Mysore J. Agric. Sci., 55 (3) : 230-236 (2021)

Studies on Methane and Nitrous Oxide Emission from Zero Budget Natural Farming Organic and Conventional Farming in Direct Seeded Aerobic Rice

R. V. Lohith, M. Mahadeva Murthy and M. T. Sanjay
Department of Forestry and Environmental Science, College of Agriculture, UAS, GKVK, Bangalore - 560 065
e-Mail : lohithrv3@gmail.com

Abstract

Rice (*Oryza sativa* L.) is the staple food of more than three billion people is generally cultivated in most part of the country. Its production is facing major challenges including scarcity of irrigation water and ongoing climate change. Cultivation of direct seeded rice with zero budget natural farming (ZBNF) could maintain yield, save water and mitigate greenhouse gas emission. The present study was conducted to compare the methane and nitrous oxide emission and CO_2 equivalent emission in zero budget natural farming, organic farming and conventional farming (Farmer's practice and UAS-B package of practice) in aerobic direct seeded rice variety MAS 26. The results showed that cumulative CH_4 emission found higher in two conventional farming practices *i.e.,* UAS-B package of practices (0.5755 kg ha^{-1}) and farmer's practice (0.5053 kg ha^{-1}), average emission was observed in organic farming (0.4311 kg ha^{-1}) and ZBNF (0.4165 kg ha^{-1}). However, high flux in cumulative N_2O emission was observed in organic farming (0.1230 kg ha^{-1}), average amount of flux is observed in farmer's practice (0.0828 kg ha^{-1}), ZBNF (0.0676 kg ha^{-1}) and UAS-B package of practices (0.0597 kg ha^{-1}). The CO_2 equivalent emission found to be high in organic farming (44.6595 kg CO_2-eq ha^{-1}), average in farmers practice (36.0888 kg CO_2-eq ha^{-1}), UAS-B package of practices (31.9274 kg CO_2-equi.ha^{-1}) and ZBNF (29.5657 kg CO_2-equi.ha^{-1}). This study showed that the ZBNF is effective in reducing CH_4, N_2O and CO_2-equivalent emission than other practices.

Keywords: Zero budget natural farming, CO_2 equivalent, Methane, Nitrous oxide

Global climate change is caused by increasing atmospheric concentrations of greenhouse gases (GHGs) such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) etc. As rapidly climate change is affecting food security and other social issues, mitigation strategies for anthropogenic GHG emissions are required worldwide (IPCC, 2014). Methane (CH_4) and Nitrous oxide (N_2O) are significant long-lived greenhouse gases and they together contribute about 20 per cent of the annual increase in radiative forcing (Smith *et al.,* 2007).

Globally, anthropogenic sources of N_2O and CH_4 are dominated by agriculture and further agricultural CH_4 and N_2O emissions have increased by nearly 17 per cent from 1990 to 2005 (Forster *et al.,* 2007). Agricultural N_2O emissions are projected to increase by 35-60 per cent up to 2030 due to increased chemical and manure N inputs (FAO, 2003).

Agriculture in its prevailing form requires farmers to rely heavily on inorganic external inputs such as fertilizers and pesticides. These contaminate ground water and other water-dependent ecosystems that reduce soil fertility over time and contribute to biodiversity loss in farm lands (Aktar *et al.,* 2009). Prevailing agricultural practices such as mono-cropping decrease soil moisture content causing tremendous stress on water resources. Agriculture today accounts for almost 70 per cent of the world’s fresh water consumption (Clay, 2004). The use of external inputs by adoption of uniform, hybridized and genetically modified crop varieties erodes genetic diversity of seeds and reduces their capacity to adapt to changing climatic conditions (Jarvis *et al.,* 2010). These practices coupled with wide spread farm land degradation to make agriculture a major contributor to global greenhouse gas (GHG) emissions and climate change.

Alternative low-input farming practices have emerged in pockets across the world promising reduced input costs and higher yields for farmers chemical-free food for consumers and improved soil fertility. Zero Budget Natural Farming (ZBNF) is one such low-input climate-resilient type of farming that encourages farmers to use low-cost locally-sourced inputs, eliminating the use of artificial fertilizers and industrial pesticides (Tripathi *et al.,* 2018).

Rice (*Oryza sativa* L.) the staple food of more than three billion people, is generally cultivated under flooded conditions demanding up to one-third of the World's fresh water resources (Bouman *et al.,* 2007). Rice paddies are considered as one of the most important sources of CH_4 and N_2O emissions, which have attracted considerable attention due to their contribution to global warming (Harris *et al.,* 1985). In India, paddy rice cultivation occupies about 44 million hactare the largest rice producing area in Asia, and accounts for 20 per cent of the total rice production worldwide. India would need to produce up to 130 million tons of milled rice by 2030 to meet the growing demands in contrast with 92 million tonnes in 2005 (Gujja and Thiyagarajan, 2009). Water requirement in aerobic rice systems (with aerobic rice cultivars) were 30-50 per cent less than in flooded systems and the yields were almost 15-20 per cent higher than puddled rice (Prabhudeva and Nagaraju, 2017). Aerobic rice cultivation is a method in which rice is grown in well-drained, non-puddled and non-saturated soils. Under appropriate management practices, the yield obtained under aerobic condition is on par with transplanted puddled rice with an average of 8 to 10 t ha^{-1} (Sylvestre *et al.,* 2018).

Hence, the present study was conducted in aerobic direct seeded Rice to compare the emission of Methane (CH_4) and Nitrous oxide (N_2O) in zero budget natural farming, organic and conventional farming practices with the main objective to estimate the emission of CH_4 and N_2O in ZBNF, organic and conventional farming.

Material and Methods

Study Area

Field experimentwas carried out from October 2020 to March 2021 in the Research Institute on Organic Farming (RIOF), GKVK, Bengaluru, Karnataka, South India. The experiment was laid out in Randomized complete block designwith five replication. The Treatments involved is five farming systems for the direct seeded rice crop *viz.,* T_1: Farmer's practice, T_2: Organic farming, T_3: ZBNF, T_4: Package of practices recommended by UAS-B, T_5: Absolute control.

Particulars	Crop
Name of the Research Station	RIOF, GKVK, Bengaluru
Name of the Crop	Direct seeded rice
Gross plot size	7.2×28=201.6 sq m
Net plot size	6×24=144 sq m
Treatments	5
Replications	5
Design	RCBD
Variety	MAS 26

T_1- Farmers practice (FP): Treatment is based on operations carried out by the farmers in their field, FYM applied at 5 t ha^{-1}, 125 kg ha^{-1} of DAP and two hand weeding.

*T_2- Organic farming (OF):*Seed treatment with Rhizobium, FYM applied based on N equivalent (25 kg N ha^{-1}), weeding at 30 DAS, straw mulching (4 t ha^{-1}) and need based plant protection using organic materials.

T_3- Zero Budget Natural Farming (ZBNF) : Ghanajeevamrutha application at 1000 kg ha^{-1}, seed treatment with beejamrutha, application of jeevamrutha at 15 days interval at 5000 litres ha^{-1} and straw mulching (4 t ha^{-1}). Need based plant protection measures using preparation like Neemastra, Agniastra, Shuntiastra etc.

T_4- Package of practices recommended by UAS-B (UAS-B PoP): Seed treatment with Rhizobium, FYM

application at 7.5 t ha^{-1} and NPK (25:50:25 kg ha^{-1}), spraying pre-emergent herbicide (pendimethalin 30 % E.C @1000 ml ha^{-1}) one hand weeding at 30 DAS.

T_5- Absolute control (AC): Only sowing of seeds all other input practices are Nil.

Gas Sample Collection, Analysis and Calculation

The samples were collected using closed chamber method for determination of CH_4 and N_2O concentrations. To avoid the diurnal variation gas samples from the field were collected in definite time span in day throughout the cropping season preferably during morning 9-11 AM and 3-5 PM (Bhatia *et al.,* 2013). Sampling frequency was done once in every 30 days. The gas samples fromall the plots were collected four times during the rice-growing period. Inside the chamber, an electric fan was installed to circulate the air. Gas samples were drawn from the chambers through a three-way stopcock using an airtight 50-mL syringe at 0, 10 and 20 minute after closure. The air inside the chamber was thoroughly mixed by flushing the syringe five times before collection of the gas samples. The gas sample were then transferred to 20-mL vacuum glass vials with rubber stoppers and kept cool and dark until analysis. The concentrations of CH_4 and N_2O were analyzed using a gas chromatograph (PerkinElmer, Arnel Engineered solutions Clarus 590 GC) equipped with a flame ionization detector (FID) and an electron capture detector (ECD), respectively. The CH_4 and N_2O fluxes were calculated by examining the linear increases in CH_4 and N_2O concentrations in the head space of the chambers over time. The total seasonal CH_4 and N_2O emissions from all plots were calculated directly from the fluxes

Calculation of Flux

The flux of methane and nitrous oxide is calculated using the following equations.

Cross-sectional area of the chamber (m^2) = A

Head space (m) = H

Volume of head space (L) = 1000 x AH

CH_4 concentration at 0 time (ìL L^{-1}) = C_o

CH_4 concentration after time t (ìL L^{-1}) = C_t

Change in concentration in time t (ìL L^{-1}) = (C_t -C_o)

Volume of CH_4 evolved in time t (ìL) = (C_t -C_o) x 1000 AH

When t is in hours, then flux (mL m^{-2} h^{-1}) = [(C_t-C_o) x AH)/(A x t)

Now 22.4 mL of CH_4 is 16 mg at STP

Hence, CH_4 flux = [(C_t - C_o)/t] x H x 16/22.4 x 10000 x 24 mg ha^{-1} d^{-1}

N_2O flux = [(C_t - C_o)/t] x H x 44/22.4 x 10000 x 24 mg ha^{-1} d^{-1}

CO_2 Equivalent Emission

The equivalent CO_2 (CO_2-equi.) emission for total CH_4 and N_2O emissions were calculated using the equation:

$$CO_2\text{-eq} = (TCH_4 \times 28) + (TN_2O \times 265)$$

Where CO_2-equi. is the total amount of equivalent CO_2 emission (kg CO_2-eq ha^{-1}), TCH_4 is the total amount of CH_4 emission (kg ha^{-1}), TN_2O is the total amount of N_2O emission (kg ha^{-1}), 28 and 265 are the CO_2 Equivalent Emission for CH_4 and N_2O, respectively, to CO_2over a 100-yr time horizon (IPCC, 2014).

Statistical Analysis

The effects of the treatment factors (cropping systems) on CH_4 and N_2O emissions from the direct seeded rice were examined. The experimental data were analyzed by analysis of variance (ANOVA) MS excel 2010.

RESULTS AND DISCUSSION

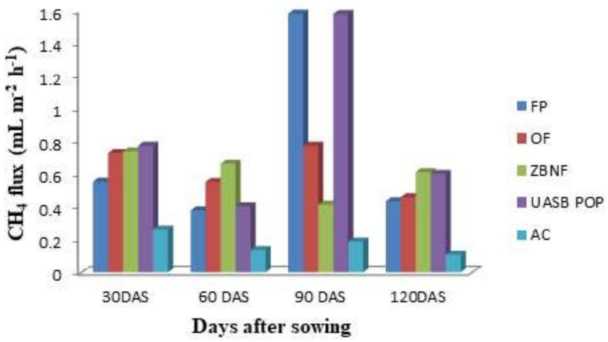
Methods of cropping systems *i.e.,* ZBNF, organic farming and conventional farming in aerobic direct seed rice cultivation recorded significant amount of Methane and Nitrous oxide emission throughout the crop growth stages. During crop growth stages from 30, 60, 90 and 120 DAS, observation were recorded and analyzed under five cropping systems.

Methane fluxes found highest at 90 DAS in UAS-B package of practice and Farmers practice. Fluxes found average at 30 DAS, 60 DAS and 120 DAS.

Plate 1: Collection of methane and nitrous oxide gases placed in the research plots using closed chamber technique and estimation of gases by using GCMS instrument

At 30 DAS, UAS-B Package of Practice (0.1325 kg ha^{-1} d^{-1}) recorded highest flux followed by ZBNF (0.1265 kg ha^{-1} d^{-1}) and organic farming (0.1250 kg ha^{-1} d^{-1}). At 60 DAS highest emission found in ZBNF (0.1139 kg ha^{-1} d^{-1}) followed by organic farming (0.0951 kg ha^{-1} d^{-1}). At 90 DAS fluxes dramatically increased in farmers practice (0.2705 kg ha^{-1} d^{-1}) and UAS-B package of practice (0.2703 kg ha^{-1} d^{-1}), fluxes found high in organic farming (0.1325 kg ha^{-1} d^{-1}). At 120 DAS averaged flux was observed in ZBNF and UAS-B Package of Practice (Table 1 & Fig. 1).

In paddy soils, CH_4 is produced by the process of methanogenesis, where organic matter undergoes decomposition in the absence of oxygen. In the rice-growing season, maximum CH_4 produced in the soil is released by diffusive transport via the aerenchyma system instead of diffusion (Xie and Li, 2002).



FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UASB POP: Package of practices recommended by UASB; AC: Absolute control.

Fig. 1: Average rate of Methane flux (mL m^{-2} h^{-1})

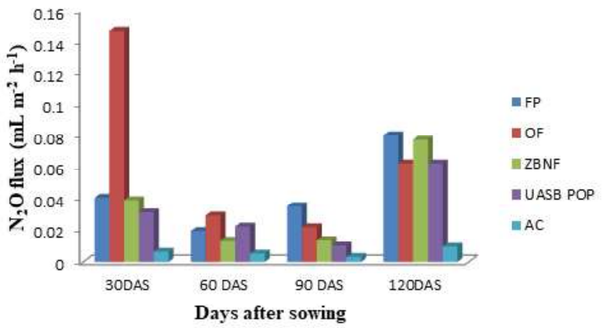
N_2O flux dramatically found highest in organic farming ((0.0693 kg ha^{-1} d^{-1}) at 30 DAS other fluxes averaged in entire crop season. At 60 DAS highest flux found in organic farming (0.0139 kg ha^{-1} d^{-1}) followed by UAS-B package of practice (0.0105 kg ha^{-1} d^{-1}). At 90 DAS highest fluxes was observed in Farmers practice (0.0166 kg ha^{-1} d^{-1}) followed by organic farming (0.0103 kg ha^{-1} d^{-1}). At 120 DAS Farmers practice (0.0378 kg ha^{-1} d^{-1}) was observed high flux followed by ZBNF (0.0366 kg ha^{-1} d^{-1}) and UAS-B package of practice (0.0295 kg ha^{-1} d^{-1}) (Table 2 & Fig. 2).

TABLE 1

Average rate of methane flux (Kg ha^{-1} d^{-1})

	30 DAS	60 DAS	90 DAS	120 DAS
FP	0.0954 ± 0.0551	0.0650 ± 0.0323	0.2705 ± 0.1282	0.0744 ± 0.0526
OF	0.1250 ± 0.0602	0.0951 ± 0.0119	0.1325 ± 0.0799	0.0786 ± 0.0337
ZBNF	0.1265 ± 0.0303	0.1139 ± 0.0289	0.0709 ± 0.0397	0.1052 ± 0.0422
UASB POP	0.1325 ± 0.0540	0.0691 ± 0.0295	0.2703 ± 0.0871	0.1035 ± 0.0405
AC	0.0453 ± 0.0296	0.0240 ± 0.0190	0.0327 ± 0.0213	0.0194 ± 0.0090
CV (%)	34.7372	31.5616	54.9401	55.8835
CD (p=0.05)	0.0489	0.0311	0.1144	0.0571
SEm±	0.0163	0.0104	0.0382	0.0190

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UAS-B POP: Package of practices recommended by UAS-B; AC: Absolute control.



FP: Farmers practice; of: Organic farming; ZBNF: Zero Budget Natural Farming; UAS-B POP: Package of practices recommended by UASB; AC: Absolute control.

Fig. 2: Average rate of Nitrous oxide flux (mL m^{-2} h^{-1})

N_2O is produced by the microbial transformation of Nitrogen (N) in soils. This transformation of N to N_2O has been related to two biological processes, *i.e.,* the loss of N as N_2O during the nitrification of NH_4^+ under aerobic conditions and the reduction of NO_3^+ to N_2 during denitrification process. Nitrogen fertilization level and water management are the main factors regulating N_2O emission in the paddy soil (Ali *et al.,* 2019). During rice-growing season, N_2O is produced due to alternate wetting / drying period in the underground saturated soil layer as well as rice-winter upland crop rotation and could move upwards with water evaporation and contribute to atmospheric N_2O. Under flooding condition, significant N_2O emission takes place predominately through the rice plants, where rice plants act as a conduit for dissolved gases from the root zone to the atmosphere (Yan *et al.,* 2000). N_2O is a water-soluble molecule and hence can be up taken byplant roots and transported to leaves via the transpiration stream.

The cumulative methane flux was found significantly highest in UAS-B Package of Practice (0.5755 kg ha^{-1}) and farmers practice (0.5053 kg ha^{-1}) followed by organic farming (0.4311 kg ha^{-1}) and ZBNF (0.4165 kg ha^{-1}). The cumulative nitrous oxide flux was found significantly high in organic farming (0.1230 kg ha^{-1}) followed by farmers practice (0.0828 kg ha^{-1}) ZBNF (0.0676 kg ha^{-1}) and UAS-B package of practice (0.0597 kg ha^{-1}). CO_2-equivalent emission was found greater in organic farming than UAS-B package of practice, farmers practice and ZBNF. ZBNF has shown less global warming potential than other three cropping systems (Table 3).

In comparison with ZBNF, organic farming and conventional farming, CH_4 emissions were significantly increased in conventional farming due to application of FYM and irrigation of rice field offered the predominant source of methanogenic substrates and thus promoted CH_4 production over the rice-growing season. N_2O is produced primarily during soil nitrification and denitrification processes, which is highly dependent on aerobic condition in rice which produce more with influence of application of FYM, manures and fertilizers.

TABLE 2

Average rate of nitrous oxide flux(Kg ha^{-1} d^{-1})

	30 DAS	60 DAS	90 DAS	120 DAS
FP	0.0192 ± 0.0217	0.0091 ± 0.0065	0.0166 ± 0.0097	0.0378 ± 0.0242
OF	0.0693 ± 0.0574	0.0139 ± 0.0183	0.0103 ± 0.0084	0.0294 ± 0.0200
ZBNF	0.0185 ± 0.0099	0.0062 ± 0.0025	0.0063 ± 0.0031	0.0366 ± 0.0558
UAS-B POP	0.0148 ± 0.0076	0.0105 ± 0.0037	0.0048 ± 0.0035	0.0295 ± 0.0561
AC	0.030 ± 0.0015	0.0025 ± 0.0013	0.0015 ± 0.0010	0.0124 ± 0.0063
CV (%)	111.2151	106.3394	77.8888	135.3195
CD (p=0.05)	0.0372	0.0120	0.0083	0.0500
SEm±	0.0124	0.0040	0.0028	0.0167

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming;
UAS-B POP: Package of practices recommended by UAS-B; AC: Absolute control.

TABLE 3

Cumulative CH_4 and N_2O emissions, its calculated CO_2-equivalent emission

	Cumulative CH_4 (Kg ha^{-1})		Cumulative N_2O (Kg ha^{-1})		CO_2-equi.
FP	0.5053	± 0.2681	0.0828	± 0.0621	36.0888
OF	0.4311	± 0.1857	0.1230	± 0.1041	44.6596
ZBNF	0.4165	± 0.1412	0.0676	± 0.0712	29.5657
UAS-B POP	0.5755	± 0.2111	0.0597	± 0.0709	31.9274
AC	0.1213	± 0.0789	0.0115	± 0.0101	4.6112

FP: Farmers practice; OF: Organic farming; ZBNF: Zero Budget Natural Farming; UASB POP: Package of practices recommended by UASB; AC: Absolute control.

The IPCC CO_2-equivalent factors (mass basis, kg CO_2-equivalent ha^{-1}) for CH_4 and N_2O are 28 and 265 in the time horizon of 100 years, respectively (IPCC, 2014)

In rice paddy, $CH_4$is produced by the Methanogenic archaea and a portion of it is oxidized by the methanotrophic bacteria, whereas the activity of microbial nitrification and denitrification together contribute about 70 per cent of N_2O emission however, denitrification is more often associated with N_2O production (Braker and Conrad, 2011).

Several explanations may be given for the higher CH_4 emissions. First, decomposition of organic matter in rice paddies offered the predominant source of methanogenic substrates, and thus promoted CH_4 production over the rice-growing season. Second, manure application may change soil microbial communities and their activities (Zheng *et al.,* 2007). The DGGE analysis showed that microbial communities, including methanogenic archaea, can change depending on the rice growth and decomposition of organic materials and this explained the difference in CH_4 emissions (Watanabe *et al.,* 2010).

Compared with continuous flooding, midseason drainage and moist irrigation significantly decreased the net GWPs inorganic and conventional rice paddies. In addition, differences in the net GWPs of CH_4 and N_2O emissions between organic and conventional rice paddies depended on irrigation regime. Under continuous flooding CH_4 and N_2O emissions from organic rice paddies were significantly greater and thereby estimated GWP was greater in organic rice paddies than in conventional rice paddies. For rice paddies with midseason drainage CH_4 emissions were significantly higher while N_2O emissions were significantly (Xiong *et al.,* 2010).

Zero budget natural farming practice reduced the CH_4 emissions compared to organic and conventional farming practices under aerobic direct seeded rice. Since the contribution from N_2O emission is higher in organic farming resulted higher CO_2-equivalent emission. The ZBNF is an effective way to mitigate total greenhouse gas emissions from aerobic rice fields. The results suggested that the ZBNF is effective in reducing CO_2-eq emissions. In the context of global warming, the ZBNF is promising way to mitigating greenhouse gas emissions.

REFERENCES

AKTAR, M. W, SENGUPTA, D. AND CHOWDHURY, A., 2009, Impact of pesticides use in agriculture: their benefits and hazards. *Inter disciplinary toxicology*, **2** (1) :1 - 12.

ALI, M. A., INUBUSHI, K., KIM, P. J. AND AMIN, S., 2019, Management of paddy soil towards low greenhouse gas emissions and sustainable rice production in the changing climatic conditions. *Soil Contamination and Alternatives for Sustainable Development*, pp: 89 - 103.

BHATIA, A., JAIN, N., BHATTACHARYYA, P., SRINIVASARAO, C. H., PRASAD, J. V. N. S. AND PATHAK, H., 2013, Measurement of greenhouse gas emissions from crop fields. *NICRA Manual Series,* **2** : 9 - 17.

BOUMAN, B. A. M., HUMPHREYS, E., TUONG, T. P. AND BARKER, R., 2007, Rice and water. *Advances in agronomy*, **92** : 187 - 237.

BRAKER, G. AND CONRAD, R., 2011, Diversity, structure and size of N_2O - producing microbial communities in soils-what matters for their functioning? *Adv. Appl. Microbiol.,* **75** : 3337.

CLAY, J., 2004, World agriculture and the environment:A commodity-by-commodity guide to impacts and practices, Island Press.

FAO, 2003, World agricultural towards 2015/2030. An FAO Perspective, FAO, Rome.

FORSTER, P., RAMASWAMY, V., ARTAXO, P., BERNTSEN, T., BETTS, R., FAHEY, D. W., HAYWOOD, J., LEAN, J., LOWE, D. C., MYHRE, G., NGANGA, J., PRINN, R.,RAGA, G., SCHULZ, M. AND VAN DORLAND, R., 2007, Changes in atmospheric constituents and in radiative forcing. In: Solomon, S., Qin, D., Manning M, Chen, Z., Marquis, M., Averyt, K. B., Tignor, M., Miller, H. L., (eds) Climate change 2007: the physical sciencebasis. Contribution of working group i to the fourth assessment report of the inter governmental panel on climate change. Cambridge University Press, Cambridge, Pp: 130 - 234.

GUJJA, B. AND THIYAGARAJAN, T. M., 2009, New hope for Indian food security? The system of rice intensification. *Gatekeeper,* **143** : 1 - 20.

HARRIS, R. C., GORHAM, E., SABACHER, D. I., BARTLETT, K. B. AND FLEBBE, P. A., 1985, Methane fluxfrom northern peatland. *Nature,* **315** (6021) : 652 - 654.

IPCC, 2014, Mitigation of climate change, introductory chapter: Synthesis report, summary for policymakers. In Climate Change 2014; Victor, D., Zhou, D., Ahmed, E.h.m., Dadhich, P.k., Olivier, J.g.j., Rogner, H.h., Sheikho, K., Yamaguchi, M., Grübler, A. And Muvunkika, A., Eds.; Cambridge University Press: Cambridge, UK.

JARVIS, A., UPADHAYA, H. D., GOWDA, C. L. L., AGGARWAL, P. K., FUJISAKA, S. AND ANDERSON, B., 2010, Climate change and its effect on conservation and use of plant genetic resources for food and agriculture and associated biodiversity for food security. Rome: Food and Agriculture Organization of the United Nations.

PRABHUDEVA, D. S. AND NAGARAJU., 2017, Influence of precision management practices on growth and yield of drip irrigated aerobic rice. *Mysore J. Agric. Sci.,* **51** (2) : 402 - 407.

SMITH, P., MARTINO, D., CAI, Z., GWARY, D., JANZEN, H., KUMAR, P., MCCARL, B.,OGLE, S. O., MARA, F., RICE, C., SCHOLES, B. AND SIROTENKO, O., 2007, Agriculture. In: Metz, B., Davidson, O. R., Bosch, P. R., Dave, R.,Meyer, L. A., (eds.) Climate Change 2007: Mitigation. Contributionof Working Group III to the Fourth Assessment Report of theIntergovernmental Panel on Climate Change. Cambridge UniversityPress, Cambridge, Pp : 497 - 540.

SYLVESTRE, H., KALYANA MURTHY, K. N. AND HANUMANTHAPPA, D. C., 2018, Effect of different weed management practices on growth and yield of aerobic rice (*Oryza sativa* L.). *Mysore J. Agric. Sci.,* **52** (2) : 263 - 270.

TRIPATHI, S., NAGBHUSHAN, S. AND SHAHIDI, T., 2018, Zero budget natural farming for the sustainable development goals, Andhra Pradesh, India. *Council on Energy, Environment and Water,* Pp : 1 - 17.

WATANABE, T., KIMURA, M. AND ASAKAWA, S., 2010, Diversity of methanogenicarchael communities in Japanese paddy field ecosystem, estimatedby denaturing gradient gel electrophoresis. *Biol.Fertil. Soils,* **4 6** (4) : 343 - 354.

XIE, J. F. AND LI, Y. E., 2002, A review of studies on mechanism of greenhouse gas (GHG) emission and its affecting factors in arable soils. *Chin Agric. Meteorol.,* **23** : 47 - 52

XIONG, Z. Q., GUANG-XI, X. AND ZHAO-LIANG, Z. H. U., 2007, Nitrous oxide and methane emission as affected by water soil and nitrogen. *Pedosphere,* **17** (2) : 146 - 155.

YAN, X. Y., SHI, S. L., DU, L. J. AND XING, G., 2000, Pathways of N_2O emission from rice paddy soil. *Soil Biol.Biochem.,* **32** (3) : 437 - 440.

(*Received :* August 2021 *Accepted :* September 2021)