Agriculture, Ecosystems and Environment 233 (2016) 75–84

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Effects of foliar application of plant growth hormone on methane emission from tropical rice paddy

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ARTICLE INFO

Article history:
Received 29 February 2016
Received in revised form 18 July 2016
Accepted 30 August 2016
Available online xxx

Keywords:
Methane
Plant growth hormones
Stomatal frequency
Xylem size
Photosynthate partitioning
Grain yield

ABSTRACT

Methane (CH_4), a major greenhouse gas, is an important agent of global warming and climate change. While rice agriculture is a major source of anthropogenic CH_4 emissions, increased production of rice is essential for ensuring global food security. Mitigating CH_4 emissions from rice cultivation with simultaneous increase in grain productivity is a challenging issue. A two-year field study was conducted to investigate the effects of foliar application of plant growth hormones on emission reduction of CH_4 from rice paddies. CH_4 emission measurement was done from rice plants treated with plant growth hormones – gibberellic acid (GA_3), indole-3-acetic acid (IAA), indole-3-butyric acid (IBA) and kinetin (KIN) (in 20 mg L^{-1} concentration) and compared with the emission from untreated/control (CONT) plants. IAA and KIN applications were found to bring about a reduction in the cumulative CH_4 emission over control primarily through regulation of leaf growth, stomatal density and xylem vessel size. Foliar application of IAA and KIN enhanced the leaf photosynthetic rate and caused maximum partitioning of photosynthates to the grains as evident from the higher grain filling ability and grain yield. The IAA and KIN treatments improved the thousand grain weight and high density grain (%) in the rice plants resulting in higher grain productivity over untreated plants. It can be concluded that foliar application of indole acetic acid and kinetin can be an effective measure for regulating methane emission from rice paddies coupled with increase in economic yield of the most popular crop of this region.

1. Introduction

Rice (*Oryza sativa* L.) is the major cereal crop and the staple food for more than half of the world's population. Annual rice cropping area in India is reported to be 44.1 million hectares which is the largest rice growing area of the world (FAOSTAT, 2013). Rice production in India needs to be increased for national food security. On the other hand, rice fields are considered as one of the major sources for greenhouse gas (GHG) emissions contributing about 30 and 11% of global agricultural methane (CH_4) and nitrous oxide (N_2O) emissions respectively (IPCC, 2007). The global warming potential (GWP) of CH_4 is 34 times higher than that of CO_2 (Myhre et al., 2013). Indian agriculture accounts for approximately 5% of the global CH_4 budget (Wassmann et al., 2009) with an emission estimate of 4.09 ± 1.19 Tg CH_4 y^{-1} from Indian paddy fields (Gupta et al., 2009).

Green plants are reported to influence the production, consumption, as well as transport of CH_4 from the soil to the atmosphere (Koelbener et al., 2010). Root exudates from plants play a significant role in CH_4 production from soil organic matter by determining the C content of the rhizosphere soil (Koelbener et al., 2010). Rice plants also mediate the transport of CH_4 from the soil to the atmosphere (Nouchi et al., 1990; Aulakh et al., 2000; Ding et al., 2005; Das and Baruah, 2008a).

Plant growth hormones (gibberellins, auxins, cytokinins) are widely known to regulate plant growth and developmental processes such as cell division, cell elongation, protein synthesis etc. and also determine overall plant architecture (Gray, 2004; Depuydt and Hardtke, 2011; Durbak et al., 2012). Therefore, application of plant growth hormones may influence the CH_4 transport capacity of the rice plants by regulating their growth and development. A two-year field study was undertaken to investigate the impact of plant growth hormones on CH_4 emissions from a rice ecosystem planted to cultivar *Luit*.

Optimization of grain yields have been suggested as an important measure for substantial CH_4 emission reduction from rice agriculture by several authors (Denier van der Gon et al., 2002;

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http://dx.doi.org/10.1016/j.agee.2016.08.033
0167-8809/

Das and Baruah, 2008b; Jiang et al., 2013). Plant growth hormones play crucial role in controlling sink and source size in plants and thus influence the grain yield (Ghodrat et al., 2012). Therefore, in the present study, attempts were also made to determine whether growth hormone application in rice agriculture can improve the grain productivity while simultaneously reducing the CH_4 emissions.

2. Materials and methods

2.1. Site description

The experiments were conducted inside Tezpur Central University Campus, Tezpur (26° 41′ N, 92° 50′ E) situated in the North Bank Plain Agro-climatic Zone of Assam, India. The region is subtropical humid having moderately hot-wet summers and dry cold winters. The soil is characterized by recent and old alluvium soils of sandy to sandy-loam texture with sand (%) 60.35, silt (%) 14.40, clay (%) 23.50 and slight to moderate acidic soil pH (5.65). The bulk density of the soil was 1.72 g cm^{-3} and the percentage of organic carbon was 0.94. The available nitrogen, phosphorous and potassium content of the soil were 108.64, 32.72 and 249.18 kg ha^{-1} respectively. The meteorological parameters recorded at a weather station located at the university campus are presented in Supplementary Fig. 1.

2.2. Field management

Rice was planted to the field during pre-monsoon season (locally known as *Ahu* rice, April–July) of 2012 and 2013. The main field was ploughed, puddled thoroughly and leveled properly before transplanting of rice. Fertilizers were applied @ 40:20:20 kg N-P_2O_5-K_2O ha^{-1} as recommended by the Department of Agriculture, Assam. One-third of the quantity of N (13.3 kg ha^{-1} applied as urea) and the whole quantity of P_2O_5 (as single super phosphate) and K_2O (as muriate of potash) were applied at the time of final puddling. Twenty-five days old rice seedlings of an improved rice cultivar *Luit* were transplanted (2 seedlings $hill^{-1}$) during the first week of April with a spacing of 20 cm between the rows and 15 cm between plant to plant in plots of size 2 m × 2m = 4 m^2. The second 1/3rd (13.33 kg ha^{-1}) and the third 1/3rd (13.33 kg ha^{-1}) doses of urea were applied at tillering (28 days after transplanting/28 DAT) and panicle initiation stages (56 DAT) respectively. The experiment consisted of five treatments (section 2.3) with 4 replications each arranged in a randomized block design.The crop was grown exclusively under rainfed condition and was properly managed during the experimental period. Insecticides were sprayed just after crop establishment (8 DAT) for protection against caseworms which was well before the first dose of hormone application (28 DAT).

2.3. Foliar application of plant growth hormones

Four different plant growth hormones viz. gibberellic acid (GA), indole acetic acid (IAA), indole butyric acid (IBA) and kinetin (KIN) were selected for this experiment. Hormone solutions were prepared by first dissolving 20 mg of GA, IAA and IBA in few drops of ethanol and 20 mg of KIN in 1N NaOH since they were insoluble in water. Then the final volume was made up to 1000 ml with distilled water in order to get the desired concentration (20 mg L^{-1}). One set of rice plants was sprayed with distilled water without any hormone and this treatment was taken as control (CONT). Thus the total number of treatments was five, viz. T1 = CONT, T2 = GA, T3 = IAA, T4 = IBA, T5 = KIN. These solutions were sprayed on the rice leaves at tillering and panicle initiation stage of the crop with a back-pack sprayer system (Ghodrat et al., 2012). Maximum care was taken during spraying to ensure that no run-off reaches the soil from the leaves which could possibly affect soil bacterial activity. In one 2 m × 2m = 4 m^2 plot, there were 130 numbers of rice plants and 500 ml of 20 mg L^{-1} solution per plot was sprayed on the rice leaves.

2.4. CH_4 sampling and measurement

CH_4 flux from both treated and untreated rice plants was recorded from 0 DAT at weekly interval up to 21 days after harvest (DAH) using the static chamber technique described by Buendia et al. (1997). Chambers of 50 cm length, 30 cm breadth and 70 cm height made of 6 mm thick acrylic sheets were used for gas collection. Chambers with height ranging from 90 to 120 cm were used during the later crop growing period to accommodate the increasing plant height. Rectangular U shaped aluminum channels (50 cm × 30 cm) were used to accommodate the chamber. The aluminum channels were inserted into the soil to a depth of 15 cm well ahead of gas sample collection. Each aluminum channel enclosed six plants of rice. A battery-operated fan was fixed inside the chamber to homogenize the inside air. The top of the chamber was fitted with two self-sealing rubber septa. A thermometer was inserted through one of these septa to record the chamber temperature. Gas samples were drawn from the chambers using a 50 ml airtight syringe fitted with a three-way stop-cock and a fine needle inserted through the other self-sealing rubber septum. The samples were drawn at fixed interval of 0, 15, 30 and 45 min at 0900 h and again at 1400 h from the day of transplanting (0 DAT) onwards at weekly interval. The samples were brought to the laboratory immediately after collection and CH_4 concentration in the gas samples were analyzed using a gas chromatograph (Varian, CP-3800 GC, USA) equipped with a flame ionization detector (FID) and a chromopack capillary column. Column, injector and detector temperatures were maintained at 50 °C, 90 °C and 150 °C, respectively. The gas chromatographic system was calibrated periodically with a standard obtained from National Physical Laboratory, New Delhi, India. Nitrogen (N_2) (99.999% pure) was used as a carrier gas whereas hydrogen (H_2) and zero air were used for ignition of the flame in the FID. CH_4 fluxes (mg CH_4 m^{-2} h^{-1}) were calculated from the temporal increase in the gas concentration inside the box using the equation of Parashar et al. (1996) and the average of morning and evening fluxes were considered as the flux value for the day. Cumulative CH_4 emission for the entire crop growth period was computed by the method given by Naser et al. (2007) by using the following formula:

$$\text{Cumulative } CH_4 \text{ emission} = \sum_{i=1}^{n-1} R_i \times D_i$$

Where R_i is the mean gas emission, D_i is the number of days in the sampling interval and n is the number of sampling times. Cumulative CH_4 emission was expressed in g m^{-2}.

2.5. Analysis of soil parameters

Prior to rice cultivation soil samples were collected randomly from different locations of the experimental plot from a depth of 0–15 cm and soil samples were analyzed for the basic soil physicochemical properties (Section 2.1) by following the methods described in Borah and Baruah (2016).

After transplanting of rice, soil samples were collected from the rice grown plots at weekly interval on the day of CH_4 gas sampling with the help of a soil core from 0–15 cm soil depth and analyzed for soil moisture content (SMC) following the method of Page et al. (1982). Soil organic carbon was analyzed in a TOC analyzer (Multi N/C 2100S with HT 1300 module, Analytik Jena, Germany) by the method of Awale et al. (2013).