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Nitrogen release pattern of different organic sources under varying levels of NPK fertilizers and their effect on yield and nutrient uptake in hybrid rice-wheat cropping system

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Abstract
A field experiment was carried out at research farm of BHU, Varanasi (U.P.), during two consecutive years to study the N-release pattern of four different organic nutrient sources, namely; farm yard manure (FYM), green leaf manure (GLM), Celrich and bio-gas slurry) combined with varying levels of NPK fertilizers and their effect on yield and NPK uptake in hybrid rice-wheat system. The study revealed that increasing fertilizer levels from 25 to 100 per cent of recommended dose of fertilizer (RDF) along with organic sources markedly increased the release of N up to 75 days after incorporation, whereas 25 per cent of RDF proved least effective. Among organic sources, FYM and GLM though remained equally effective but proved significantly superior to Celrich and biogas slurry both in quantity and duration of N release. Application of 75 and 100 per cent RDF remained on par in increasing grain and straw yield of rice as well as succeeding wheat crop but increase in yield of rice and wheat was significant over others rate of fertilizer. Effect of FYM and GLM also brought about significant increase in grain and straw yield of both the cropsbut remained on par with Celrich. Biogas slurry proved least effective among organic sources. Study of NPK uptake by both crops also showed significant improvement due to successive increase in RDF up to 100 per cent RDF whereas among the organic sources GLM and Celrich brought about maximum uptake of nutrient by both crops. Almost similar trend was recorded in case of NPK balance in soil after harvest of both crops.

Keywords: Integrated nutrient management, hybrid rice-wheat cropping system, fertility levels, organic sources

Introduction
Rice and wheat are the staple food crops occupying nearly 13.5 million hectares of the Indo-Gangetic plains (IGP) of South Asia covering Pakistan, India, Bangladesh and Nepal.Rice-wheat cropping system occupies about 10.2 million hectare area, plays a vital role in food security system of India(Mahajan and Gupta,2009). In wetland rice cultivation, the efficiency of applied nitrogen is very less and is thus deterrent to get the full potential yield from the modern hybrid rice varieties. The use of FYM and green leaf manure along with chemical NPK fertilizer is well known tostabilize productivity over a considerable period of time (Bhandari *et al*., 1992). However other organic sources like biogas slurry and celrich are to be identified for organic recycling and supplementing plain nutrient (Mondal *et al*., (1992) and Dhiman *et al.* (2000). For developing fertilizer recommendations under integrated system both direct and its residual effect of nutrients on rice- wheat cropping system is thus needed to ensure a balance and optimum supply of nutrients for high yield with sustainability.

Materials and Methods
A field experiment was carried out at Agricultural Research Farm of Institute of Agricultural Sciences, BHU, Varanasi (U.P.) to evaluate the nitrogen release pattern of different organic sources applied in rice crop, in combination with variable levels of NPK fertilizers on yield of hybrid rice and succeeding unfertilized wheat. Field experiments were laid out on sandy clay loam soil having pH 7.5, organic carbon 0.37%, available nitrogen 180 kg ha^{-1}, phosphorus (P_2O_5) 22 kg kg ha^{-1} and potassium (K_2O) 230 kg ha^{-1}in a split plot design with three replications. Four levels of recommended dose of NPK fertilizers (RDF, i.e., 150:75:60 kg $N:P_2O_5:K_2O$ ha^{-1}), viz, 25% (F_1), 50% (F_2), 75% (F_3) and 100% (F_4) of along with four organic manures namely; FYM (M_2), green leaf manure (M_3), bio-gas slurry (M_4) and Celrich (M_5) and an organic manure control (M_1) were tested.

All the four organic manures were applied to supply 50 kg N ha^{-1}, uniformly. Hybrid rice (ProAgro 6201) and wheat (var. HUW-464) were grown as test crops. Urea, single super phosphate and muriate of potash were used as carriers of N, P & K and wheat crop remained unfertilized to study the residual effect. Half of the total N and full dose of P and K were applied at the time of transplanting and remaining dose of N was top-dressed into two equal splits at tillering and panicle initiation stages. The quantity of all the organic manures was determined as per their N content on dry weight basis (Table-1) and was applied and mixed uniformly in soil one day before transplanting of rice seedlings. Wheat crop was taken entirely on residual fertility of previously applied treatments with same layout. The uptake of N, P and K was determined by multiplying respective nutrient contents with their corresponding grain and straw yields. Soil samples were collected after harvest of each crop and analysed for residual status of nitrogen, phosphorus and potassium in soil. The nitrogen release pattern of various organic sources were made through incubation study taking 200 g of experimental soil in plastic pots for each treatment and analysed at 15, 30, 45, 60,75 and 90 days after incubation as per the method suggested by Subbiah and Asija (1956).

Result and Discussion

N release pattern

Nitrogen release pattern of incubated soil markedly increased with increasing rate of fertilizer application (Fig. 1.1a, 1.1b, 1.1c, 1.1d, 1.1e, 1.1f and 1.1g). However, release of N increased upto 45 days after incubation with maximum in case of 100% RDF (Fig.1.1a). Minimum N release from soil was noted under 25% RDF only upto 30 days. Though in case of 50 and 75% RDF, it increased upto 45 days thereafter decrease while it increased upto 75 days after incubation under 100% RDF (Fig.1.1c)

The nitrogen release pattern followed a constant increasing trend with time variable (Fig.1.1b). No marked difference was noted in release pattern of FYM and green leaf manure at any fertility levels (Fig.1.1d and 1.1e). Biogas slurry showed distinct trend of N release at various fertility levels. N release with Biogas slurry due to 75% RDF and 50% RDF at 60 days remained almost equal (Fig.1.1f). The amount of N released from Celrich followed a definite increasing trend with time and fertilization rate and was recorded highest in case of 75 and 100% RDF (Fig.1.1g).

Fertility levels

Direct effect on rice

Significant improvement in grain and straw yield was observed with every successive increment in fertility level. Application of 100% RDF produced maximum grain yield of 73.15 and 75.24 qha^{-1}during the first and second year, respectively (Table-2), though it remained at par with 75% RDF. It is by and large true that hybrid rice have high rate of responsiveness towards heavy fertilization application particularly nitrogen because of their conducive genetic makeup. Increased availability of N, P and K. under high fertility proved instrumental in increasing yield. These findings were in conformity with the findings of Om *et.al*. (1998) and Sonour *et.al*. (1998)Mahajan and Gupta, (2009).

Increasing fertility levels significantly increased the total uptake of N, P and K. However the magnitude of total N uptake was much higher between 25% and 50% RDF in relation to 50% to 75% RDF and 75% to 100% RDF. Successive reduction of 25% in RDF reduced the uptake of N by 8.0, 18.1 and 38.9 per cent during the first year and 7.9, 19.8 and 36.3 percent during the second year, respectively. Similarly total P and K uptake increased significantly with each increment in fertility level up to 100% RDF. Maximum P uptake of 40.26 and 43.52 kg ha^{-1}during first and second year respectively was recorded with 100% RDF. Increase in N, P and K uptake remained associated with increased grain and straw yield of the crop. Similar findings were also reported by Rao and Shukla (1999).

Indirect (Residual) effecton wheat

Significant variation in grain and straw yield due to carry over effect of various fertility levels was observed. Maximum grain and straw yield of wheal was recorded due to carry over effect of 100% RDF. Marked reduction in grain yield was noticed due to 50 and 75% reduction in 100% RDF during both the years. However, the effect of 75 and 100% RDF remained at par.

Residual effect of various fertility levels applied to rice manifested a profound influence on total N, P and K uptake by succeeding wheat crop during both the years. Maximum uptake of N, P and K was observed due to residual fertility of 100% RDF and their uptake markedly increased with each successive increase in the rate of fertilizer application.

Organic sources

Direct effect on rice

Incorporation of varying organic sources of nutrients in addition toRDF brought about significant increase in grain yield. Though highest yield of 68.33 and 69.79 $qha^{-1}$was observed due to green leaf manure and FYM in first and second year, respectively but their affectivity in comparison to Celrich remained statistically at par. Almost similar trend of response was noted in case of straw yield. Biogas slurry remained least effective due to faster N release, which enabled maximum N availability only up to 30 days coincides with tillering stage. In addition to 50 kg N ha^{-1}, organic sources also supplied sufficient quantities of P, K, Mn, Zn and Fe (Table 1), and thus showed distinct advantage in terms of continued balanced supply of major and micro-nutrients for prolonged period thereby mitigating the chance of nutrient stress. Adequate supply of N and other nutrient through FYM, GLM and Celrich were the main cause for their better performance. Higher yields under green leaf manure and FYM has been reported By Raju and Reddy (2000) and Subbaiah and Kumar (2001).

Organic manure enhanced the total N. P and K. uptake during both the years. Maximum total N uptake i.e. 119.58 and 125.87 kg $ha^{-1}$was observed with green leaf manure (M_3) and Celrich (M_5) in respective years and proved significant over biogas slurry. Maximum P and K uptake was found associated with Celrich though it remained at par with green leaf manure and biogas slurry but proved significantly superior to FYM while other organic sources remained equally effective. Higher N uptake due to green leaf manure and Celrich than FYM and biogas slurry may be attributed to their higher N content. Similar findings were also reported by Singh *et al.* (2001). Increasing fertility status along with organic sources is expected to increase the availability of P and K in soil solution and consequently their uptake (Datta 2002 and Dhiman *et al.* 2000).

Indirect effect on wheat

Residual carry over effect of increasing rates of fertility along with different organic manures brought about significant

improvement in grain and straw yield of succeeding wheat. Among organic sources Celrich registered maximum yield whereas biogas slurry proved least effective.

Maximum grain and straw yield were observed under 100% RDF. Application of N fertilizer in combination with organic manure not only increased the availability of soil N status but also proved instrumental in enhancing the microbial activities responsible for organic matter decomposition. Effect of Celrich may be attributed due to its higher N balance and release coupled with supplementation of more quantity of micro-nutrients. It also contains several micro-organisms, responsible for better quantity of P and K release in soil pool.

Maximum straw yield was recorded due to carry over effect of I'YM (36.00 q ha^{-1}) and Celrich (38.04 q ha'1) during first and second years, respectively. No marked difference among the residual effect of organic manure was recorded in the first year, however Celrich and green leaf manure proved significantly superior to FYM in first year and biogas slurry during second year.

Organic manure application favoured uptake of N and P by the succeeding crop. Celrich treated plots recorded maximum total N and P uptake by residual crop during both the years. Minimum uptake of N was noticed with carry over effect of biogas slurry. The residual effect of organic manure on uptake of N, P and K could be attributed due to more hydrolysable and non-hydrolysable organic N on account of green leaf manure. These results also corroborated the findings of Singh *et.al*. (2001).

Nutrient status of soil

Available N

Quantity of available N, P and K after harvest of rice as well as wheat markedly increased with increasing rates of fertilizer application. Similarly incorporation of organic manure in addition to fertilizer also brought about profound improvement in available NPK after harvest of both the crops in each year. However in case of N, it was recorded positive gain in comparison to initial soil value after rice harvest but not after wheat harvest. Increasing levels of fertility, however failed to produce proportionate increase in available N. Among organic sources, Celrich produced maximum available N balance due to its low N release pattern whereas biogas slurry proved least effective mainly because of its higher N release and subjected to various losses (Yadav& Kumar, 2002 and Singh *et al*. 2001).

Available P and K

P balance was positive beyond 50% RDF while positive K balance was noticed beyond 75% RDF after rice harvest during both the years. All organic manure produced positive influence on available P and K status of soil after rice harvest. Maximum available P and K were recorded with Celrich and green leaf manure after harvesting of rice during both the years mainly due to increased P and K supplementation.

P balances after wheat harvest was also noted positive under residual effect of 75 and 100% RDF. Lower fertility levels failed to produce positive balance mainly because of limited P availability. Among the organic sources application of biogas slurry and Celrich produced positive P balance probably due to higher P content and P solubilizing microorganism which solubilise non-labile P. These findings were corroborated with the findings of Bhandari *et al.* (1992) Gupta *et al*. (2000) and Mehdi *et al*. (2011)

Available K balance in soil remained negative, although maximum value was observed with 100% RDF after harvest of wheat. None of the organic manure exerted positive effect on available K balance. However maximum K balances (228.0 kg K_2O ha^{-1}) after rice-wheat system was associated with green leaf manure during second year. Negative K balance after harvest of wheat crop might be due to higher uptake of K by the crop, owing to the fact that in rice-wheat system, available K in soil decreases under absence of K fertilizer application (Nambiar, 1994).

Table 1: Nutritional Composition of different organic sources tested under trial

Organic Sources	Nutrient content (%)			Micro-Nutrient content (ppm)				C:N ratio	Biomass added Fresh wt. t ha^{-1}
	N	P_2O_5	K_2O	Fe	Mn	Zn	Cu		
FYM	0.6	0.25	0.5	4032	220	270	48	26	10.00
Green leaf manure (*Sesbaniaaculeata*)	1.6	0.60	1.2	4000	280	410	60	17	7.00
Biogas spent slurry	1.1	0.45	0.55	2504	241	205	50	12	8.00
Celrich	1.8	1.25	1.05	6000	740	740	275	15	2.75

Table 2: Effect of Different treatments on grain yield, straw yield of Hybrid rice and wheat

Treatment	Rice				Wheat			
	Grain yield (q ha^{-1})		Straw yield (q ha^{-1})		Grain yield (q ha^{-1})		Grain yield (q ha^{-1})	
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2
A. Fertility level								
F_1	45.35	48.12	61.67	62.65	20.77	21.63	31.37	32.77
F_2	62.55	63.77	77.84	81.94	23.94	24.33	34.77	35.80
F_3	70.32	73.37	81.46	85.85	26.14	26.23	36.61	38.37
F_4	73.15	75.24	83.39	86.13	27.10	27.40	37.17	39.07
LSD (P=0.05)	3.51	2.01	3.08	2.14	1.83	1.95	1.95	2.04
B. Organic Manure								
M_1	46.50	50.34	64.38	73.26	21.42	22.25	32.17	33.83
M_2	66.74	69.79	78.05	81.88	25.88	24.83	36.00	36.67
M_3	68.33	69.46	80.84	81.78	25.04	26.45	35.92	37.88
M_4	64.98	66.66	77.66	78.03	24.13	24.38	35.13	36.08
M_5	67.66	69.36	79.51	80.75	25.97	26.59	35.68	38.04
LSD (P=0.05)	3.23	2.37	3.19	2.56	1.58	1.41	1.45	1.19

Details of treatments are given in text

Y_1= First year Y_2= Second year

Table 3: Effect of different fertility levels and organic manure on nutrient uptake by Hybrid Rice and Wheat

Treatment	Direct (Hybrid Rice)						Residual (wheat)					
	Total Nutrient uptake (kg ha^{-1})						Total Nutrient uptake (kg ha^{-1})					
	Y_1			Y_2			Y_1			Y_2		
	N	P	K	N	P	K	N	P	K	N	P	K
A. Fertility level												
F_1	61.30	16.94	112.57	66.95	18.50	116.90	34.74	9.31	61.49	36.44	10.17	64.80
F_2	100.42	26.57	153.06	105.04	28.80	161.51	46.81	12.64	72.31	48.36	13.37	74.78
F_3	122.64	32.93	169.43	130.96	36.62	179.83	55.71	14.81	78.49	57.71	16.43	82.43
F_4	133.40	40.26	184.53	142.31	43.52	191.66	66.41	18.23	82.87	70.06	19.52	87.46
LSD (P=0.05)	6.81	3.13	6.06	4.44	3.80	8.85	2.86	1.03	3.67	2.62	1.82	3.66
B. Organic Manure												
M_1	59.65	19.54	116.00	67.23	22.82	132.18	33.31	10.38	62.02	35.82	11.50	65.90
M_2	112.37	29.07	161.28	120.83	32.02	170.40	55.89	14.25	77.77	54.74	18.48	77.94
M_3	119.58	32.16	166.79	123.79	34.55	170.86	55.52	15.03	76.95	59.33	15.90	81.33
M_4	111.26	32.05	163.07	116.36	33.93	166.49	52.21	13.96	74.61	54.58	15.42	78.11
M_5	119.32	33.06	167.37	125.87	35.98	172.44	57.32	15.11	77.61	61.24	17.05	83.56
LSD (P=0.05)	5.82	2.90	7.48	6.42	3.21	8.33	3.24	1.05	3.75	3.46	1.52	3.43

Table 4: Nitrogen, Phosporus and Potassium content of Soil after harvest of each crop as affected by diferent treatments

Treatment	Available nutrients in Soil (Kg ha^{-1})											
	After Rice			After Wheat			After Rice			After Wheat		
	Y_1			Y_1			Y_2			Y_2		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
A. Fertility level												
F_1	(180.00) 166.4	(22.0) 21.4	(230.0) 224.8	134.1	16.8	196.7	161.6	20.7	213.1	140.9	17.2	199.2
F_2	174.4	26.4	229.6	144.8	19.8	198.8	183.4	25.1	226.8	153.3	21.0	204.5
F_3	189.6	29.5	240.4	155.3	22.3	207.2	199.9	28.6	236.0	165.7	23.2	213.3
F_4	211.8	31.1	245.4	173.3	24.5	215.8	214.8	30.4	243.1	179.5	25.8	222.4
LSD (P=0.05)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B. Organic Manure												
M_1	167.8	23.0	222.5	135.4	18.1	190.2	164.9	22.0	217.9	144.0	18.5	190.7
M_2	185.5	26.0	240.5	154.2	20.6	210.6	192.6	25.9	234.0	163.2	21.4	220.6
M_3	187.5	25.0	241.9	156.2	19.9	214.2	196.1	25.5	234.2	163.6	21.7	228.9
M_4	181.7	28.0	239.5	158.8	22.0	208.5	191.4	28.3	232.9	165.1	22.8	212.4
M_5	188.1	29.9	240.9	169.3	23.7	212.5	197.8	30.4	236.8	166.5	24.6	216.5
LSD (P=0.05)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Data in parenthesis are initial nutrient status of soil NA = Not anaylsed
Details of treatments are given in text
Y_1= First year Y_2 = Second year

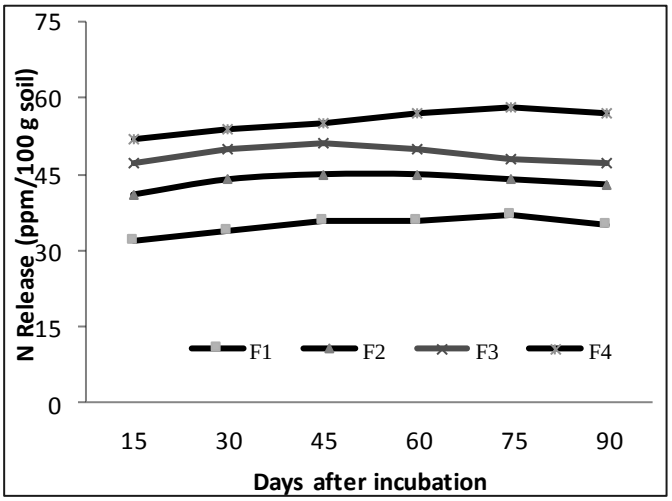

Fig 1.1a: Mean N release of various fertility levels (Irrespective of organic manures)

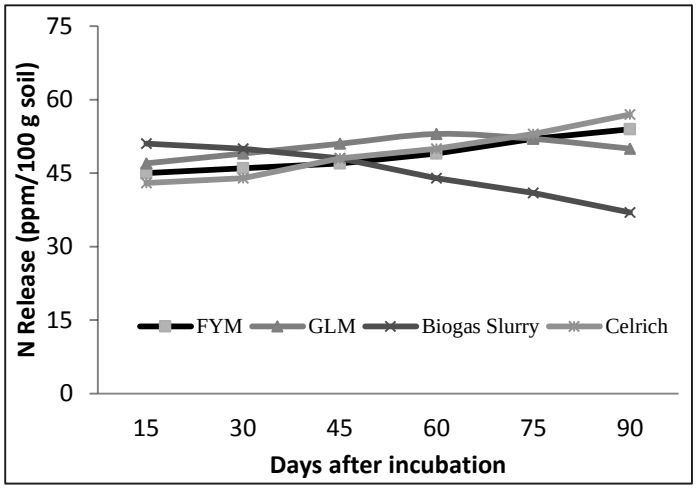

Fig 1.1b: Mean N release of different organic manures (Irrespective of fertility levels)

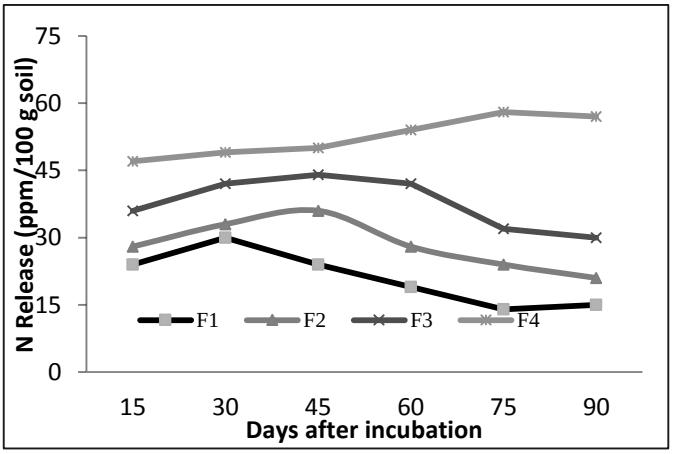

Fig 1.1c: N release of soil at various fertility levels

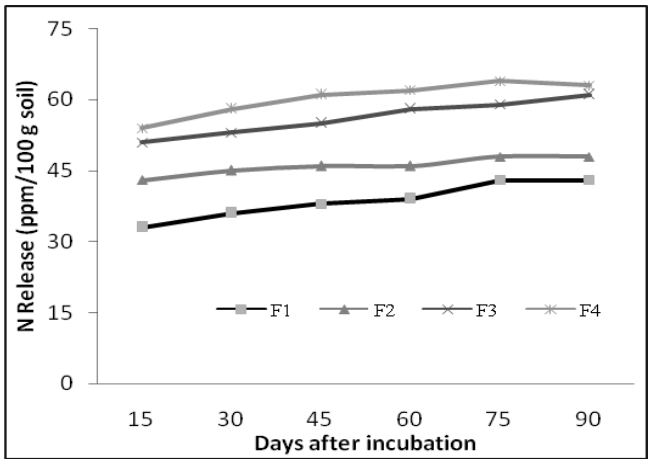

Fig 1.1d: N release of FYM at various fertility levels

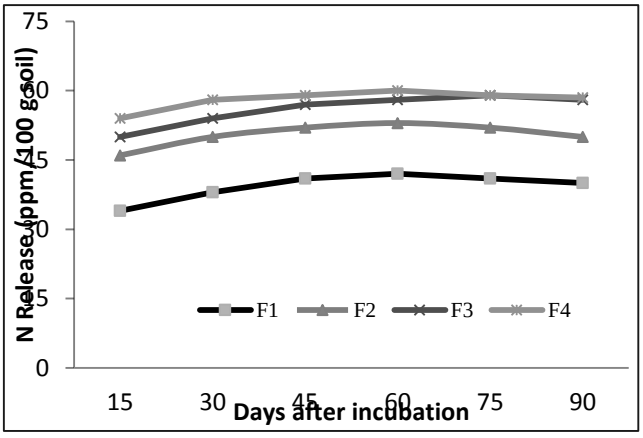

Fig 1.1e: N release of green leaf manure at various fertility levels

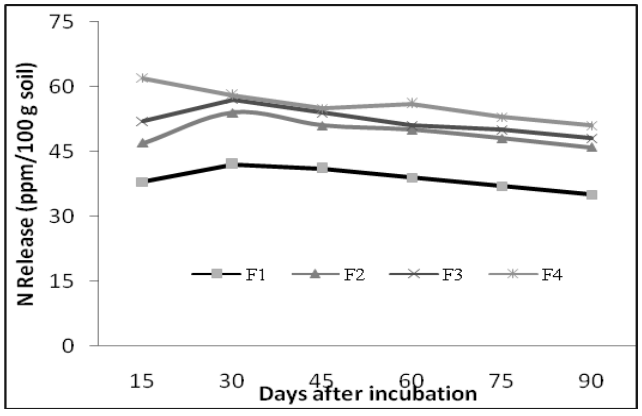

Fig 1.1f: N release of Biogas slurry at various fertility levels

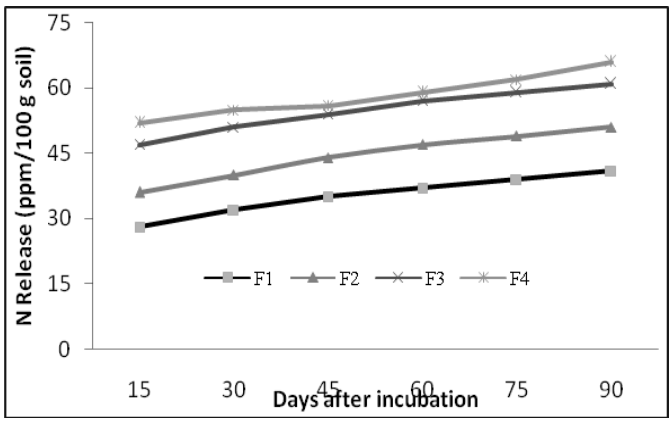

Fig 1.1g: N release of Celrich at various fertility levels

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