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Research Paper

Effect of nutrient sources on grain yield, methane emission and water productivity of rice (*Oryza sativa*) under different methods of cultivation

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ABSTRACT

A field experiment was conducted during the rainy seasons of 2012 and 2013 at Zonal Agricultural Research Station, Mandya, to study the sources of nutrient on yield, methane emission, and water productivity of rice (*Oryza sativa* L.) under different methods of cultivation. Among the different methods of rice cultivation, system of rice intensification (SRI) method recorded higher water productivity (54.3 kg/ha-cm) than aerobic method (46.6 kg/ha-cm) and conventional method (29.9 kg/ha-cm) and resulted to the higher grain and straw yields of rice (8.55 and 10.07 t/ha) than the other methods of rice cultivation like conventional (7.05 and 8.38 t/ha) and aerobic method (6.48 and 7.83 t/ha). Among the sources of nutrients, application of recommended dose of fertilizer (100% N through neem-coated urea) recorded higher grain and straw yields (8.49 and 9.83 t/ha) over the other sources of nutrients, whereas the aerobic method of rice cultivation recorded lower methane emission (3.95 mg/plant/day) and total methane production (24.2 kg/ha) than SRI method (4.42 mg/plant/day and 28.1 kg/ha) and conventional method (6.25 mg/plant/day and 80.7 kg/ha) 90 days after sowing (DAS). Among the sources of nutrients, application of recommended dose of fertilizer (100% neem coated urea) recorded significantly lesser methane emission (4.35 mg/plant/day) and total methane production (37.9 kg/ha) than the other sources of nutrients but higher methane emission and production resulted by application of 50% N through paddy straw incorporation + 50% N through urea + recommended dose of P and K (5.56 mg/plant/day and 50.5 kg/ha) 90 days after sowing.

Key words : Methane emission, Methods of rice cultivation, Water productivity, Yield

India has the largest area among the rice-growing countries and ranks second in production after china. It is the grain that has shaped the cultures, diets, and economies of billions of Asian's. For them, life without rice is simply unthinkable. Between now and 2020, about 1.2 billion new rice consumers will be added in Asia. Rice occupies the enviable prime place among the field crops cultivated around the world.

Rice is the major crop of India and occupies the largest cropped area of 43.97 million ha with an annual production of 109.5 million tonnes and productivity of 2.49 tonnes/ha. The Krishnarajasagara (KRS) command is one of the major rice-growing areas in the Karnataka state, covering 73,409 ha and is mainly grown under canal irrigation during rainy (*kharif*) and summer seasons. Among the major sources of methane emission, rice fields contribute a dominant share and estimated budget of methane emission from rice fields is in the range of 18 to 280 Tg/year, which corresponded to between 10 and 70% of the total anthropogenic methane emissions (Khalil and Rasmussen, 1990). India, having largest area of land under paddy cultivation in the world is also a major contributor to global methane emission.

Rice is cultivated by different methods. Among different methods of rice cultivation, conventional method is the most dominant and traditional method under irrigation, which not only consumes more water but also causes severe wastage of water and soil leads to degradation of land and cause environmental pollution by emitting methane under anaerobic condition. Hence in recent years to tackle the problem of water scarcity and methane emission, a number of methods of rice cultivation have been developed, 2 among them are system of rice intensification (SRI) and aerobic method of rice cultivation. These 2 methods are considered as system rather technology, as they involve holistic management of resources to provide ideal growing condition for rice plant. Both the methods

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are emerged as water-saving technology, which can help the farmers to overcome the present water scarcity and increasing yield and mitigating methane emission from rice field by keeping the soil at field capacity. Microbial diversity is more and inhibits the oxidation of methane from rice field under SRI and aerobic methods of rice cultivation (Bharati *et al.,* 1999).

The most important source of nutrients on methane emission is not clear. Because most of methane gas emitted from rice field due to organic and inorganic nutrient application increased the methane emission. But source, type and method of application of nutrient sources have direct effects (Schutz *et al.,* 1989) on rice cultivation. Use of slow-releasing nitrogenous fertilizers like neem-coated urea (NCU), ammonium sulphate (AS), lac-coated urea (LCU), humified organic manure reduces methane emission by inhibiting methanogenic bacterial activity in soil and mitigating the methane emission and production under anaerobic methods of rice cultivation.

MATERIALS AND METHODS

The field experiment was conducted at Zonal Agricultural Research Station, Visweshwaraiah Canal Farm, Mandya (12º45' and 30º57' and 76º45' and 78º24' E, 695 m above mean sea-level). University of Agricultural Sciences, Bengaluru during rainy season of 2012 and 2013 coming under southern dry zone (SDZ) of Karnataka (Zone-VI). The station comes under Krishnarajasagara command area. The experimental soil was red sandy loam, neutral *p*H (6.60), bulk density of 1.66 g/cc, organic carbon 0.62% and electrical conductivity of 0.71 dS/m. Rice hybrid ‘KRH 4’ was used. The soil had medium available nitrogen (330.4 kg/ha) and phosphorus (35.1 kg/ha) and low available potassium (249 kg/ha). The total normal rainfall during crop-growth period was 480.6 mm, and average minimum and maximum temperature varies between 19.8 and 29.5ºC and 14.5 to 29.3ºC respectively. Humidity ranges from 83 to 88% and bright sunshine varies between 6.1 and 6.6 hours. The experiment was laid out in a split-plot design with 3 replications. The main plot consisted of 3 methods of rice cultivation, viz. conventional method (transplanting), system of rice intensification (SRI) and aerobic method and 5 different sources of nutrients including both organic and inorganic sources, *viz.,* S_1, recommended dose of fertilizer (100% N through urea); S_2 recommended dose of fertilizer (100% N through neem-coated urea); S_3, 50% N through straw left out in a rice field and incorporation + 50% N through urea + recommended dose of P and K; S_4, 50% N through FYM + 50% N through urea + recommended dose of P and K; and S_5, 50% N through *in-situ* green-manuring (sunhemp) + 50% N through urea + recommended dose of P and K were used and replicated thrice. In either side of the main plot, polythene sheet of 45 cm were inserted to avoid the seepage of water and 2 main plots were separated by bunds and channel. Sunhemp seed (green-manure crop) was sown and incorporated in to soil 30 days before sowing; paddy straw (8.7 t/ha) and FYM (10 t/ha) were incorporated 15 days before sowing or planting in the main plot of the experimental area. For aerobic method, irrigation was given once in a week in the rainy season by portable water meter. Whenever rainfall occurred, irrigation to aerobic plots was avoided. In SRI method, regular irrigation was given to keep the soil moist. For transplanted plots, 2.5 cm water height was maintained from planting to 10 days after planting (DAP) and 5 cm water height was maintained from 11 DAP to physiological maturity. The measured quantity of water was given to the field experiment by using water meter.

Methane gas collection and analysis

Methane (CH_4) fluxes were measured by closed chamber method (Adhya *et al*., 1998) at 15 days intervals from day 30 of seeding in aerobic, SRI and transplanting method of rice cultivation. Sampling for CH_4 emission measurement was done during morning (9.00 to 10.30 AM) and in the afternoon (2.00 to 3.30 PM) and the average of the morning and evening flux was used as the flux value of the day. Individual planted pots were placed on a tray and covered with locally fabricated Perspex chambers (53 cm length × 37 cm breadth × 91 cm height) based on requirement and average height of selected rice variety or hybrid. The tray was filled with water to a depth of 5 cm, which acted as an air seal when the Perspex box was placed on the tray. In field, the Perspex chambers were placed on 4 (aerobic and SRI), 14 (conventional) hills of rice plants. The chamber was placed in the grooves of the aluminum bases to avoid air leakage. A battery-operated air-circulation pump was connected inside the chamber at top of the chamber. The glass sample collection tubes and syringes with stopcock were used to collect the sample from the chamber. The air samples from the sample tubes or syringes were analysed for CH_4 in gas chromatography (GC) equipped with flame-ionized detector (FID). The column and detector were maintained at 70˚C and oven was maintained at 100˚C. The carrier main was maintained at 55 Psi or 4.5 kg/cm², discharges gas was maintained at 60 Psi and column was maintained at 10 Psi. Stainless steel column of 1/8th inch diameter was used. One ml gas samples were injected through a sample loop with the help of column injector using a multiport valve. The GC was calibrated before and after each set of measurements using 95% pure CH_4 obtained from Chemtron Sciences Laboratories, Navi Mumbai, and used as primary standard. Under these conditions the retention time of methane was 1.72 minutes.

Estimation of methane emission and production

Methane emission from paddy field was estimated by the following equation of Rolston (1986) based on the following equation:

F= D × E/B

where F is the methane emission rate (mg/m^3), D is the actual area of methane obtained after 0.5 ml gas sample fed to GC, E is the cross-section of chamber or volume of chamber (m^3), B is the 0.5 ml concentration of gas feed to GC using syringes. Mean of methane flux was calculated as arithmetic mean of measurements taken at 6 AM and 12 PM. Total methane emission and production were computed using the summation of methane emission in the different sampling stages of rice plants (4 hills in SRI and aerobic methods and 14 hills in conventional method) at different time intervals. The CH_4 emission and production per season was calculated as per plant or treatment and expressed in mg/plant/day or kg/ha (area basis).

RESULTS AND DISCUSSION

Grain and straw yield

The SRI method recorded higher grain and straw yield (8.55 and 10.07 t/ha) than conventional method and aerobic method (Table 1). The increase in yield under SRI method owing to higher growth and yield-attributing parameters and better supply of nutrients, water and less competition for sunlight resulted in higher grain and straw yield than conventional and aerobic methods. Among sources of nutrients, application of recommended dose of fertilizer (100% N through neem-coated urea) recorded higher grain and straw yield than other sources of nutrients due to availability of nutrients throughout the crop-growth period to plants. Neem-coated urea also helped to reduce the N loss through NH_3-N volatilization and greater N availability throughout the crop growth period (Shivay *et al.,* 2001).

Methane emission and production

Methods of rice cultivation recorded significant influence on methane emission throughout the rice crop-growth stages. During the crop-growth stages from 30 to 105 days after seeding/transplanting (DAS/T) under conventional method recorded significantly higher methane emission at 30, 45, 60, 75, 90 and 105 DAS/T and total methane production was highest (Tables 2 and 3). The increased methane emission under conventional method of rice cultivation throughout the crop-growth stage (30 to 105 DAP) due to flooding, which intensifies soil reaction and the decomposition of organic matter in the soil, which favours methanogenesis. The possible reason for increased methane emission under submerged condition might be decreased in gas diffusion, resulting in several changes in soil physico-chemical and biological conditions that favour CH_4 production and its emission. The results are in line with the findings of Wang *et al*. (1999). As in a natural wetland, flooding rice field cuts off the oxygen supply from the atmosphere to the soil, which results in anaerobic fermentation of soil organic matter. Methane is a major end-product of anaerobic fermentation. The results obtained in this investigation are also in line with the findings of Bharati *et al*. (2001) and Majumdar (2003).

Aerobic method of rice cultivation recorded significantly lower methane emission than conventional method at 30, 45, 60, 75, 90 and 105 DAS/T and total methane production was less compared with conventional method. The reduction in methane emission under aerobic method may be attributed to an increase in soil redox potential (Eh) and proper aeration of soil and more activity of beneficial microbial activity and lack of anaerobic condition which make inactivity of methanogenic bacteria leads to

Table 1. Grain yield, straw yield and harvest index of rice as influenced by methods of cultivation and nutrient sources (pooled data of 2 years)

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Harvest index (HI)
Rice cultivation methods (M)			
M_1	7.05	8.38	0.45
M_2	8.55	10.07	0.46
M_3	6.48	7.83	0.45
SEm±	0.143	0.75	0.01
CD (P=0.05)	0.56	0.29	NS
Nutrient sources (S)			
S_1	7.86	9.31	0.46
S_2	8.49	9.83	0.47
S_3	6.14	7.52	0.45
S_4	6.83	8.19	0.45
S_5	7.48	8.96	0.46
SEm±	0.179	0.159	0.01
CD (P=0.05)	0.523	0.463	NS
Interaction (M × S)			
SEm±	0.310	0.275	0.009
CD (P=0.05)	NS	NS	NS

M_1, Conventional method; M_2, SRI method; M_3, Aerobic method; S_1, RDF (100 % N through urea); S_2, RDF (100 % N through neem-coated urea); S_3, 50% N through paddy straw incorporation + 50 % N through urea + Rec. P and K; S_4, 50% N through FYM + 50% N through urea + Rec. P and K; S_5, 50% N through *In-situ* green manuring (sunhemp) + 50% N through urea + Rec. P and K; NS, Non-significant; RDF, Recommended dose of fertilizer; FYM, Farmyard manure; Rec., Recommended

Table 2. Methane emission of rice as influenced by methods of cultivation and sources of nutrient at different growth stages (pooled data of 2 years)

Treatment	30 DAS/T	45 DAS/T	60 DAS/T	75 DAS/T	90 DAS/T	105 DAS/T
	Methane emission (mg/plant/day)					
Rice cultivation methods (M)						
M_1	0.71	4.22	6.13	6.42	6.25	6.02
M_2	0.54	3.24	4.45	4.73	4.42	4.08
M_3	0.13	2.22	3.85	4.27	3.95	3.66
SEm±	0.05	0.11	0.22	0.18	0.17	0.08
CD (P=0.05)	0.21	0.42	0.86	0.71	0.67	0.33
Nutrient sources (S)						
S_1	0.42	2.92	4.45	4.73	4.49	4.22
S_2	0.39	2.71	4.13	4.40	4.17	3.88
S_3	0.54	3.64	5.49	5.86	5.56	5.20
S_4	0.47	3.51	4.84	5.20	4.90	4.66
S_5	0.48	2.61	5.13	5.51	5.25	4.98
SEm±	0.03	0.13	0.07	0.07	0.06	0.04
CD (P=0.05)	0.08	0.37	0.19	0.20	0.17	0.11
Interaction (M × S)						
SEm±	0.04	0.21	0.11	0.11	0.11	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	NS

M_1, Conventional method; M_2, SRI method; M_3, Aerobic method; S_1, RDF (100% N through urea); S_2, RDF (100% N through neem-coated urea); S_3, 50% N through paddy straw incorporation + 50% N through urea + Rec. P and K; S_4, 50% N through FYM + 50% N through urea + Rec. P and K; S_5, 50% N through *in-situ* green manuring (sunhemp) + 50% N through urea + Rec. P and K; NS, Non-significant; RDF, Rec. dose of fertilizer; FYM, Farmyard manure; Rec., recommended; DAS/T days after sowing/transplanting

Table 3. Methane production of rice as influenced by methods of cultivation and sources of nutrient at different growth stages (pooled data of 2 years)

Treatment	Methane production (kg/ha)					
	30–45 DAS/T	45–60 DAS/T	60–75 DAS/T	75–90 DAS/T	90–105 DAS/T	Total
Rice cultivation methods (M)						
M_1	10.90	16.78	18.09	17.76	17.14	80.68
M_2	6.53	5.87	6.39	6.07	6.04	28.07
M_3	4.79	5.01	5.74	5.42	5.08	24.21
SEm±	0.40	0.34	0.30	0.29	0.14	1.38
CD (P=0.05)	1.56	1.34	1.17	1.14	0.54	5.44
Nutrient sources (S)						
S_1	6.91	8.64	9.36	9.03	9.57	41.20
S_2	6.04	7.99	8.69	8.40	7.97	37.93
S_3	8.92	10.46	11.39	11.01	9.95	50.45
S_4	7.20	9.25	10.17	9.87	9.67	44.56
S_5	7.96	9.77	10.77	10.44	9.93	47.45
SEm±	0.37	0.10	0.09	0.09	0.06	0.39
CD (P=0.05)	1.07	0.29	0.27	0.27	0.17	1.15
Interaction (M×S)						
$M_1 S_1$	10.67	16.11	17.14	16.65	15.65	76.22
$M_1 S_2$	9.60	14.95	15.86	15.54	14.66	70.60
$M_1 S_3$	12.33	18.56	20.06	19.57	19.15	89.67
$M_1 S_4$	10.44	16.78	18.17	18.22	17.62	81.24
$M_1 S_5$	11.46	17.47	19.24	18.85	18.64	85.65
$M_2 S_1$	6.12	5.28	5.72	5.42	7.73	25.42
$M_2 S_2$	5.31	4.93	5.40	5.13	4.87	23.55
$M_2 S_3$	7.63	6.81	7.37	7.12	5.65	32.62
$M_2 S_4$	6.58	5.98	6.58	6.00	6.03	28.35
$M_2 S_5$	6.99	6.37	6.89	6.66	5.89	30.40

Table 3. *Continued ...*

Treatment	Methane production (kg/ha)					
	30–45 DAS/T	45–60 DAS/T	60–75 DAS/T	75–90 DAS/T	90–105 DAS/T	Total
M_3 S_1	3.94	4.51	5.21	5.03	5.33	21.95
M_3 S_2	3.19	4.08	4.81	4.53	4.39	19.65
M_3 S_3	6.79	6.01	6.73	6.33	5.06	29.06
M_3 S_4	4.58	4.99	5.74	5.40	5.35	24.09
M_3 S_5	5.45	5.47	6.19	5.82	5.26	26.29
SEm±	0.63	0.17	0.16	0.15	0.10	0.68
CD (P=0.05)	NS	0.49	0.47	0.46	0.29	1.98

M_1, Conventional method; M_2, SRI method; M_3, Aerobic method; S_1, RDF (100 % N through urea); S_2, RDF (100 % N through neem-coated urea); S_3, 50% N through paddy straw incorporation + 50 % N through urea + Rec. P and K; S_4, 50% N through FYM + 50% N through urea + Rec. P and K; S_5, 50% N through *In-situ* green manuring (sunhemp) + 50% N through urea + Rec. P and K; NS, Non-significant; RDF, Recommended dose of fertilizer; FYM, Farmyard manure; Rec., Recommended; DAS/T days after sowing/transplanting

mitigate methane emission. Similar results were obtained by Wang *et al.* (1999) and Ishibashi *et al.* (2001). Among sources of nutrients, application of RDF (100% N through neem-coated urea) recorded lesser CH_4 emission and total methane production compared to application of 50% N through paddy straw manuring + 50% N through urea + recommended dose of P and K and total methane production. Though nitrification inhibitors like neem-coated urea (nimin) inhibit CH_4 oxidation and CH_4 oxidizing microbial population, their exact role in CH_4 emission is not clear but inhibition of CH_4 production in neem-coated urea-amended alluvial soil was related to high redox potential, low *p*H, Fe^{2+} and readily mineralizable carbon content as well as lower population of methanogenic bacteria and their activity. Similar results of higher CH_4 emission were reported by Bharati *et al.* (1999) and Adhya *et al*. (2000). The increase in CH_4 emission with application of 50% N through paddy straw manuring + 50% N through urea + recommended P and K was recorded compared with application of recommended dose of fertilizer (100% N through neem-coated urea). As the paddy straw contains wider C:N ratio (80:1), hemicellulose (27.4%) and cellulose content (29.3%), it lowers the soil redox potential (Eh) and paddy straw selectively enhanced the growth of particular methanogenic populations by providing them carbon source resulting in more production and emission of CH_4. Several-fold increase in CH_4 emission with straw additions to rice fields was reported by Chareonsilp *et al.* (2000).

Table 4. Water requirement (WR) and water productivity (WP) of rice as influenced by methods of cultivation and nutrient sources at different growth stages (pooled data of 2 years)

Treatment	Water applied (cm/ha)	Total water requirement (cm/ha) [Irrigation + effective rainfall]	Water productivity (kg/ha-cm)
Rice cultivation methods (M)			
M_1	198.0	235.7	29.9
M_2	119.5	157.1	54.3
M_3	101.1	138.7	46.6
SEm±			0.9
CD (P=0.05)			3.5
Nutrient sources (S)			
S_1	139.5	177.2	46.6
S_2	139.5	177.2	50.4
S_3	139.5	177.2	36.3
S_4	139.5	177.2	40.5
S_5	139.5	177.2	44.3
SEm±			1.0
CD (P=0.05)			3.1
Interaction (M × S)			
SEm±			1.8
CD (P=0.05)			NS

Water productivity

Methods of rice cultivation registered significant influence on water productivity. The SRI method of rice cultivation recorded significantly higher water productivity followed by aerobic method than conventional method of rice cultivation (Table 4). This was attributed to higher grain yield and lower total volume of water used for its production. Further, the loss of water through evaporation and percolation are considerably reduced under SRI and aerobic methods, where stagnation of water does not exist. Similar results obtained and confirmed by Wang *et al.,* (1999).

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