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Investigations on nitrous oxide emissions from organic rice fields as influenced by atmospheric factors

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ABSTRACT

The increasing demand of the growing population requires enhancement in the production of rice. This has a direct bearing on the global environment since the rice cultivation is one of the major contributors to the nitrous oxide (N_2O) emissions. As the rice cultivation is intensified with the current practices and technologies, the nitrous oxide fluxes from paddy fields will substantially rise. Improved high yielding rice varieties together with efficient cultivation techniques will certainly contribute to the curtailment of the nitrous oxide emission. The effect of organic-fertilization on rice yield and their relationships with nitrous oxide fluxes as influenced by various weather factors was investigated taking various treatment as two dates of transplanting, two different aged seedlings for a most promising variety of Oryza sativa L. (Satabdi) under irrigated and rainfed condition. Trace gas fluxes from the soil were measured fortnightly throughout the entire growth period using a closed chamber method. Experimental results showed that N_2O emission rate was highest for rainfed rice fields than irrigated ones especially after 30 and 60 days of transplanting. Canopy temperature and ambient temperature significantly affect the N_2O emission rate. In case of irrigated system a positive correlation exists in between ambient temperature and N_2O emission after 30 and 60 DAT (R^2= 0.98 and 0.31 respectively) but for rainfed condition the correlation was 0.45 and 0.33 only after 30 and 75 days after transplanting respectively. Another significant correlation was found in between canopy temperature and N_2O emission from both water treatments as R^2 = 0.35 and 0.38 for irrigated fields (30 and 60DAT respectively) and as R^2 = 0.38 and 0.57 for rainfed fields (30 and 60 DAT respectively). These two climatic factors also affect the productivity of rice. Same trend of association was observed between N_2O emission potentiality and yield of rice where R^2= 0.46 (rainfed) and 0.17 (irrigated) during 30DAT. So it is concluded that during organic rice cultivation atmospheric parameters plays pivotal role in N_2O emission from rice field followed by productivity of rice.

***Keywords**: Atmospheric parameters, N_2O emission, organic rice, productivity*

Nitrous oxide, an atmospheric trace gas is one of the major contributors to the global warming accounting for 15% of total Global Warming Potential (GWP) (Iserrman, 1994). About 62% of Nitrous oxide emitted from anthropogenic activities comes from agricultural sources (Duxbury *et al.,* 1994). Rice paddy which is cultivated throughout the year in North Eastern regions of India are known to be important source of global warming by releasing green house gases. N_2O emissions dependent on moisture content of the soil and prefer the drained period. The altering dry -wet cycle in rice paddy enhance the N_2O emission (Yan *et al.,* 2000, Bronson *et al.,* 1997). Edaphic factors *i.e.,* water content, soil temperature, soil compaction and complexities of microbial processes as well as a multitude of physical and chemical factors are affecting the N_2O emission. Role of these factors in controlling N_2O emission have been largely reported (Bouwman, 1994, Watson *et al*., 1992). Use of nitrogenous fertilisers and rate of their application also enhance N_2O emission. In South East Asia 20% of total nitrogen emissions are resulted from application of animal manure as a source of nitrogen in the field (Yan *et al.,* 2000) the controlling factors of in the emission of green house gases *viz*. soil organic C pools, soil nutrients, and microbial environment affected by the Soil management and organic amendments (Intergovernmental Panel on Climate Change, 1996). In view of this we are trying to find out the role of climatic factors to N_2O emission from irrigated and rainfed rice fields where vermicompost was used as a source of nitrogen.

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MATERIALS AND METHODS

A field experiment was conducted at C-Block farm of Bidhan Chandra Krishi Viswavidalya under New Alluvial Agro-climatic Zone of West Bengal, India during kharif season (June to October), 2013. The experiment was consisted of two dates of transplanting (27th June, 12th July) along with two ages of seedlings (25 days and 18 days) under irrigated and rainfed condition taking single rice (*Oryza sativa*) variety 'satabdi'. The experiment was replicated thrice under randomise block design. Vermicompost was used as organic source of fertilizer. Nitrous oxide emission was measured using the closed chamber technology during rice growing period. The chamber is made of PVC (polyvinyl chloride) sheet covering 1.22 m^2 area. The chamber is equipped with a battery powered fan to ensure thorough mixing of air inside the chamber. Measurements were started after 30 days of transplanting and continued at 15 days interval till harvesting. Nitrous oxide analyser (Technovation Series 2005, Serial No. 12045) was used to record N_2O emission. Thermometer was used to record the chamber temperature. Simultaneously canopy temperature was measured using infra red thermometer (Model: Metravi MT-2).

Flux rate was calculated according to the following equation

$$F = \frac{PVMU}{dt\ ART} * dc /$$

where, F is flux rate (gm/m²/d), P is pressure of chamber, V is chamber volume (3.66m^3), M is molecular weight of nitrogen, U is unit converter factor (0.00144) A is the area covered by the chamber (1.22 m^2), R is gas constant (0.082), T is chamber temperature (Kelvin), and dc/dt is changes of concentration with changing time.

Daily weather data was collected from University weather station. Yield and yield attributes *viz*. length of panicle and 100 seed weight was estimated during harvesting.

RESULTS AND DISCUSSION

Fig. -1 shows the distribution of average ambient temperature and total rainfall throughout the rice growing season. The ambient temperature was ranging in between 32.5 to 25.5 °C with an average of 29.7 °C along with total rainfall 715.2mm throughout the rice growing season. The data presented in graph indicated that rainfall and temperature were in opposite direction *i.e.*, increasing rainfall with decreasing temperature and vis-versa.

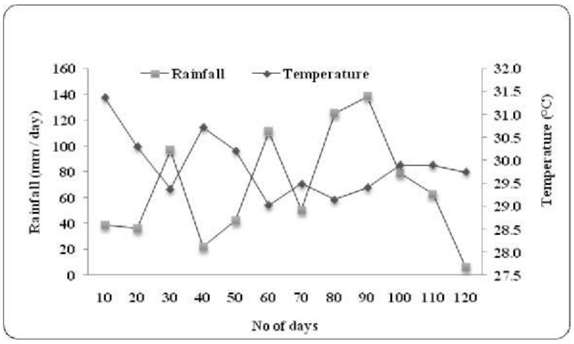

Fig 1: Distribution pattern of average ambient temperature and total rainfall during crop growing season

Table 1: Influence of individual and combination of factors on nitrous oxide flux (mg m^{-2} day^{-1}) during different dates after transplanting of rice

Experimental Factors		30 DAT	45 DAT	60 DAT	75 DAT
A1 (Age of seedling-25 days)		-13.85	-1.9	-0.24	9.25
A2 (Age of seedling-18 days)		9.5	6.26	18.98	-13.72
SEm(±)		**0.13**	**0.06**	**0.27**	**0.09**
LSD (0.05)		**0.43**	**0.22**	**0.9**	**0.31**
T1 (Transplanting date-27th June)		-2.94	12.62	5.74	-22.64
T2 (Transplanting date-12th July)		-1.42	-8.26	12.99	18.17
SEm(±)		**0.13**	**0.06**	**0.27**	**0.09**
LSD (0.05)		**0.43**	**0.22**	**0.90**	**0.31**
I (Irrigated)		16.1	4.23	-6.65	-1.58
R (Rainfed)		-20.46	0.12	25.39	-2.88
SEm(±)		**0.13**	**0.06**	**0.27**	**0.09**
LSD (0.05)		**0.60**	**0.32**	**1.27**	**0.44**
A× T	**SEm(±)**	**0.18**	**0.09**	**0.38**	**0.13**
	LSD (0.05)	**NS**	**0.31**	**1.27**	**0.44**
A×MR	**SEm(±)**	**0.18**	**0.09**	**0.38**	**0.13**
	LSD (0.05)	**0.60**	**0.31**	**1.27**	**0.44**
T×MR	**SEm(±)**	**0.18**	**0.09**	**0.38**	**0.13**
	LSD (0.05)	**0.60**	**0.31**	**NS**	**0.44**
T×A×MR	**SEm(±)**	**0.18**	**0.09**	**0.38**	**0.13**
	LSD (0.05)	**0.60**	**0.31**	**1.27**	**NS**

Note: MR: Moisture regime (irrigated and rainfed)

Effect of age of seedlings, date of transplanting and moisture regime on nitrous oxide emission potentiality during different growth stages of rice

Experimental results indicated that individual and combined effect of different factors played significant role in N_2O emission from organic rice fields especially after 30 and 60 days of transplanting. Maximum variations in N_2O emission had observed after 60 days of transplanting. Age of seedlings and transplanting date also had some association with N_2O emission during these periods (Table 1).

Under irrigated condition continuous flooding was resulted an anaerobic environment. Nitrifying bacteria does not favour this anaerobic condition to produce N_2O emission because N_2O is rapidly broken down to N_2 under such condition (Granli and Bockman, 1994). In irrigated plots partial aerobic condition was occurred during various phases of crop. This condition enhanced the microbial activity to produce N_2O (Kumar *et al.*, 2000, Flessa and Bees 1995). We also get well distributed rainfall throughout the rice growing season and the rainfed plots were also in altering dry-wet cycle leading to N_2O emission. Due to this there were very less variations in N_2O emission from irrigated and rainfed plots.

Application of organic manure may increase N_2O emission because it is mineralised during dry phase and produce N_2O. Chao *et al.*(2001) reported that application of animal dung emitted more N_2O than chemical fertilisers.

Seedling ages and transplanting dates had some direct association with N_2O emission. The 25 days old seedling matured earlier as compared to 18 days old seedlings. Depending on the date of transplanting duration to attain different phenological phases were different. So physiological condition of rice crop under different environment influenced directly to the emission potentiality of N_2O Differing growth attributes altered the microclimatic as well as soil environment which are the key factors for N_2O production and emission.

In our study maximum emission was observed during reproductive stage (60 DAT) of rice crop. Yang and Cai (2005) also found emission peak during reproductive stage of rice. He suggested that senescence of older leaves and decomposition of crop roots resulted in higher N_2O production in rice rhizosphere.

Table 2: Effect of individual and combination of factors on canopy temperature (CT) (°C) during different dates after transplanting of rice

Experimental Factors		30 DAT	45 DAT	60 DAT	75 DAT
A1 (Age of seedling-25 days)		26.52	24.87	27.23	30.83
A2 (Age of seedling-18 days)		26.02	26.15	27.43	30.36
SEm(±)		**0.04**	**0.05**	**0.05**	**0.04**
LSD (0.05)		**0.14**	**0.18**	**0.16**	**0.14**
T1 (Transplanting date-27th June)		25.20	23.98	28.67	29.93
T2 (Transplanting date-12th July)		27.35	27.03	26.00	31.26
SEm(±)		**0.04**	**0.05**	**0.05**	**0.04**
LSD (0.05)		**0.14**	**0.18**	**0.16**	**0.14**
I (Irrigated)		25.9	24.06	27.15	30.9
R (Rainfed)		26.65	26.96	27.52	30.3
SEm(±)		**0.04**	**0.05**	**0.05**	**0.04**
LSD (0.05)		**0.19**	**0.25**	**0.23**	**0.20**
A× T	**SEm(±)**	**0.06**	**0.07**	**0.07**	**0.06**
	LSD (0.05)	**0.19**	**0.25**	**0.23**	**0.20**
A×MR	**SEm(±)**	**0.06**	**0.07**	**0.07**	**0.06**
	LSD (0.05)	**0.19**	**0.25**	**0.23**	**0.20**
T×MR	**SEm(±)**	**0.06**	**0.07**	**0.07**	**0.06**
	LSD (0.05)	**0.19**	**0.26**	**0.23**	**0.20**
T×A×MR	**SEm(±)**	**0.06**	**0.07**	**0.07**	**0.06**
	LSD (0.05)	**NS**	**NS**	**NS**	**0.20**

Table 3: Effect of individual and combined factors on yield and yield attributes of rice

Experimental Factors		Yield (kg ha^{-1})	100 seed wt(g)	Panicle length(cm)	No. of panicle plant^{-1}
A1 (Age of seedling-25 days)		4268.9	2.3	22.79	8.7
A2 (Age of seedling-18 days)		4125.18	2.31	22.9	9.2
SEm(±)		**247.76**	**0.14**	**0.38**	**0.4**
LSD (0.05)		**NS**	**NS**	**NS**	**NS**
T1 (Transplanting date-27th June)		4840.35	2.52	22.05	8.88
T2 (Transplanting date-12th July)		3553.74	2.09	23.64	9.01
SEm(±)		**247.76**	**0.14**	**0.38**	**0.4**
LSD (0.05)		**NS**	**NS**	**NS**	**NS**
I (Irrigated)		4572.06	2.5	23.4	8.81
R (Rainfed)		3822.03	2.12	22.3	9.08
SEm(±)		**247.76**	**0.14**	**0.38**	**0.4**
LSD (0.05)		**NS**	**NS**	**NS**	**NS**
A× T	**SEm(±)**	**350.38**	**0.20**	**0.54**	**0.56**
	LSD (0.05)	**1169.42**	**NS**	**1.80**	**NS**
A×MR	**SEm(±)**	**350.38**	**0.20**	**0.54**	**0.56**
	LSD (0.05)	**NS**	**NS**	**NS**	**NS**
T×MR	**SEm(±)**	**350.38**	**0.20**	**0.54**	**0.56**
	LSD (0.05)	**1169.42**	**NS**	**1.80**	**NS**
T×A×MR	**SEm(±)**	**350.38**	**0.20**	**0.54**	**0.56**
	LSD (0.05)	**NS**	**NS**	**NS**	**1.89**

Effect of age of seedlings, date of transplanting and moisture regime on canopy temperature during different growth stages of rice

Significant variations in canopy temperature were observed due to moisture regime and all two factor interactions at 45 and 60 days after transplanting. Canopy temperature expresses the crop water status. Thus the moisture regime of rice field is the major determinant of the canopy temperature variation as canopy temperature indicates the crop condition whether the crop is in stress or non stress condition. Rice crop is in active vegetative phase to reproductive phase during 45 - 60 DAT. Depending on crop growth character canopy cover may change which regulate canopy temperature pattern.

Effect of age of seedlings, date of transplanting and moisture regime on productivity component of rice

Transplanting date in combination with age of seedling as well as moisture regime played key role in affecting the yield. Numbers of panicles/plant were greatly influenced by interactive effects of all factors. Individual factors had no influence on yield and yield attributes. There were no significant influences of all the factors on 100 seed weight and panicle length. Rice Crop was subjected to grow under varying weather conditions and differing water availability situation through transplanting of rice variety with differing seedling ages at 15 days interval. This is the reason for the differences in yield and yield attributes.

It is natural process that the crop which had taken more number of days from seeding to maturity might have a more vigorous and extensive root system, increased growth rate during vegetative growth, more efficient sink formation and greater sink size, greater carbohydrate translocation from vegetative plant parts to the spikelets and longer leaf area index during grain filling period. So, this might be the possible reason to have high yields in earlier transplanting (27th June). Reduction in grain yield of direct sown rice with delayed sowing has been documented by Walia *et al.*, 2014.

Relationships among N_2O emission and canopy temperature, ambient temperature and yield

Following graphs represents the significant relationships between N_2O emission and canopy temperature (Fig. 2-5), ambient temperature (Fig.6-9) and yield (Fig. 10).

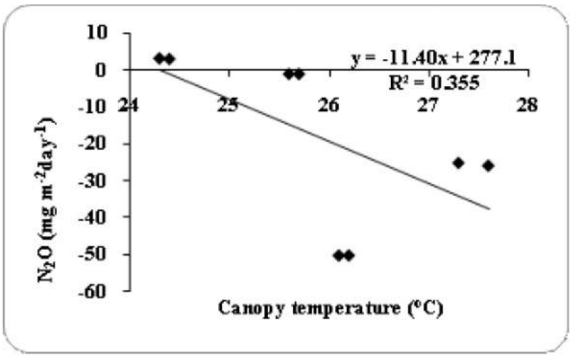

Fig. 2: Relationships between N_2O flux and canopy temperature under irrigated condition at 30 DAT

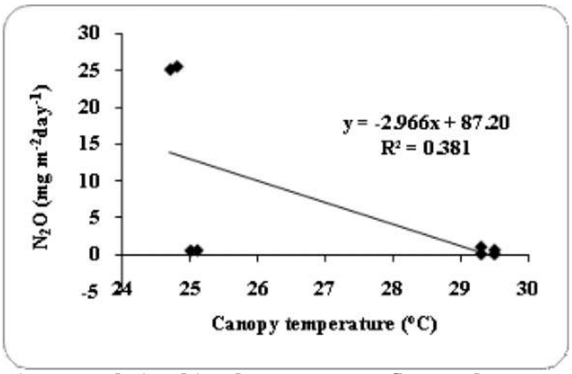

Fig. 3: Relationships between N_2O flux and canopy temperature under irrigated condition at 60 DAT

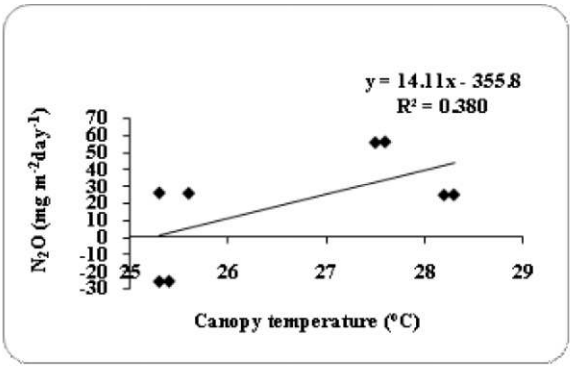

Fig. 4: Relationships between N_2O flux and canopy temperature under rain-fed condition at 30 DAT

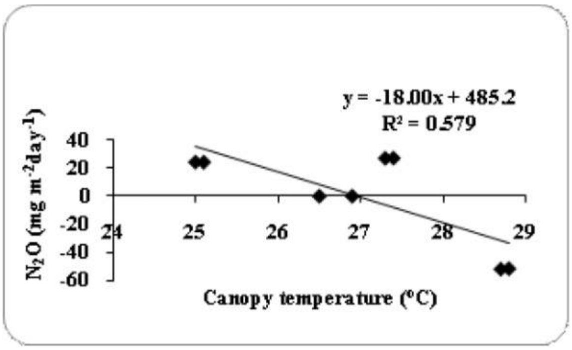

Fig. 5: Relationships between N_2O flux and canopy temperature under rain-fed condition at 45 DAT

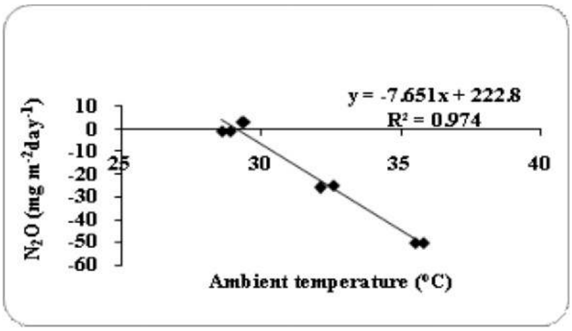

Fig. 6: Relationships between N_2O flux and ambient temperature under irrigated condition at 30 DAT

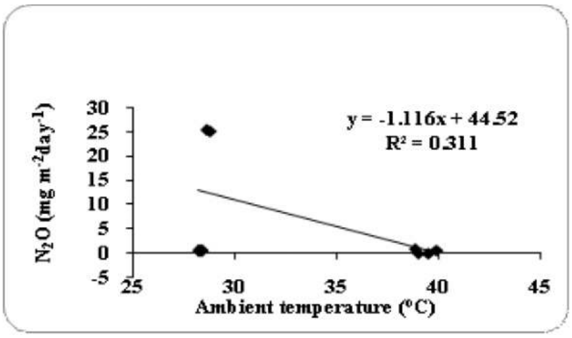

Fig. 7: Relationships between N_2O flux and ambient temperature under irrigated condition at 60 DAT

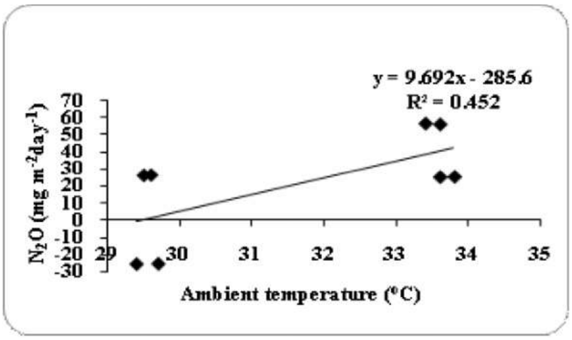

Fig. 8: Relationships between N2O flux and ambient temperature under rain-fed condition at 30 DAT

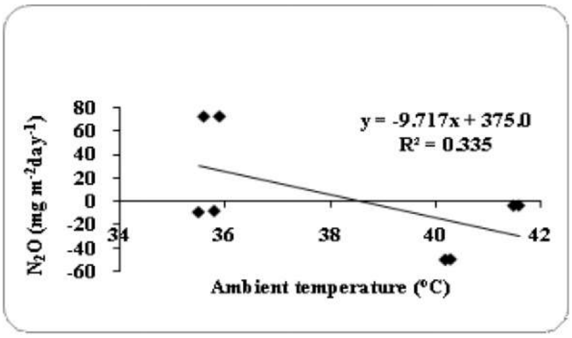

Fig. 9: Relationships between N2O flux and ambient temperature under rain-fed condition at 75 DAT

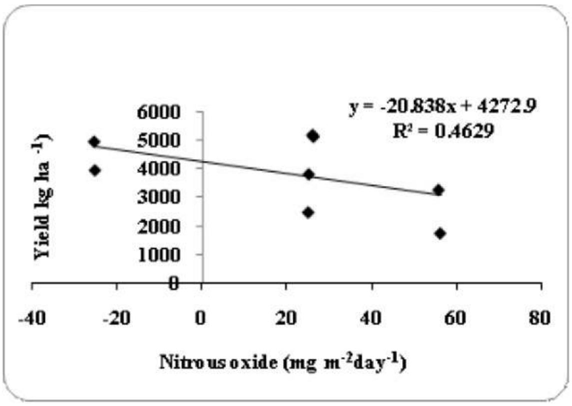

Fig. 10: Relationships between N_2O flux and yield under rain-fed condition at 30 DAT

Under irrigated and rainfed condition close relationships observed in between nitrous oxide emission and canopy temperature and ambient temperature after 30 and 60 days of transplanting. Canopy tempearture depends on soil moisture status. Soil moisture acts as a driving force for the activity of soil microbes which are responsible for Nitous oxide emission. During 30 to 60 DAT crop canopy density was maximum resulting change in microclimatic environment followed by N_2O emission rate from crop soil.

After 30 days of transplanting productivity was significantly correlated with N_2O emission. This may be due to active efficiency of organic substances which can increase the productivity but simultaneously enhance green house gas eission. The same results was also reported in corn by Hoben *et al.*, (2011)

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