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Ramesh T
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India

Rathika S
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India

Ravi V
Tamil Nadu Rice Research Institute, Aduthurai, Tamil Nadu, India

Sabarinathan R
Agronomist, Netafim Irrigation India Pvt. Ltd., Coimbatore, Tamil Nadu, India

Eli Vered
Head Agronomist, Netafim Irrigation Pvt. Ltd., Hadera Area, Israel

Correspondence
Ramesh T
Department of Agronomy, Anbil Dharmalingam Agricultural College and Research Institute, Tiruchirappalli, Tamil Nadu, India

Drip irrigated paddy: An adaptation strategy to mitigate the climate change

Ramesh T, Rathika S, Ravi V, Sabarinathan R and Eli Vered

Abstract
A field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai to quantify the greenhouse gases (CH4, CO_2 and N_2O gas flux) emission in drip irrigated paddy in comparison with conventional flooded paddy. Gas flux was collected during critical stages of rice by static chambers installed in the field. Gas chromatography Varian 450 equipped with three different detectors was used for gas analysis. Results on greenhouse gases (GHG) emission revealed that drip irrigated paddy emitted lesser methane as compared to transplanted paddy in all stages of sampling. In tillering stage, both Hybrid CORH 3 and variety ADT 45 under drip irrigated system emitted lesser quantum of CH_4 as compared to transplanted paddy (9.31 mg/m^2/day). Comparing two cultivars under drip system, variety ADT 45 emitted more CH_4 (6.37 mg/m^2/day) than Hybrid CORH3 (3.97 mg/m^2/day). In case of CO_2, drip irrigated paddy emitted higher CO_2 during tillering stage (CORH3-4107.1 mg/m^2/day and ADT45-5184.2 mg/m^2/day) over conventional paddy (1061.4 mg/m^2/day). Variety ADT 45 emitted more CO_2 in all stages than Hybrid CORH3 under drip irrigated system. The quantification of N_2O emission revealed that there was not much variation during early stages of crop growth in both drip and conventional system of planting. However, flooded paddy emitted higher NO_2 in both flowering (2.3 mg/m^2/day) and maturity stages (2.9 mg/m^2/day) over drip irrigated paddy (0.5 mg/m^2/day in both stages). In general, CH_4 and CO_2 emission were higher during tillering stage with steady decline in later stages in drip irrigated paddy. In flooded paddy, lesser CO_2 emission during tillering stage and reached maximum at flowering stage, then decline towards maturity. Growing paddy under drip irrigation saved 31.8% water in ADT 45 variety and 28.2% in hybrid CORH 3 as compared to transplanted paddy. Hybrid CORH 3 registered 45.4% higher yield over ADT 45 under drip irrigation and 7.0% lesser yield than ADT 43 variety grown as conventional transplanted paddy.

Keywords: Drip irrigated paddy, transplanted paddy, greenhouse gases, quantification

Introduction
Rice (*Oryza sativa* L.) is the most stable food crop in the world and in Asia, more than two billion people getting 60-70% of their food energy from rice and its derived products. Recently, rice cultivation has under severe threat mainly by climate change impacts like availability of water, extreme weather events and depletion in soil health. Owing to increasing water scarcity, it is highly essential to find out alternate methods of rice cultivation which require less water. One of the approaches that lead to a considerable amount of water saving in rice production is drip irrigation. Shifting of traditional rice production system to growing rice aerobically using drip irrigation, especially in water scarce irrigated lowlands will mitigate occurrence of water related problems. Drip irrigation is one such tool that can reduce water use and at the same time increases yield. Many research findings on drip irrigation to field crops indicated that this technique is useful in reducing water use, uniform application of water and nutrients, increased input use efficiency besides increased productivity and economic returns.
Global warming is an important issue for human beings. A major attributor of global warming is increases in concentration of greenhouse gases *viz*., Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) in the atmosphere. Majority of rice production in India is from flooded paddy fields which contribute about 11% of total global methane emissions to the atmosphere (Moran and Pratt, 2010) [2]. Field studies have shown that alternative management practices such as changes in water, fertilizer, and crop residue management can have a significant influence on GHGs emissions from rice (Wassmann *et al.*, 2000). Growing of paddy under drip irrigation is totally under aerobic condition with efficient use fertilizer nutrients may have positive impact on the reduction in emission of GHGs. In this context, a study has been proposed to quantity of GHGs emission in drip irrigated paddy in comparison with conventional flooded paddy.

Materials and Methods

Tamil Nadu Rice Research Institute is present in the middle of the Cauvery Delta Zone, Tamil Nadu, India, geographically located at 11° N latitude 79.3° E longitude with an altitude of 19.4 m above MSL. The soil of the experimental field was alluvial clay with pH of 7.5 and EC of 0.3 dS/m and low, high and medium in available nitrogen, phosphorus and potassium contents respectively.

Field experiment

A field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai during dry season to quantify the greenhouse gases (CH4, CO_2 and N_2O gas flux) in drip irrigated paddy in comparison with conventional flooded paddy. Short duration varieties/ hybrids *viz*., ADT 45 and CORH 3 were used for drip irrigation and ADT 43 was raised under conventional transplanted system. Drip system was installed with the lateral spacing of 80 cm and emitter/dripper spacing of 30 cm. Manual sowing of seeds was done in the finely prepared dry soil at the spacing of 20x 10 cm. Discharge rate of drippers was 2.0 litre per hour. Irrigation was given at 150% Pan Evaporation during throughout the cropping period in every alternate day. Recommended dose of fertilizer (150: 50: 50 kg NPK/ha) was applied. The entire P as single super phosphate was applied as basal during land preparation. The N as urea and K as MOP were given in 15 splits starting from 14 DAS to heading stage at 5 days interval along with irrigation water. In conventional flooded paddy system, transplanting of 22 days old seedling was done in the puddled field at 20 x 10 cm spacing. Flood irrigation was given at 5 cm depth after the disappearance of standing water. Basal fertilizer application was done with 100% P, 25% of each N and K. Remaining 75% of N and K was top dressed during tillering, panicle initiation and flowering stages.

Gas sampling and analysis

Gas flux was collected by static chambers installed in the field as method suggested by Mosier (1989) [3]. There were two parts in static chamber (anchor or base and chamber). Anchor was made up of thin-walled stainless steel to minimize physical disturbance upon insertion. Round chambers diameter and height was 47 cm and 24 cm respectively. Chambers were fabricated with non-reactive materials and were painted with white paint. It had two ports for air thermometer and gas sampling. Area occupied by round chamber for measuring plant-mediated emissions was 1562 cm^2. Anchors were installed at 10 cm into the ground at least 24 hours prior to first flux measurement and were packed well around the sides. Chamber was kept upside down upon the base at time of gas sampling. Plants were included inside the chambers during gas sampling (Smart and Bloom, 2001) [5].

Before sampling, the base position and presence of water in the rim of base were noticed. Flood water level both inside and outside the base were noted, soil temperature were recorded and chamber temperature was recorded immediately after sampling. Sampling was performed by inserting a polypropylene syringe into the chamber septa and slowly removing a gas sample. The sampling was done in four times at ten minutes interval *viz*., 0, 10, 20 and 30 minutes after deployment of chamber. Typically, 50 ml sample were removed and transferred to a previously evacuated 30 ml glass vial sealed with a grey butyl rubber septum. Excess gas was injected into the evacuated vial to produce an overpressure. This overpressure facilitates the subsequent removal of a gas sample for analysis.

Gas chromatography Varian 450 equipped with three different detectors was used for analysis of gas. Thermal Conductivity Detector for CO_2, Electron Capture Detector for N_2O and Flame Ionization Detector for CH_4 analysis were used. To run GC, 5 gases were used namely Helium, Hydrogen, Nitrogen, Mixed air (argon + methane) and Zero air. Several different standard concentrations were fed to run, as detector response was nonlinear. The range of standards was 0.5 and 1 ppm for N_2O, 2 and 10 ppm for CH_4 and 1000 ppm for CO_2 were used. Standard curves used to convert the GC output of the samples into units of ppm.

Results and Discussion

Greenhouse gases emission

Growing of rice under drip irrigation emitted lesser methane as compared to transplanted rice in all stages of sampling (Table 1). In tillering stage, Hybrid CORH 3 and variety ADT 45 under drip irrigated system emitted lesser quantum of CH_4 as compared to transplanted rice (9.31 mg/m^2/day). Comparing the two cultivars grown under drip system, variety ADT 45 emitted more CH_4 (6.37 mg/m^2/day) than Hybrid CORH3(3.97 mg/m^2/day). In the case of CO_2, drip irrigated rice emitted higher CO_2 during tillering stage (CORH3-4107.1 mg/m^2/day and ADT45-5184.2 mg/m^2/day) over conventional flooded rice (1061.4 mg/m^2/day). Variety ADT 45 emitted more CO_2 in all stages than Hybrid CORH3 under drip irrigated system. The quantification of N_2O emission revealed that there was not much variation during early stages of crop growth in both drip and conventional system of planting. However, flooded paddy emitted higher NO_2 in both flowering (2.3 mg/m^2/day) and maturity stages (2.9 mg/m^2/day) over drip irrigated paddy (0.5 mg/m^2/day in both stages).

In general, CH_4 and CO_2 emission were higher during tillering stage with steady decline in later stages under drip irrigated paddy. But, flooded paddy emitted lesser CO_2 during tillering stage and reached maximum at flowering phase, then decline towards maturity. Variation in water and nutrient availability under drip and flooded transplanted paddy would have been the reason for creating such difference in greenhouse emission. Under flooded conventional system, 5 cm depth of standing water was maintained throughout crop period and fertilizers were applied in four splits at planting, tillering, panicle initiation and heading stages whereas in drip irrigated paddy, irrigation at150% PE on alternate days and fertigation was given in every fifth day from 21 DAS upto flowering. Variation in water, fertilizer, and crop residue management strategies can have a significant influence on GHG emissions from paddy fields (Wassmann *et al.*, 2000) [7]. Appropriate application of nitrogen fertilization and irrigation in paddy fields decreased the greenhouse gases emission (Minamikawa *et al.*, 2003) [1].

Table 1: Greenhouse gases emission (mg/m^2/day) during critical stages in drip irrigated rice as compared to transplanted rice.

Paddy cultivation methods	Tillering			Panicle initiation			Flowering			Maturity		
	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO_2	CH_4	N_2O
Drip irrigated paddy -CORH 3	4107.1	3.97	0.34	645.1	2.4	0.5	722.2	1.7	0.4	566.5	1.5	0.5
Drip irrigated paddy-ADT 45	5184.2	6.37	0.15	937.5	2.6	0.5	802.6	1.4	0.5	539.2	1.5	0.4
Mean	4645.7	5.17	0.25	791.3	2.5	0.5	762.4	1.6	0.5	552.9	1.5	0.5
Transplanted paddy -ADT 43	1061.4	9.31	0.18	3164.2	8.3	0.6	3340.3	6.4	2.3	1794.3	4.7	2.9

Growth and yield

Variation in growth, yield parameters and grain yield of paddy was noticed in drip irrigation as well as conventional flooding. Transplanted paddy registered higher plant height (77 cm), number of leaves per hill (71.3), productive tillers (397 Nos./m^2), filled grains per panicle(128.4) and grain yield of 5200 kg/ha as compared to drip irrigated rice (Table 2). Availability of more water under conventional paddy supported uniform as well as higher growth and yield parameters of rice. Whereas in drip irrigated paddy, growth and yield characters were comparatively lesser than conventional paddy. Under drip irrigation, rows close to the lateral performed better than rows away from the lateral which resulted in variation in growth and yield and consequently lower yield than conventional flooded paddy. Between the cultivars tested, hybrid CORH 3 performed better over ADT 45 variety, produced higher plant height (73.7 cm), number of leaves per hill (62.4), productive tillers (378 Nos./m^2), filled grains per panicle(115.2). Hybrid CORH 3 registered 45.4% higher yield over ADT 45 under drip irrigation and 7.04% lesser yield than ADT 43 grown as conventional flooding (Fig 1).

Table 2: Growth and yield components of rice under drip irrigated and flooded condition

Cultivation methods	Variety	Plant height (cm)	Number of leaves /hill	Productive tillers (Nos./m^2)	Filled grains (Nos./panicle)	1000 grain weight (g)
Drip irrigated rice	CORH 3	73.3	62.4	378	115.2	19.9
	ADT 45	68.9	43.2	350	98.5	17.5
Transplanted Rice	ADT 43	77.0	71.3	397	128.4	16.4
S. Ed. (+)	-	1.7	2.8	14.3	3.8	0.5
C.D. (P=0.05)	-	3.7	5.9	30.0	8.0	1.0

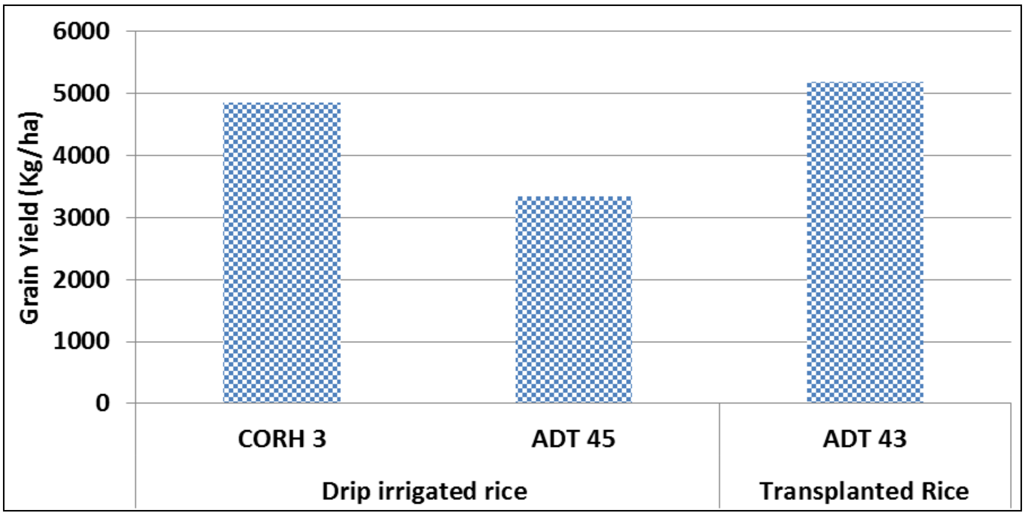

Fig 1: Grain yield of rice drip and conventional irrigated paddy

Water usage and water productivity

Growing rice under drip irrigation saved 31.8% water in ADT 45 variety and 28.2% in CORH 3 as compared to flooded paddy. Conventional flooded paddy consumed 1931 mm of water whereas drip irrigated rice used 1317 mm in ADT 45 and 1386 mm in CORH 3. Elimination of puddling and conveyance losses under drip irrigation saved considerable amount of water over transplanted paddy which resulted in higher water productivity of 3.50 kg/ha/mm in CORH 3. Field demonstrations on use of drip irrigation technology for rice production in Punjab, Rajasthan and Andhra Pradesh during 2009–2011 concluded that drip irrigated paddy saved 40% of water over transplanted paddy (Soman, 2012) [6]. At University of Missouri Marsh Farm in 2005 and 2006, subsurface drip-irrigation saved 80% of water as compared to conventional flood-irrigation. However, no yield differences observed between the main effects of irrigation technique, with only minor milling quality were reductions with drip-irrigation (Ottis *et al.*, 2006) [4].

Table 3: Total water used, water saving and water productivity of rice under drip and conventional transplanted condition.

Cultivation methods	Variety	Total water used (mm)	Water saving (%)	Water productivity (kg/ha/mm)
Drip irrigated rice	CORH 3	1386	28.2	3.50
	ADT 45	1317	31.8	2.51
Transplanted Rice	ADT 43	1931	-	2.69

From this experiment, it could be concluded that growing of paddy hybrid CORH 3 under drip irrigation emitted lesser emission of GHGs in comparison with conventional flooded paddy besides saving of 28.2% water and higher water productivity and considered as an adaptation strategy to mitigate the climate change.

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