phosphorous contents were estimated calorimetrically by using spectrophotometer (Analytic Jena A G. Germany). For the estimation of potassium, Flame photometer (Systronics 128, India) and other minerals, Atomic absorption Spectrometer (Analytic Jena AG, Germany) was used.

III. Results

The soil pH values at harvest of summer 1989 crop (initial year) did not bring any significant variations between treatments compared (Table 3). However, (2008-09 to 2012-13) the pH values varied significantly among the treatments. In general there was decrease in pH values over the years and fluctuationswere observed within the treatments also (Basumantaryand Talukdar, 1998).

The data on organic carbon status at harvest of summer 1989 crop showed variation ranging from 0.63 per cent to 0.71 per cent but these values were not statistically significant in bringing variations between treatments indicating the slow nature of organic sources in releasing the nutrients (Table 4). The results at harvest of 25th year crop showed significant variations among the treatments. There was an improvement (> 0.72 %) in treatments receiving both the sources of nutrients in one of the season over the years which may beattributed tohigher contribution of biomass to the soil in the form of crop residues, which upon decomposition might have resulted in enhanced organic carbon content of the soil (Udayasoorian, *et al*., 1988 and KamleshKukreja*et al.*, 1991). 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.

The results furnished in table 5 showed that the available P status has decreased in many treatments at harvest of 1st year crop and in all treatments in the soil data of 5th year crop when compared to initial level. The post harvest soil data of 1styear crop showed wide fluctuations among treatments. However, during 25th year crop there was improvement in available P status in all the treatments except in control and varied significantly among the treatments which is possibly due to the magnitude of yield triggered P uptake. The increase was prominent in treatments receiving both organic and inorganic fertilizers in kharif followed by only inorganic fertilizers in summer which could be attributed to the influence of organic manure which enhanced the labile P in the soil by complexing Ca, Mg and Al (Subramanian and Kumaraswamy, 1989). The decrease in available P in control could be due to fixation of P.

The available K status has decreased over the years (Table 6), it was more prominent in treatment receiving only inorganic fertilizers during both the seasons. Relatively higher available K was observed in INM treatments and lower values were noticed in control which did not receive any fertilizer over period of 25 years. This could be due to continuous cropping and non addition of organic manure in control as observed by Laxminarayana (2006). The long term studies has clearly proved the importance of organic manuring in improving the physical and microbial conditions of soil and enhances the fertilizer use efficiency when applied in conjunction with inorganic fertilizers under rice – maize cropping sequence. The data on NPK uptake by rice grain (1989 initial year, 2008) and maize grain (1989, 2008) crop at harvest are reported in Table 7. The treatments were statistically significant for all the three nutrients in all the years. The results showed variations in uptake pattern corresponding to the yield fluctuations throughout the experimental period. Treatments which received combination of organic and inorganic fertilizer showed higher uptake values of all the three nutrients most probably due to higher yields received in these treatments. Among two seasons, higher NPK uptake was noticed in kharif rice crop than in summer maize crop may be due to favorable effect of organic manure addition, higher biomass addition and yield. The lower NPK uptake in *summer* could be due to poor availability as there was no addition of organic manure.

Among all the treatments, whenever both organic and inorganic fertilizers were used in kharif season yield of rice and maize has increased, similar trend was observed over the years which could be due togradual decomposition of organic manure and its slow availability throughout the growing period of the crop (Kumar *et al*., 2003; Gunri*et al.*, 2004 and Rajkhowa and Baroova, 1994). The similarity in yields among different organic sources indicates better utilization of nutrients from all the sources (Ahmed *et al.*, 2006). Treatment T_9 recorded significant and higher rice grain yields over the years (Table 8) when compared to control which might be due to incorporation of rice straw and supply of naturally available N derived from mineralized soil N and biological nitrogen fixation by free living and plant associated diazotrophs present in submerged rice soils. On perusal of yield data of maize in *summer* season among various treatments T6 recorded significantly higher grain yield from past few years, which might be due to slow release of nutrients in FYM applied treatments and lower grain yields were observed in control (Sharma *et al.*, 2001) which has not received any fertilizers. The yield data of both crops over the years indicate an improvement in the efficiency of NPK fertilizers when used in conjunction with organic manure in at least one season (minimum of 25 % N through organic manures) for obtaining higher yield (Narain*et al.* 1990). Hence, in order to derive maximum benefit both in terms of higher yields as well as maintaining soil fertility and fertilizer use efficiency, rice – maize cropping system has to be followed with integrated nutrient supply.

IV. Conclusion

Rice-rice is the predominant cropping system under Bhadra command area and mono-cropping over the year and excessive dependence on chemical fertilizers that has led to decrease in soil health and nutrient status. The long term integrated nutrient management hasprovedthe efficiency of NPK fertilizers when used in conjunction with organic manure at least one season (minimum of 25 % N through organic manures) for obtaining higher yield. Further, incorporation of rice straw and supply of naturally available N derived from mineralized soil N and biological nitrogen fixation by free living and plant-associateddiazotrophs present in submerged rice soils has contributed nitrogen pool in soil. Burning of rice straw has resulted in environmental pollution and losses of soil organic matter and nutrients. Hence, incorporation of paddy straw as organic source of nutrient after harvest of crop in order to derive maximum benefit both in terms of higher yields as well as maintaining soil fertility and fertilizer use efficiency resulted bysaving 25 percent of recommended dose of nitrogen.

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Table1: Characteristics of the surface (0-15 cm) soil of the experimental field

1.Physical properties	**Units**	**Quantity**
Mechanical analysis		
Sand	(Kgha-^{1})	20.39
Silt	(Kgha-^{1})	19.06
Clay	(Kgha-^{1})	38.46
2. Chemical properties		
pH(1:2.5 soil/water)		6.40
Electric conductivity	(dsm^{-1})	0.13
Organic carbon	(gmKg-^{1})	6.80
Available Nitrogen	(Kgha-^{1})	288.0
Bray-P(Kgha-1)	(Kgha-^{1})	12.30
NH_4OA_C-K	(Kgha-^{1})	211.4

Table-2. Treatments Details

Treatments	**Nutrient Source**	
	Kharif **(Rice)**	***Summer*** **(Maize)**
1	Control	Control
2	50% NPK	50% NPK
3	50% NPK	100% NPK
4	75% NPK	75% NPK
5	100% NPK	100% NPK
6	50% N + 50% N FYM	100% NPK
7	75% N + 25% N FYM	75% NPK
8	50% N + 50% N Paddy Straw	100% NPK
9	75% N + 25% N Paddy Straw	75% NPK
10	50% N + 50% N Gliricidia	100% NPK
11	75% N + 25% N Glyricidia	75% NPK
12	Farmers Practice (85:50:30 kg NPK/ha & FYM 5 t/ha)	Farmers Practice (75:37.5:38.75 kg NPK/ha)

Table 3: Soil pH changes under integrated nutrient supply in rice-maize sequence, over five years

Treatments	**Soil pH (1:2.5)**						
	1989	**2008**	**2009**	**2010**	**2011**	**2012**	**Pooled data(2008-12)**
1	6.23	6.10	5.39	5.56	6.23	6.36	5.93
2	6.30	5.92	5.65	5.60	6.07	5.96	5.84
3	6.33	5.91	5.60	5.94	5.97	6.02	5.89
4	6.38	5.99	5.63	5.80	5.98	5.96	5.87
5	6.45	5.78	5.65	5.90	5.95	6.00	5.86
6	6.33	5.91	6.10	6.96	6.05	6.10	6.22
7	6.40	5.96	6.18	5.99	5.82	5.85	5.96
8	6.35	6.14	5.99	6.10	5.89	6.01	6.03

9	6.35	6.00	6.04	6.11	6.04	5.98	6.03
10	6.45	5.96	6.02	5.99	6.24	6.14	6.07
11	6.43	6.08	6.00	6.03	6.17	6.20	6.10
12	6.50	6.09	5.99	5.95	6.01	6.18	6.04
SEm±	0.101	0.028	0.01	6.40	6.40	6.40	
CD (P≤0.05)	NS	0.080	0.03	0.13	0.150	0.385	

Table 4: Soil organic carbon changes under integrated nutrient supply in rice-maize sequence, over five years

Treatments	**Soil OC (%)**						
	1989	**2008**	**2009**	**2010**	**2011**	**2012**	**Pooled data(2008-12)**
1	0.69	0.57	0.62	0.62	0.59	0.57	0.59
2	0.68	0.61	0.63	0.63	0.62	0.61	0.62
3	0.71	0.63	0.65	0.64	0.62	0.60	0.63
4	0.67	0.55	0.63	0.61	0.60	0.62	0.60
5	0.67	0.59	0.67	0.65	0.64	0.65	0.64
6	0.68	0.60	0.76	0.73	0.70	0.71	0.70
7	0.66	0.62	0.75	0.73	0.71	0.73	0.71
8	0.69	0.63	0.73	0.72	0.71	0.72	0.70
9	0.66	0.63	0.73	0.75	0.75	0.76	0.72
10	0.63	0.59	0.73	0.70	0.72	0.71	0.69
11	0.69	0.59	0.75	0.71	0.72	0.73	0.70
12	0.68	0.54	0.71	0.63	0.62	0.60	0.62
SEm±	0.025	0.0.013	0.09	0.68	0.68	0.60	
CD (P≤0.05)	NS	0.04	0.28	0.028	0.019	0.036	

Table 5: Soil available P changes under integrated nutrient supply in rice-maize sequence, over five years

Treatments	**Soil Av.P (kg/ha)**						
	1989	**2008**	**2009**	**2010**	**2011**	**2012**	**Pooled data**
1	15.30	21.80	15.39	18.25	17.71	17.70	18.17
2	10.80	22.56	19.65	17.66	20.58	19.35	19.96
3	13.33	22.18	21.02	19.23	20.61	21.60	20.93
4	11.25	22.05	18.78	18.85	19.33	20.45	19.89
5	11.25	21.38	21.86	21.99	21.16	21.64	21.61
6	11.60	21.72	23.98	23.12	21.50	21.53	22.37
7	9.83	23.23	21.56	22.01	22.53	21.98	22.26
8	15.00	21.48	20.94	21.38	21.92	23.00	21.74
9	12.23	22.61	22.99	22.06	23.11	23.95	22.94
10	8.63	21.47	22.18	21.85	22.92	21.10	21.90
11	14.75	20.94	22.08	21.98	21.52	19.79	21.26
12	11.53	21.24	20.90	19.01	21.09	22.42	18.17
SEm±	2.284	0.25	0.97	12.30	12.30	12.30	
CD (P≤0.05)	NS	0.75	2.96	0.69	1.04	3.243	

Table 6: Soil available K changes under integrated nutrient supply in rice-maize sequence, over five years

Treatments	**Soil Av.K (kg/ha)**						
	1989	**2008**	**2009**	**2010**	**2011**	**2012**	**Pooled data(5 Year)**
1	201.05	197.54	135.22	128.81	156.99	153.46	154.40
2	211.68	193.67	172.82	169.63	188.37	185.75	182.05
3	183.58	196.76	186.91	184.24	174.75	176.45	183.82
4	213.35	197.62	184.53	187.85	166.08	168.72	180.96
5	210.55	194.63	185.15	182.36	163.83	173.45	179.88
6	212.90	192.97	192.53	190.63	195.00	198.40	193.91
7	200.60	192.74	191.67	189.18	182.37	184.46	188.08
8	237.55	194.67	189.67	188.24	192.93	196.23	192.35
9	218.08	195.03	188.21	189.34	184.95	198.45	191.20
10	204.95	193.54	191.67	185.86	184.64	188.35	188.81
11	192.93	192.91	187.48	185.16	185.16	186.40	187.42
12	244.50	195.40	148.92	142.88	166.50	164.35	163.61
SEm±	14.02	0.37	5.70	211.40	211.40	211.40	
CD (P≤0.05)	NS	1.09	17.10	5.17	10.39	4.471	

Table7: UptakeofNPKbyrice and maizeatharvestunderintegratednutrientmanagementinrice-maizesequence(1989&2008)

Treatments	**Up take.N (kg/ha)**		**Up take.P (kg/ha)**		**Up take.K (kg/ha)**	
	1989(Initial Year)	**2008**	**1989**	**2008**	**1989**	**2008**
1	45.90	24.76	6.90	8.52	59.30	35.10
2	49.50	39.68	11.30	23.69	64.80	60.60
3	65.40	69.85	9.60	23.91	65.40	105.67
4	70.90	64.18	8.40	24.94	69.00	95.91
5	78.80	75.47	7.60	23.49	69.80	105.25
6	64.00	90.45	7.20	29.95	70.70	121.47
7	67.90	88.56	15.70	21.63	98.20	100.17
8	60.90	73.80	7.80	23.60	67.50	113.77
9	78.90	79.20	9.10	19.85	75.00	104.85
10	81.70	69.28	9.40	25.05	97.80	107.33
11	71.10	65.25	9.80	18.49	92.30	105.67
12	68.80	48.35	10.50	16.65	66.50	73.30
SEm±	1.111	4.83	0.263	2.08	0.644	4.72
CD (P≤0.05)	3.204	13.88	0.759	5.99	1.857	13.59

Table 8: Yield as influenced by integrated nutrient supply in paddy-maize system (1989 to 2013)

Treatments	1989 (Initial Year)		2008-09		2009-10		2010-11		2011-12		2012-13		Average yield (2008-09 to 2012-13)	
	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)	Rice grain yield (kg/ha)	Maize grain yield (kg/ha)
1	2797	672	3511	1772	4299	2434	4101	1243	3966	1221	3700	1243	3915	1583
2	4813	2046	5519	2573	5556	3428	6213	3754	5906	3724	5525	3754	5744	3447
3	4356	5195	5512	4204	5848	4335	6287	4616	6287	4558	5750	4616	5937	4466
4	4953	3898	5684	4267	6067	3721	6469	3830	6557	3830	6275	3830	6210	3896
5	5449	4831	6098	4892	6281	4605	6506	4576	6542	4569	6675	4576	6420	4644
6	5270	6003	5958	4437	6111	4357	6250	3779	5848	5117	5750	3779	5983	4294
7	5012	4022	5955	3907	6089	3809	6396	4572	6406	4572	6600	4572	6289	4286
8	5514	6199	6293	5379	6756	4686	6798	3951	6506	3951	6725	3951	6616	4384
9	5577	3701	6333	5535	6588	5015	7149	5157	6616	3779	6975	5157	6732	4929
10	5278	4360	5915	4294	6082	4298	6308	3615	6447	3615	6525	3615	6255	3887
11	5463	3460	5946	4138	6188	3428	6360	4028	6067	4028	6450	4028	6202	3930
12	5501	2959	5939	3953	5355	3348	5694	3286	5921	3286	5725	3286	5727	3432
SEm±	439	714	439	714	292	285	341	249	290	242	177	249		
CD (P≤0.05)	892	1454	892	1454	842	820	981	714	871	725	508	715		