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The effect of organic and inorganic amendments on methane emission in a riverine alluvial soil

(Kesan penambahan baja organik dan tak organik terhadap pengeluaran metana di tanah lanar sungai)

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Key words: methane emission, amendments, alluvial soil

Abstrak

Penentuan pembebasan metana di bendang tabur terus yang diberi bahan organik dan tak organik telah dijalankan. Kaedah 'kebok tertutup' digunakan dalam pengukuran pembebasan metana pada setiap peringkat pertumbuhan bagi pelbagai amalan pengurusan. Kepekatan metana ditentukan dengan menggunakan gas kromatograf. Peningkatan kepekatan metana udara di dalam kebok diukur pada dua jarak waktu bagi mengira kadar metana yang dibebaskan.

Pengurangan keupayaan pengoksidaan dan penurunan adalah cepat dengan penggaulan bahan organik. Selepas 6 hari penggaulan, petak tersebut mempunyai keupayaan pengoksidaan dan penurunan yang berjulat antara –132 mV dan –165 mV. Petak tanpa tambahan bahan organik mempunyai keupayaan pengoksidaan dan penurunan yang bernilai –104 mV. Keupayaan pengoksidaan dan penurunan berubah-ubah mengikut pertumbuhan pokok padi. Pemberian baja merendahkan keupayaan pengoksidaan dan penurunan.

Hanya sedikit perbezaan nilai pH antara perlakuan dan perbezaan dalam sesuatu perlakuan semasa pertumbuhan padi adalah dalam lingkungan 0.5 unit. Penurunan nilai pH selepas pemberian bahan organik lebih cepat bagi petak sesbania dan/atau *Bioferti*. Antara perlakuan yang dinilai, penggaulan jerami menyebabkan perubahan nilai pH yang paling kecil.

Pengeluaran metana berbeza antara perlakuan dan peringkat pertumbuhan padi. Umumnya, POMES mengakibatkan pengeluaran metana yang banyak. Sebaliknya petak yang diberi *Complehumus* dan *Bioferti* kurang mengeluarkan metana. Kemuncak pengeluaran metana berlaku pada peringkat pembentukan tangkai atau peringkat pembahagian penurunan. Petak yang diberi POMES mengeluarkan metana pada kadar 195 mg/m^2 sejam pada peringkat pembentukan tangkai iaitu lima kali lebih banyak daripada yang dikeluarkan oleh petak *Complehumus*. Kemuncak pengeluaran metana dari petak jerami dan jerami + POMES berlaku pada peringkat pembahagian penurunan dengan kadar 924 dan 895 mg/m^2 sejam. Sebaliknya, petak NPK atau *Bioferti* + NPK hanya mengeluarkan metana sebanyak 58 mg/m^2 sejam. Pengeluaran metana berkurangan dengan cepat selepas peringkat pembungaan dan pada peringkat penuaian, metana tidak dapat dikesan.

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Abstract
A field determination of methane emission from direct-seeded rice plots treated with amendments of organic and inorganic sources was conducted. The 'closed chamber' method was used in the measurement of methane flux at several phenological growth stages for the various management practices. Gas chromatography was used to determine methane concentration. The increase in methane concentration of the air within the chamber measured over two time intervals was used to calculate the methane fluxes.

The decline in oxidation-reduction potential was rapid with organic matter incorporation. After 6 days of incorporation, plots with organic matter additions had an oxidation-reduction potential in the range of –132 mV to –165 mV. Plots without organic matter additions had an oxidation-reduction potential of –104mV. Oxidation-reduction potential fluctuated with the growth of the rice crop. Fertilizer application caused a decline in oxidation-reduction potential.

There were only slight differences in pH between treatments and variations in pH within a treatment during the crop growth period were within 0.5 unit. The decrease in pH following application of organic matter was more sudden for plots with sesbania and/or *Bioferti*. Among the treatments evaluated, straw incorporation caused the least fluctuation.

Methane emission varied with treatments and with crop growth stages. POMES generally caused a large methane emission. In contrast, methane emission from plots treated with *Complehumus* and *Bioferti* was relatively smaller. Peak emissions of methane occurred either at the panicle initiation stage or at the reduction division stage of rice growth. Plots with POMES had an emission flux of 195 mg/m^2 per hour at the panicle initiation stage, five times the amount emitted from *Complehumus* plots. Peak emission of methane from straw and POMES + straw treated plots occurred at the reduction division stage with an emission flux of 924 and 898 mg/m^2 per hour, respectively. In contrast, NPK treated plots or *Bioferti* + NPK had an emission of 58 mg/m^2 per hour. Methane emission declined substantially subsequent to flowering stage and methane emission was not detected at the time of harvest.

Introduction

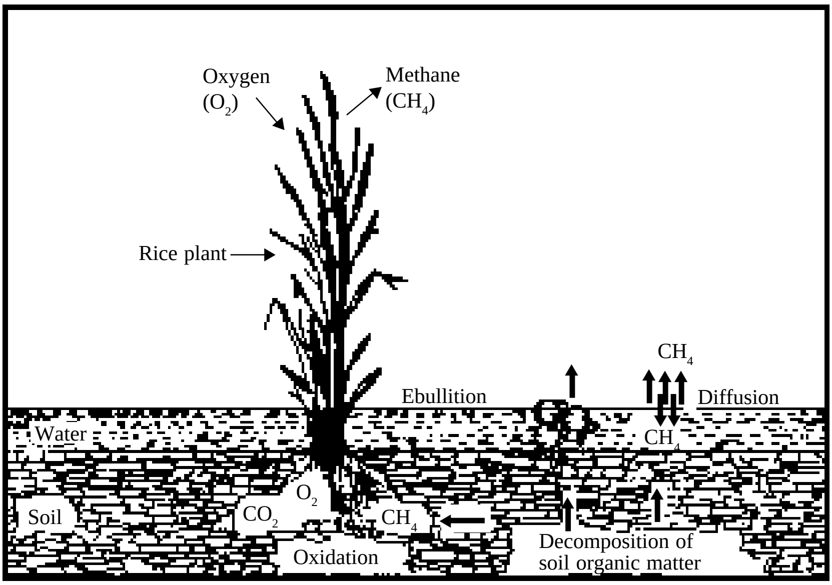
The increased awareness in global climate change leads to the identification of methane as one of the most important 'greenhouse' gases. The other 'greenhouse' gases are CO_2, N_2O, NO, possibly NO_2 and chlorofluorocarbons. The 'greenhouse' gases have strong infrared absorption bands and trap part of the thermal radiation from the earth's surface causing a possible elevation of the global surface temperature (Wong et al. 1976; Ramanathan et al. 1985; Dickinson and Cicerone 1986). The atmospheric concentration of methane is reportedly increasing by about 1% per year and a single methane molecule traps heat about 30 times more effectively than carbon dioxide molecule (Fraser et al. 1981; Blake and Rowland 1988; Papen and Renenberg 1990). Although the rate of increase of atmospheric methane has slowed down in the last decade (Steele et al. 1992; Khalil and Rasmussen 1993), it is postulated that with the current rate of increase in atmospheric methane concentration which is faster than the increase in carbon dioxide concentration, methane will become even more important as a 'greenhouse' gas than carbon dioxide. Such concerns still require research to construct an accurate budget relating sources and sinks of methane to atmospheric concentrations. Papen and Renenberg (1990) reported that significant methane production and emission into the atmosphere occurred only in ecosystems where anaerobic soil conditions prevail and methane emissions were exclusively caused by the activities of the strictly anaerobic methanogenic bacteria.

Flooded rice fields which account for 90% of the total rice production, are the source for 25% of the 500 million t of methane that reaches the atmosphere each year (Anon. 1991). The process of anaerobic decomposition of soil organic matter provides the required substrate for biogenic methane production. The methane gas reaches the atmosphere in three ways: via the rice plant, by the process of ebullition, and by diffusion *(Figure 1)*. Several studies have confirmed that rice plant is the major passage way of methane gas from soil to the atmosphere (Cicerone and Shetter 1981; Seiler et al. 1984; Inubushi et al. 1990; Anon. 1991).

An integrated nutrient management using organic and inorganic nutrient sources is required to enhance productivity and to ensure sustainable soil productivity. In the Kemubu irrigation scheme, about 60% of the yield is dependent on the fertility status of the soils and therefore the low organic matter status amongst other factors have to be increased to achieve higher productivity. The current philosophy of rice productivity improvement through an integrated approach using inorganic fertilizers with organic amendments is known to have strong influence in methane emission. It was therefore necessary to evaluate and quantify methane emission in a riverine soil under various management practices.

Materials and methods

Five commonly available organic amendments were evaluated to assess their potentials for use as an amendment to improve soil productivity. Measurements of methane emissions were made at various growth stages for the five organic materials evaluated. The organic materials evaluated were sesbania (a green manure), palm oil mill effluent sludge (POMES), *Bioferti* (a commercially available organic material fortified with microorganisms), *Complehumus* (a commercially available organic-based fertilizer) and rice straw. A control plot receiving only nitrogen, phosphorus and potassium was included



Source: Anon. (1991)

Figure 1. Process of methane emission in paddy field

(Table 1). The sesbania seeds were sown under saturated conditions and a water level of 5–10 cm was maintained during the growing period up to 55 days. The sesbania plants were then slashed with a bushcutter and incorporated into the soil. Samples were taken to determine the approximate amount of biomass incorporated. Treatments with other organic amendments (POMES and rice straw) were also incorporated on the same day. *Bioferti* and *Complehumus* were evaluated following the recommended rates for the respective product.

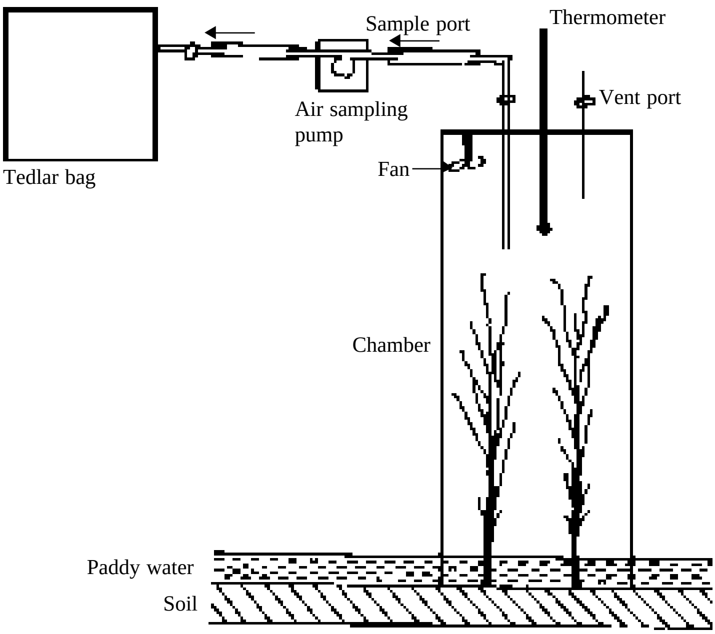
The trial was conducted at Perol (Chempaka series) during the second season (wet season 1992), in a randomized complete block design with four replications. Method of crop establishment was direct seeding. Methane emissions, soil pH and oxidation-reduction potential were determined in all the treatment plots of the first replicate. Soil pH and oxidation-reduction potential were determined in the field at weekly intervals commencing from incorporation of the organic matter. Methane emission was determined at seven stages: (i) before ploughing in of the organic amendments, (ii) 3 days after organic amendment application, (iii) 6 days after organic amendment incorporation before sowing of pregerminated seed, (iv) active tillering stage around 30 days after seed broadcast, (v) just before fertilizer application at the panicle initiation stage, (vi) the reduction division stage, 2 weeks after panicle initiation, and (vii) at harvest.

The closed chamber method as proposed by Minami and Yagi (1988) was used for the measurement of methane flux from the soil to the atmosphere *(Figure 2)*. The chambers were constructed from polycarbon material with internal measurements of 40 cm x 40 cm x 90 cm. Each chamber was fitted with a small fan to mix the air and a pump to enable sampling of the air within the chamber. Soon after seedling establishment, areas within each treatment plot were identified corresponding to the length and breadth of the chamber and a wooden support was placed at the soil surface. At the time of measuring methane emission, the chamber was carefully lowered

Table 1. Organic fertilizer treatments

No.	Treatment
1 NPK	NPK fertilizer at 100:40:30. P and K were applied 15 DAS. N was applied in three split doses at 15, 40 and 55 DAS in the ratio of 1/4:1/4:1/2
2 Sesbania	Seed rate 125 g/plot (50 kg/ha). Sesbania plants were ploughed in at 45 days old.
3 Sesbania + N	As in treatment 2. At 55 DAS, N was applied in similar amount as in treatment 1 for that stage.
4 Sesbania + POMES	As in treatment 2. POMES was incorporated into the soil at 6 000 kg/ha.
5 POMES + N	POMES was incorporated into the soil at 6 000 kg/ha. N was applied at 55 DAS as in treatment 1 for that stage.
6 *Complehumus* (8:8:8 + 3MgO)	At 15 and 40 DAS, 2.8 kg/plot (1 120 kg/ha). At 55 DAS, 5.6 kg/plot (2 240 kg/ha).
7 Sesbania + *Bioferti* + N	As in treatment 2. *Bioferti* was applied at 1 125 g/plot (450 kg/ha) on the day of sesbania incorporation. N was applied at 55 DAS as in treatment 1 for that stage.
8 *Bioferti* + NPK	*Bioferti* was applied at time of sowing seeds. NPK as in treatment 1.
9 Straw + NPK	Straw was incorporated into the soil at 6 000 kg/ha, 6 days before sowing of seed. NPK as in treatment 1.

*DAS = days after sowing (pregerminated rice seeds were wet broadcast on 9 August 1992)



Source: Minami and Yagi (1988)

Figure 2. Schematic representation of the chamber and the sampling system for the measurement of the CH_4 flux from paddy field

into the water and placed onto the wooden support at the soil surface without disturbing the soil surface. The time of placing chamber was recorded and air samples were collected after 30 min and 60 min. The chamber temperature, air temperature and water depth were recorded at each time period. The air samples were collected in tedlar bags of volume 1 200 cm^3. Methane concentrations in the tedlar bags were determined using gas chromatograph equipped with a gas sampler and flame ionization detector (FID). Before determining the methane concentrations in the samples, various volumes of standard gas with known methane concentrations were injected and the response by FID was used to obtain a linear regression equation. The linear regression equation was used to translate FID response of sample gas for calculation of methane concentration in the samples. The concentration differences between the two time intervals of 60 min and 30 min were used to calculate the methane flux.

Results and discussion

Oxidation-reduction potential

From the date of sowing of sesbania seeds till the incorporation of the amendments, the sesbania and fallow plots were kept under reduced conditions. The oxidation-reduction potential and pH of the sesbania plots were –68 mV and 6.11, respectively. The fallow plots had an oxidation-reduction potential of –101 mV and a pH of 6.75. The differences in oxidation-reduction potential and pH between fallow and sesbania plots were attributed to microbial activities. Nitrogen-fixing activities in the root nodules of sesbania plants lowered oxidation-reduction, while the root exudations reduced pH. However, on the day of incorporation, with the water drained off from the field, the oxidation-reduction potential in all the plots was about +220 mV. The field was inundated with water soon after the incorporation activities. Within 3 days of organic matter incorporation, the redox potential dropped to +9 mV in all the plots. On the sixth day of incorporation, there was a noticeable difference in the oxidation-reduction potential between the treatments but the pH was not markedly different between the treatment plots. The oxidation-reduction potential of the plot receiving only inorganic fertilizers was –104 mV. Plots receiving organic matter had an oxidation-reduction potential in the range of –132 mV to –165 mV. Plots with straw incorporation were the most reduced.

The oxidation-reduction potential fluctuated within the growing period of the rice crop. The degree of fluctuation varied between treatments *(Figure 3)*. Plots (sesbania, sesbania + N, sesbania + POMES, POMES + N, straw + NPK) which had organic matter additions 6 days before rice seed broadcast had markedly lower negative potentials than the control plot (NPK) on the day of rice seed broadcast *(Table 2)*. In general, highly negative potentials occurred after 30 days from sowing. This highly reductive state was maintained for the entire growing period for the *Complehumus* treatment.

Fertilizer applications caused a decline in oxidation-reduction potential. This was probably due to a more reduced environment created by the organic matter decomposition which was enhanced by fertilizer application. This phenomenon, exhibited by all treatment plots except in the sesbania + N and POMES + N treatments, was most clearly manifested in the *Complehumus* treatment, an organic-based fertilizer which was applied at growth stages of 15 DAS, 35 DAS and panicle initiation stages. As the sesbania + N and POMES + N treatments received the organic matter 6 days before rice seed broadcast and had no inorganic fertilizer additions at the vegetative stages, the rice plants were not vigorous in growth and exhibited nitrogen deficiency.

pH

There were only slight differences in pH between treatments and variations in pH within a treatment during the crop growth period were within 0.5 unit *(Figure 4)*. pH decreased initially during the first week of seedling establishment for all treatments except in the sesbania + *Bioferti* + N treatment. The decrease in pH following application of organic matter was more sudden for plots with sesbania and/or *Bioferti*. Among the treatments evaluated, straw incorporation showed the least fluctuation. pH decreased from 6.72 to 6.50 in the first week and this value was generally maintained for the remaining crop growth period. It is evident that the organic amendment was unlikely to cause a detrimental effect related to pH changes during the decomposition process *(Figure 4)*.

Methane emission

Methane emission from plots with sesbania plants before incorporation was 2.35 mg/m^2 per hour. Methane emission from the control plot at 3 days after incorporation of organic amendments was almost negligible, having a value of 0.55 mg/m^2 per hour. However, methane emission increased but in varying amounts with the incorporation of organic amendments *(Table 3)*. POMES caused a high emission of methane. Methane emission was largest in the sesbania + POMES or POMES treatment with an emission flux of 159 and 83 mg/m^2 per hour, respectively. Sesbania incorporated plots had an emission of 2–42 mg/m^2 per hour. Straw incorporation after 3 days caused a methane emission of 31 mg/m^2 per hour but increased markedly soon after and had the largest methane emission at 6 days after incorporation with a flux of 128 mg/m^2 per hour.

At the tillering stage, methane emission was small, at about 20 mg/m^2 per hour except with the application of sesbania + POMES where methane emission was about three times larger.

There was a sharp increase in methane emission at the panicle initiation stage for all treatments. At this stage, the emission was contrastingly different among treatments due to the differences in growth

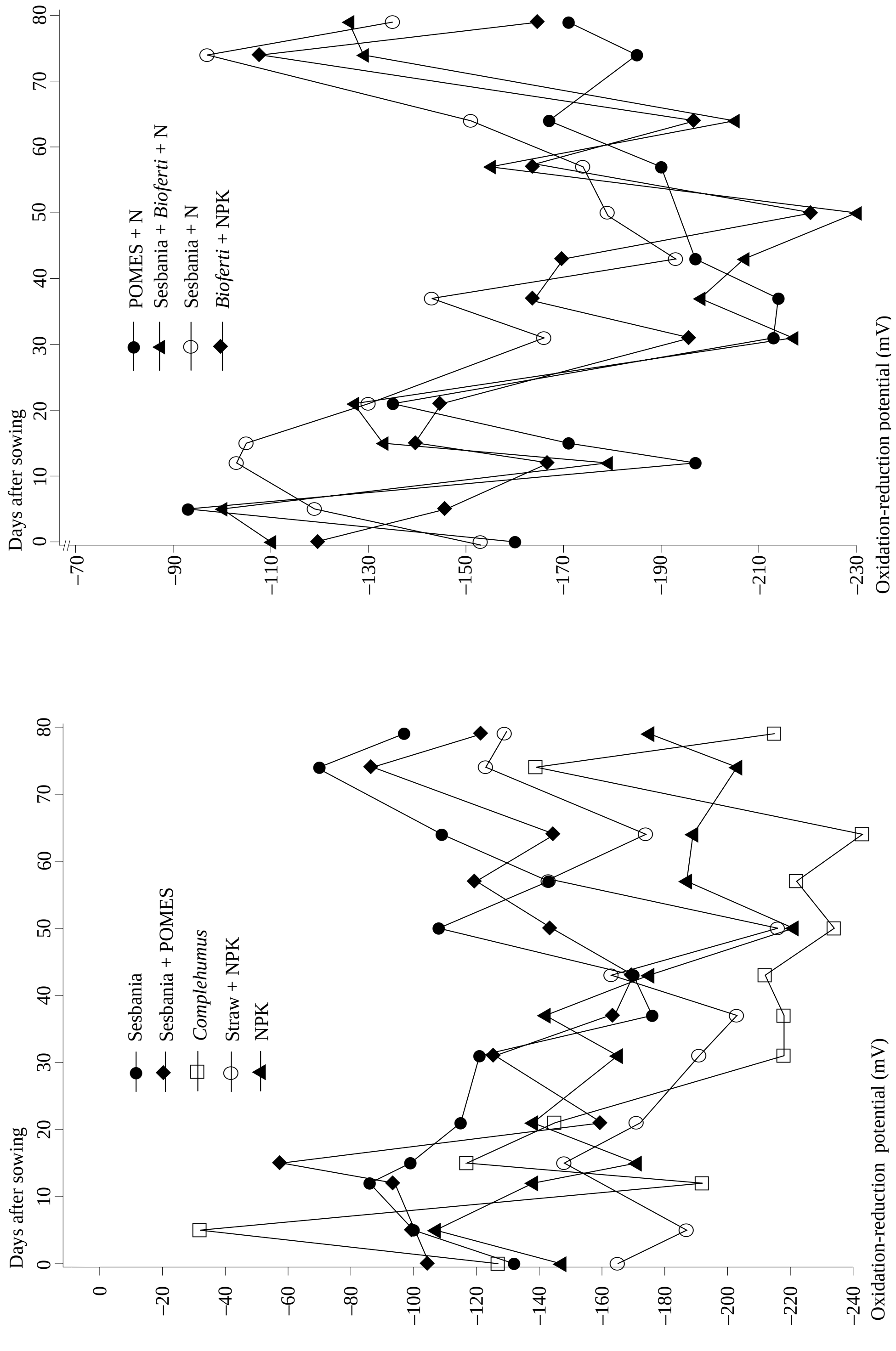


Figure 3. Changes in oxidation-reduction throughout the growing period with organic amendments

Table 2. Redox potential at four growth stages

Treatment	Redox potential (mV)			
	0 DAS	30 DAS	56 DAS	74 DAS
NPK	–104	–127	–119	–85
Sesbania	–132	–121	–145	–71
Sesbania + N	–152	–166	–174	–81
Sesbania + POMES	–148	–165	–187	–203
POMES + N	–158	–212	–189	–185
Complehumus	–126	–219	–221	–139
Sesbania + *Bioferti* + N	–108	–215	–153	–128
Bioferti + NPK	–119	–196	–164	–97
Straw + NPK	–165	–192	–144	–123

DAS = days after sowing

caused by the various amendments as well as the effect of fertilizer application before panicle initiation. It is interesting to note that *Complehumus* treatment and *Bioferti* treatment plots had markedly smaller amounts of methane emission. The POMES treatment plot reached a peak emission at the panicle initiation stage with an emission flux of 196 mg/m^2 per hour, five times the amount emitted from *Complehumus* plots which had the most impressive growth of rice crop at this stage.

The peak emission of methane from straw and POMES + sesbania plots occurred at the reduction division stage with an emission flux of 924 and 898 mg/m^2 per hour, respectively. In contrast, the NPK-treated plots or *Bioferti* + NPK had an emission of 59 mg/m^2 per hour. It is apparent that the difference in methane emission is accentuated by the fertilizer application at the panicle initiation resulting in crop growth differences. In the trial, 50% of the nitrogen fertilizer was applied at the panicle initiation stage. Nitrogen applied at the panicle initiation stage seemed to have a priming effect on the decomposition process of POMES + sesbania and straw resulting in large methane emissions.

At the flowering stage, whilst the plot with *Complehumus* maintained its peak emission, there was a marked decline in methane emission for the remaining treatments. The declining trend continued for all treatments as crop growth stage advanced and at harvest, with the fields already drained for a period of 10 days, methane emissions were undetectable for all the treatments.

Conclusion

Methane emission fluxes varied with organic amendments. Peak emissions occurred either at the panicle initiation stage or the reduction division stage with a range of 56.71–924.40 mg/m^2 per hour. The incorporation of straw or POMES had the highest peak methane emission in contrast to the organic amendments *Bioferti* and *Complehumus* which had the lowest peak methane emission. Subsequent to the reduction division stage, methane emission followed a declining trend and at harvest, methane emissions were undetectable.

There were wide variations in the reduction state of the rice root environment with crop growth and between treatments. The amendments of POMES, *Bioferti* and *Complehumus* had oxidation-reduction potential values smaller than –200 mV at about the panicle initiation stage. pH values were within 6.3–6.8 for all treatments throughout the crop growth period.

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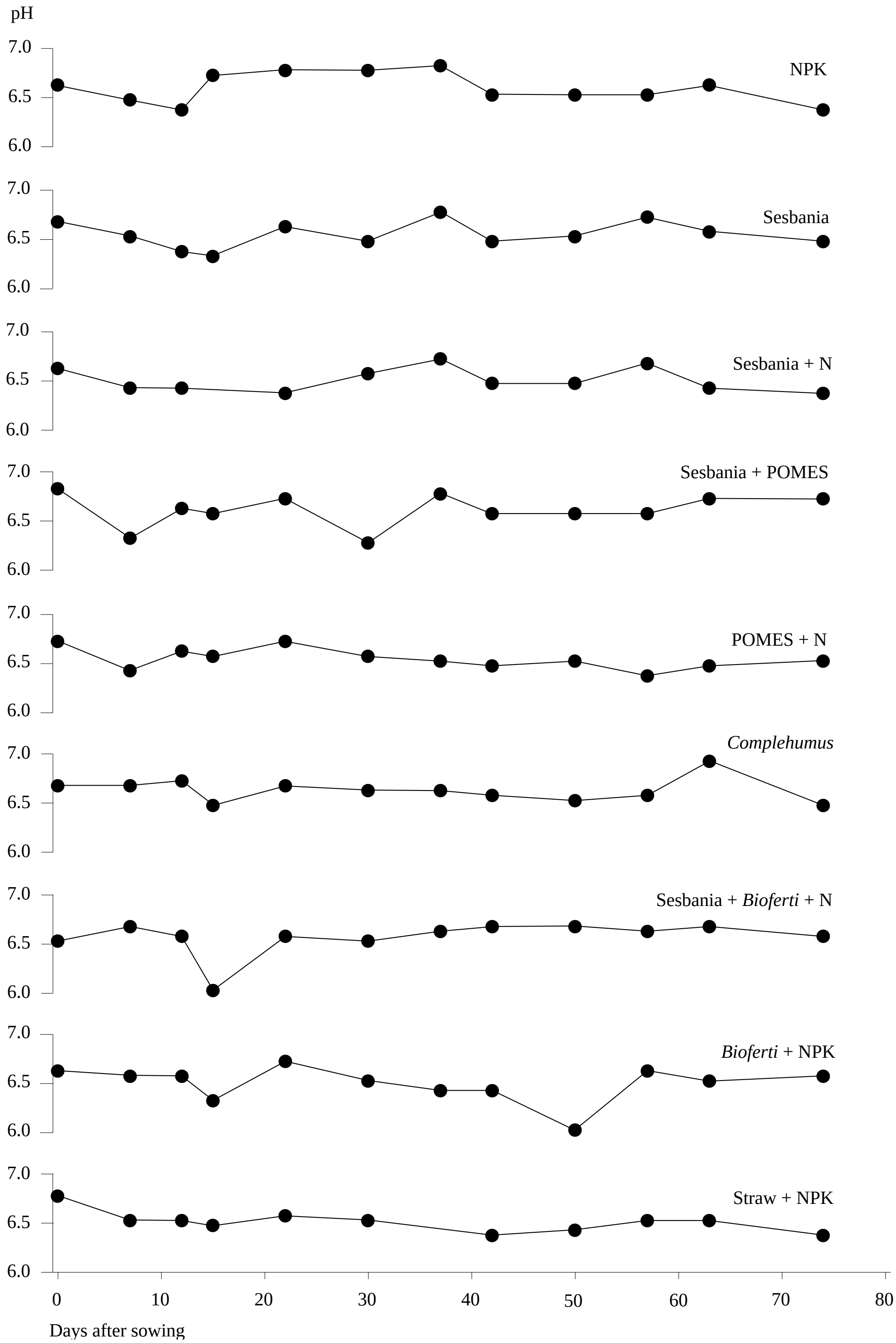

Figure 4. Changes in pH with organic amendments

Table 3. Methane emission at nine growth stages for direct-seeded rice

Treatment	Methane emission (mg/m^2 per hour)								
	–6 DAS	–3 DAS	0 DAS	30 DAS	56 DAS	74 DAS	88 DAS	103 DAS	At harvest
NPK	nd	0.55	10.49	10.51	164.80	58.56	50.67	32.18	ud
Sesbania	2.35	7.21	6.56	11.96	61.28	105.31	101.21	nd	ud
Sesbania + N	nd	41.87	55.31	13.51	113.29	130.40	28.19	9.31	ud
Sesbania + POMES	nd	158.61	15.46	61.02	83.94	924.40	1.04	7.94	ud
POMES + N	nd	82.72	72.64	23.91	195.61	68.82	14.59	31.24	ud
Complehumus	nd	39.91	14.59	23.00	36.81	81.94	81.19	30.17	ud
Sesbania + *Bioferti* + N	nd	2.14	4.95	4.30	48.99	58.67	8.80	32.91	ud
Bioferti + NPK	nd	nd	nd	9.81	28.13	56.71	3.78	nd	ud
Straw + NPK	nd	30.82	127.87	15.47	51.22	897.61	200.20	nd	ud

DAS = days after sowing
nd = not done
ud = undetectable

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