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Effect of biogas slurry and neem oil-treated urea sources on rice (*Oryza sativa*)–wheat (*Triticum aestivum*) cropping system

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ABSTRACT

A field experiment was conducted during the rainy season (*kharif*) and winter season (*rabi*) of 1999–2000 and 2000–2001 at New Delhi, to study the effect of biogass slurry (BGS) and neem oil-treated urea sources on rice (*Oryza sativa* L.)–wheat (*Triticum aestivum* L. emend. Fiori. & Paol.) cropping system. Except plant height, all the growth and yield attributes of rice such as effective tillers/hill, panicle length, filled grains/panicle and 1,000-grain weight differed significantly due to different sources of N and their combinations with biogas slurry (BGS). Pusa neem micro-emulsion urea 120 ($PNME_{120}$) alone or with BGS in 70:30 gave the significantly higher grain yield of rice compared to prilled urea 120 (PU_{120}), BGS_{120} and Pusa neem golden urea 120 ($PNGU_{120}$). The $PNME_{120}$ also recorded significantly higher apparent N recovery (59.3%) and agronomic efficiency (28.7 kg grain/kg N) compared to rest of sources and their combinations. Also, significantly more total N, P, K uptake was associated with $PNME_{120}$. Direct application of 60 kg N/ha to wheat significantly increased (16.6%) its grain yield over no nitrogen. Inorganic fertilizers applied to rice did not show significant influence on succeeding wheat crop. Biogas slurry resulted in the higher grain yield (3.97 tonnes/ha) than the control (3.14 tonnes/ha), prilled urea @ 120 kg N/ha (3.18 tonnes/ha), Pusa neem golden urea (3.37 tonnes/ha) and PNME (3.54 tonnes/ha). However, Pusa neem micro-emulsion urea significantly differed with the control, but not with rest of the sources. The $PNGU_{120}$ + BGS_{120} in 50 : 50 ratio resulted in higher grain yield (3.78 tonnes/ha) than (prilled urea + biogas slurry)$_{120}$ in 70 : 30 ratio, however it remained statistically at par with other combinations.

Key words : Rice, Wheat, Modified urea forms, Biogas slurry, Residual effect, Yield attributes, Yields, Nutrient uptake

Rice–wheat cropping system is most widely adopted cropping system in India which occupied 10.3 million ha area, contributing 25% to the national foodgrain production. However, there are indications of stagnation or even decline in the productivity of rice–wheat cropping system due to decline in the soil organic matter, overmining and losses of nutrients from soil and non-availability of cost-effective fertilizers. Therefore, we need the fertilizers which are not only cost effective but also maintain soil health favourably. This could be possible by 2 ways, firstly, using the inorganic fertilizers which can meet the crop nutrient demand for entire crop season through single application and secondly, supplementing inorganic fertilizers with proper proportions of organic sources.

The present study was therefore undertaken to find out the effect of neem oil-treated urea sources and biogas slurry on the productivity of rice and rice–wheat under wheat cropping system.

MATERIALS AND METHODS

A field experiment was conducted during rainy and winter seasons of 1999–2000 and 2000–2001, respectively, on sandy clay loam soils of the research farm of Indian Agricultural Research Institute, New Delhi (28°40'N latitude 77°10.E longitude and 228.6 m altitude). The experimental field was slightly alkaline, having pH 7.8 with organic carbon 0.53%, available nitrogen 218 kg/ha, available P 16.8 kg/ha, available K 315 kg/ha (mean of 2 years). The experiment was laid out in randomized block design with 3 replications for rice. Twelve treatments applied to rice consisted of control, prilled urea (PU) at 60 and 120 kg N/ha, biogas slurry (BGS), Pusa neem golden urea (PNGU), Pusa neem micro-emulsion urea (PNME) @ 120 kg N/ha, 3 combinations in 70 : 30 ratio, viz. (PU + BGS)$_{120}$, (PNGU+BGS)$_{120}$ and (PNME + BGS)$_{120}$, and 3 combinations in the ratio of 50:50, viz. (PU+BGS)$_{120}$, (PNG+BGS)$_{120}$ and (PNME+BGS)$_{120}$. In the winter season, the same rice plots were divided into 2 plots to investigate the direct and residual effect of N on wheat. Thus, wheat experiment was laid out in split-plot design comprising 24 treatments under no nitrogen and 60 kg N/ha with 3 replications. Recommended dose of P (60 kg P_2O_5/

ha) and K (40 kg K_2O/ha) were applied as basal. The variety used in present investigation was 'PRH 10' for rice and 'HD 2329' for wheat.

RESULTS AND DISCUSSION

Growth and yield attributes of rice

Except for plant height, all the growth and yield attributes, such as effective tillers/hill, panicle length filled grains/panicle and 1,000-grain weight differed significantly because of different sources of N and their combinations (Table 1). The highest number of effective tillers/hill were recorded with $PNME_{120}$ and it remained statistically at par with $PNGU_{120}$ in both the years. Treatment $(PNME+BGS)_{120}$ was significantly superior to $(PU+BGS)_{120}$, when applied along with biogas slurry in 70:30 or 50:50 ratio. However, no significant difference was observed between $(PNME+BGS)_{120}$ and $(PNGU+BGS)_{120}$ in either ratios. Panicle length was increased with successive increase in N levels of prilled urea and application of 120 kg N/ha produced maximum longer panicle length among the nitrogen levels. In general, the longest panicle length was recorded with $PNME_{120}$ and it was significantly longer to PU_{120}. Treatment $(PNME+BGS)_{120}$ was found superior for panicle length over $(PU+BGS)_{120}$ in 70:30 ratio; however, no significant difference was recorded in 50:50 ratio. The $PNME_{120}$ also recorded significantly higher number of filled grains/panicle over PU_{120}, BGS_{120} and $PNGU_{120}$. Similar results were also recorded with 1,000-grain weight. Among the different sources and their combinations, $PNME_{120}+BGS_{120}$ in 70 : 30 ratio recorded the highest number of filled grains/panicle. In general, a beneficial effect was observed on all growth and yield attributes on applying modified urea materials and biogas slurry compared to prilled urea because of slow release of N from modified urea sources and higher uptake by plants which in turn increased the growth and development. The superior effect of modified urea fertilizers on yield attributes compared to PU confirms the findings of Prasad *et al.* (1999) and Singh and Shivay (2003).

Grain and straw yields of rice

A significant increase in grain and straw yields of rice were recorded with increase in level of nitrogen from 0 to 120 kg N/ha. Based on pooled data the extent of increase in grain yield with 120 kg N/ha was 57.3 and 24.4% over the control and 60 kg N/ha respectively. This positive response could be because of more effective tillers/hill, longer panicles, more filled grains/panicle and higher 1,000-grain weight in case of increasing nitrogen level. Treatment $PNME_{120}$ resulted in highest grain and straw yields among all treatments. The PNME and PNGU differed significantly for grain yield. However, PU_{120}, BGS_{120} and $PNGU_{120}$ were statistically at par. The $PNME_{120}$ gave 24% higher grain yield over prilled urea. The PNME maintained its superiority to PU even when applied along with BGS in 70:30 or 50:50 ratio. This increase in grain yield can be correlated with enhanced apparent recovery (59.3%) compared to prilled urea (36.5), which clearly shows lesser N losses due to volatilization, dentrification and leaching losses with PNME. This resulted in increased availability of nitrogen to entire growth period which might have led more effective tillers/hill, longer panicle length, more filled grains/panicle and higher 1,000-grain weight in case of $PNME_{120}$. The availability of N to plant, again can be correlated with agronomic efficiency, $PNME_{120}$ produced 28.7 kg grains/kg N compared to 17.2 kg grain/N with PU_{120}. Prasad *et al.* 2001 also reported that urea coated with neem formulations gave 12–13% higher

Table 1. Effect of prilled urea, biogas slurry, neem oil-treated urea sources and their combinations on growth and yield attributes of rice

Treatment	Plant height (cm)		Effective tillers/ hill		Panicle length (cm)		Filled grains/ panicle		1,000-grain weight (g)	
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Control	94.6	96.8	8.1	9.3	25.0	26.3	121.3	122.4	18.6	20.1
PU_{60}	97.6	99.3	9.3	10.5	25.9	26.9	123.4	124.8	19.5	21.2
PU_{120}	101.6	103.5	10.1	11.3	27.8	28.3	125.7	126.8	20.5	22.1
BGS_{120}	100.2	103.1	9.8	10.3	27.5	28.7	124.9	132.4	20.9	21.8
$PNGU_{120}$	102.2	105.7	11.8	12.5	28.0	29.2	130.9	135.5	21.6	22.7
$PNME_{120}$	104.5	108.6	12.2	13.5	30.7	31.6	136.8	139.5	22.8	24.0
$PU_{120}+BGS_{120}$ 70:30	99.8	100.9	9.3	9.8	26.8	27.5	130.3	132.5	19.6	20.6
$PNGU_{120}+BGS_{120}$ 70:30	101.6	104.6	10.7	10.9	27.3	28.3	133.5	134.8	20.8	20.9
$PNME_{120}+BGS_{120}$ 70:30	104.1	107.5	11.9	12.0	29.2	30.4	134.1	136.2	21.5	22.3
$PU_{120}+BGS_{120}$ 50:50	96.9	98.5	8.8	9.4	26.3	27.5	128.1	128.6	19.5	21.1
$PNGU_{120}+BGS_{120}$ 50:50	99.5	101.4	9.2	10.9	26.6	27.3	130.2	132.4	19.8	21.4
$PNME_{120}+BGS_{120}$ 50:50	101.1	103.2	10.2	11.2	27.3	28.7	131.3	133.2	20.6	22.8
CD (P=0.05)	NS	NS	1.3	1.4	1.5	1.5	2.4	2.4	1.3	1.3

rice yield than uncoated urea at the IARI Research Farm and 6–12% higher on farmers' fields.

Nutrient uptake by rice

There was a significant increase in total N uptake with each successive increase in N levels, being highest at 120 kg N/ha. This significant increase was owing to an increase in grain yield and straw yield as well as N concentration with increasing N levels. The PNME alone or along with biogas slurry in 70:30 or 50:50 ratio resulted in significantly more total N uptake than PU. This could be attributed to higher nitrogen concentration in grain and straw and maximum grain and straw yields with $PNME_{120}$ owing to more availability of N during entire growth period. Thus N had a distinct role in determining the nitrogen uptake in rice. Significantly more total P uptake with $NPME_{120}$ was observed over PU_{120}, BGS_{120} and $PNGU_{120}$. These results confirm the findings of Hagin *et al.* (1990) and Shaviv (1993). The $PNME_{120}$, being neem oil-treated urea, acts as nitrification retarder and therefore more concentration of NH_4^+ might have resulted in higher concentration of P in the soil leading to more uptake. Total K uptake was also significantly higher with $PNME_{120}$ alone or 50:50 ratio, compared to PU_{120}, BGS_{120} and $PNGU_{120}$. This increased uptake is attributed to synergistic effect of N and K due to increased availability of nitrogen with PNME which in turn increased the K concentration in grain and straw and finally led to increased K uptake. The present results are also in accordance to Olsen (1986) who reported the synergistic effect of N and K when plants were supplied with mixed ammonium nitritate nutrition.

Nitrogen-use efficiency and apparent N recovery

Nitrogen-use efficiency (NUE) and apparent N recovery were affected significantly due to different sources of nitrogen and their combinations (Table 2). Among the sources of nitrogen, $PNME_{120}$ resulted in significantly higher NUE and apparent N recovery than PU_{120}, BGS_{120} and $PNGU_{120}$. In general, in respect of NUE and apparent N recovery, the different N sources exhibited the following order : $PNME_{120}$>$PNGU_{120}$>BGS_{120}> PU irrespective of their combinations or alone.

Yield attributes of wheat

Direct application of 60 kg N/ha resulted in a significantly more effective tillers/m² over no nitrogen during both the years. Residual effect of biogas slurry showed significantly influence on the production of effective tillers/m² in both years compared to neem oil-treated urea sources. Among slow-release fertilizers, PNME had abysmally residual effect on effective tillers and produced more number of tillers/m² than the control. The combination of PNME with BGS in 50:50 ratio produced significantly more effective tillers than PU or PNGU with BGS in either ratio, however, it was at par with BGS alone (Table 3).

The other yield attributes, viz. plant height, spikes/m row length and grains/spike, increased significantly owing to the residual effect of biogas slurry alone or with PNME in 50:50 ratio compared with the control and PU_{60}. Biogas slurry gave the highest value of spikes/m row-length and grains/spike. Spike length and 1,000-grain weight was not influenced by the residual effect of biogas slurry.

Table 2. Effect of prilled urea, biogas slurry, neem oil-treated urea sources and their combinations on grain yield, straw yield (mean of 2 years), total, N, P, K uptake, apparent N recovery and N use-efficiency in rice

Treatment	Grain yield (tonnes/ha)	Straw yield (tonnes/ha)	Total N uptake (kg/ha)		Total P uptake (kg/ha)		Total K uptake (kg/ha)		Apparent N recovery (%)	Agronomic efficiency (kg grain/ kg N)
			1999	2000	1999	2000	1999	2000		
Control	3.63	6.63	62.2	61.6	11.6	12.5	99.2	100.6		
PU_{60}	4.59	7.82	80.2	80.3	16.7	18.0	121.2	121.3	30.3	16.0
PU_{120}	5.71	9.49	105.1	106.2	22.6	24.2	114.2	157.3	36.5	17.2
BGS_{120}	5.73	7.92	103.3	102.9	21.1	22.8	148.7	152.0	34.3	17.5
$PNGU_{120}$	6.13	9.90	110.6	110.3	24.5	26.5	158.8	164.1	40.4	20.8
$PNME_{120}$	7.09	10.70	133.5	132.8	29.3	31.7	179.8	184.3	59.3	28.7
PU_{120}+BGS_{120} 70:30	5.27	9.35	95.3	97.2	20.1	21.0	148.5	149.0	28.5	14.1
$PNGU_{120}$+BGS_{120} 70:30	5.89	9.89	109.6	109.4	22.2	25.5	165.1	159.4	39.6	18.8
$PNME_{120}$+BGS_{120} 70:30	6.71	10.50	124.3	124.0	26.8	33.5	164.9	167.7	51.9	25.6
PU_{120}+BGS_{120}50:50	5.22	9.28	93.8	93.7	18.4	19.3	144.9	147.7	26.5	19.6
$PNGU_{120}$+BGS_{120} 50:50	5.73	9.61	104.8	104.6	21.1	23.1	150.3	158.4	35.5	17.5
$PNME_{120}$+BGS_{120} 50:50	6.50	11.02	114.2	117.3	24.4	27.3	177.9	181.4	44.9	23.8
CD (P=0.05)	0.74	1.15	12.3	15.9	1.7	2.3	11.6	13.4	11.2	6.3

Table 3. Direct effect of N application and residual effect of prilled urea, biogas slurry, neem oil-treated urea sources and their combinations on yield attributes of succeeding wheat crop under rice–wheat cropping system

Treatment	Plant height (cm)		Effective tillers/m^2		Spikes/m length		Spike length (cm)		Grains/ spike		1,000-grain weight (g)	
	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Direct effect of N (kg/ha) applied to wheat												
0	73.9	79.3	298.2	301.3	76.1	80.9	9.4	9.6	32.5	36.6	45.0	45.6
60	81.2	83.6	307.1	313.4	82.1	88.6	10.0	10.3	37.9	41.8	46.3	47.5
CD (P=0.05)	3.10	3.20	6.28	6.22	2.55	3.66	0.40	0.39	1.80	1.33	1.10	1.11
Residual effect of N applied to rice												
Control	72.5	77.6	290.0	296.6	74.9	82.4	9.3	9.5	33.6	37.5	45.2	46.3
PU_{60}	73.1	80.0	291.9	298.1	75.5	82.9	9.3	9.7	33.7	37.9	45.3	46.3
PU_{120}	73.9	81.2	295.3	302.2	76.0	83.2	9.5	9.7	34.0	38.4	45.4	46.3
BGS_{120}	80.0	87.1	325.5	331.9	82.9	89.5	10.0	10.4	36.6	41.6	46.0	46.9
$PNGU_{120}$	74.9	79.7	297.6	300.1	79.4	81.9	9.6	9.8	34.2	38.4	45.5	46.5
$PNME_{120}$	76.2	80.5	308.2	307.2	79.4	83.4	9.7	9.8	34.2	38.4	45.5	45.5
PU_{120}+BGS_{120} 70:30	77.8	78.7	287.6	290.3	78.1	82.1	9.6	9.8	34.0	38.5	45.6	46.5
$PNGU_{120}$+BGS_{120} 70:30	78.9	80.4	292.4	296.1	79.4	83.7	9.7	10.0	35.0	39.1	45.7	45.5
$PNME_{120}$+BGS_{120} 70:30	79.3	81.3	307.0	311.4	79.9	86.1	9.8	10.0	35.4	39.5	45.3	46.6
PU_{120}+ BGS_{120} 50:50	80.3	82.8	301.8	307.0	80.4	86.1	10.0	10.0	36.5	39.8	45.8	46.6
$PNGU_{120}$ + BGS_{120} 50:50	81.5	83.1	308.7	314.2	82.1	87.3	10.1	10.2	37.1	40.5	46.0	46.7
$PNME_{120}$ +BGS_{120} 50:50	82.4	84.6	326.1	333.5	82.6	88.4	10.2	10.3	37.3	41.1	46.0	46.8
CD (P=0.05)	6.6	6.3	16.3	16.1	6.0	5.7	NS	NS	2.4	2.5	NS	NS

Table 4. Direct effect of N levels and residual effect of prilled urea, biogas slurry, neem oil-treated urea sources and their combinations on grain yield, straw yield (mean data of 2 years) and total N, P, K uptake of wheat crop under rice–wheat cropping system

Treatment	Grain Yield (tonnes/ha)	Straw yield (tonnes/ha)	Total N uptake (kg/ha)		Total P uptake (kg/ha)		Total K uptake (kg/ha)	
			1999–2000	2000–2001	1999–2000	2000–2001	1999–2000	2000–2001
Direct effect of N (kg/ha) applied to wheat								
0	3.25	5.84	72.3	78.2	23.6	24.7	96.5	99.6
60	3.79	6.66	84.7	93.1	27.7	29.7	116.2	119.2
CD (P=0.05)	0.15	0.27	0.30	7.53	0.05	0.06	0.24	0.29
Residual effect of N applied to rice								
Control	3.14	5.76	69.1	77.2	21.0	22.6	93.0	97.0
PU_{60}	3.18	5.96	70.9	78.4	22.1	24.4	97.6	102.1
PU_{120}	3.24	6.01	71.7	79.7	22.7	23.8	98.1	102.5
BGS_{120}	3.97	6.90	89.8	98.7	22.7	32.4	117.3	120.1
$PNGU_{120}$	3.37	5.92	74.1	81.3	24.1	25.3	101.6	102.7
$PNME_{120}$	3.54	6.25	79.0	85.5	26.4	28.0	109.6	108.8
PU_{120}+BGS_{120} 70:30	3.36	5.93	74.3	80.7	24.4	25.2	101.2	106.2
$PNGU_{120}$+BGS_{120} 70 : 30	3.50	6.20	78.6	84.7	25.6	27.6	109.5	112.2
$PNME_{120}$+BGS_{120} 70 : 30	3.57	6.39	80.3	86.7	26.5	27.1	108.2	111.1
PU_{120}+BGS_{120} 50:50	3.66	6.43	81.9	88.8	27.3	28.7	111.0	113.3
$PNGU_{120}$+BGS_{120} 50 : 50	3.72	6.53	84.1	91.0	27.8	29.1	111.7	115.6
$PNME_{120}$+ BGS_{120} 50 : 50	3.78	6.67	87.3	95.0	29.9	31.9	117.2	120.7
CD (P = 0.05)	0.39	0.65	6.90	7.53	0.13	0.16	6.17	7.50

Grain and straw yield of wheat

Direct application of 60 kg N/ha to succeeding wheat crop on the residual fertility plot of rice resulted in a significant increase of grain yield in order of 15.7 and 17.5% over no nitrogen during 1999–2000 and 2000–2001 respectively. The increase in wheat yield might be attributed to the significant effect of nitrogen on growth and yield attributes, viz. plant height, effective tillers/m², spikes/m row length, spike length, grains/spike and 1,000 grain weight, which led to increased grain yield significantly. Similar results were recorded with wheat straw yield. Sharma and Prasad (1980) also reported significantly yield improvement in succeeding wheat with the application of 50 kg N/ha.

The application of biogas slurry to rice resulted in significant residual effect on grain yield of wheat and recorded significantly higher grain yield over PU, PNGU and PNME. This might be owing to an additional N availability to succeeding wheat through mineralization from residual organic matter of biogas slurry. Dwivedi and Thakuar (2000) also reported that fertilizers applied to rice did not show any significant effect on succeeding wheat, however, biogas slurry resulted in significant residual effect. The PNME also resulted in significantly more grain yield than the control, but was at par with PU and PNGU. The integrated use of biogas slurry with different sources did not influence the grain yield of succeeding wheat except $PNME_{120}+BGS_{120}$ in 50:50 ratio which surpassed $PU_{120}+BGS_{120}$ in 70:30 ratio (Table 4).

There was no significant difference in grain yield of wheat due to residual N levels through prilled urea and neem oil-treated urea sources. Hedge and Dwivedi (1992) and Kumar (1994) also noticed non-significant response of succeeding wheat to inorganic fertilizers in rice–wheat cropping system.

Nutrient uptake by wheat

Direct application of 60 kg N/ha to wheat significantly N, P and K uptake over no nitrogen. This increased in total N, P, K uptake by wheat crop with 60 kg N/ha application was because of higher grain and straw yields than the control. The results corroborated with those of Kumar and Balyan (2002). Residual effect of biogas slurry alone or with PNME in 50:50 ratio showed highest N, P and K uptake. This may be ascribed to more availability of these major nutrients and increased yields which accounted for higher uptake of N, P and K. Dwivedi and Thakur (2000) also reported higher N, P and K uptake with residual biogas slurry by succeeding wheat crop.

Higher uptake of N, P and K with biogas slurry alone or in combination with PNME in 50:50 ratio indicated that slow mineralized nutrient from biogas slurry could sufficiently meet the nutritional requirement of the wheat crop.

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