Timing of midseason aeration to reduce CH$_4$ and N$_2$O emissions from double rice cultivation in China

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China is the world’s largest producer of rice, with a gross sown area of 29.6 million hectares in 2009, of which double rice systems covered more than 50% (Ministry of Agriculture of the People’s Republic of China 2010).
**CH$_4$ and N$_2$O emissions**

- **Annual CH$_4$ emission** from Chinese rice fields was estimated to be 7.4 Tg, about 29% of the global CH$_4$ emission from rice cultivation (Yan *et al.* 2009).

- **Annual N$_2$O emission** from the rice fields in China was estimated to be 91 Gg N, of which 50 Gg N was emitted during the rice growing seasons (Zheng *et al.* 2004).

- **Mitigation options** for CH$_4$ and N$_2$O emissions from rice fields include altering water management, improving organic matter management, selecting proper rice cultivars, improving nitrogen fertilization, applying nitrification inhibitors, *etc* (Akiyama *et al.* 2005; Wassmann *et al.* 2004; Xing *et al.* 2009; Yagi *et al.* 1997; Yan *et al.* 2009).
Conventional management for rice cultivation

- Transplanting
- Basal fertilizer
- Tillering fertilizer
- Panicle initiation fertilizer
- Flooding
- MSA and reflooding
- Dry-wet cycling
- Harvest

Note: MSA: midseason aeration.
Midseason aeration (MSA)

- **MSA** is an effective way to reduce net GWP \((CH_4+N_2O)\) during the rice growing season.

  Field experiments: compared with continuous flooding, midseason aeration decreased \(CH_4\) emission by 29-65% and net 100-year GWP \((CH_4+N_2O)\) by 5-43%, while enhancing \(N_2O\) emission by a factor of 1.2-47.7 (Bronson *et al.* 1997; Qin *et al.* 2010; Towprayoon *et al.* 2005; Yuan *et al.* 2008; Yue *et al.* 2003; Zou *et al.* 2005).

- Altering timing of MSA would affect \(CH_4\) and \(N_2O\) emissions from rice cultivation.

  Single rice field experiments: shifting the drainage period to an early stage could mitigate \(CH_4\) emission by 46% (Wassmann *et al.* 2000) and 5% (Itoh *et al.* 2011), respectively; with wheat straw incorporated, normal aeration increased \(CH_4\) emission by 14-37% and net 100-year GWP \((CH_4+N_2O)\) by 8-26% but decreased \(N_2O\) emission by 16-52% in comparison of early aeration (Li *et al.* 2010, 2011).
Objectives

- To quantify net GWP (CH$_4$+N$_2$O) from double rice cultivation as affected by timing of MSA.

- To find out optimum water management in double rice fields for environmental benefits.
Yujiang Town, Yingtan City, Jiangxi Province in the southeast of China (28° 15′ N, 116° 55′ E).

Rotation of double rice and winter fallow.

Precipitation: 1789 mm (mainly from March to June); Averaged Temp.: 17.6 °C.

Paddy soil: pH (H$_2$O) 4.74, SOC 17.0 g kg$^{-1}$, total N 1.66 g kg$^{-1}$.
Experimental design

- Treatments: Continuous flooding; Early aeration; Normal aeration; Late aeration.
- Experimental plot: 20 m² (4 m × 5 m).
- Rice cultivars: Early rice -- Zhongzao 33; Late rice -- Nongxiang 98.
- Fertilization: Basal fertilizer -- 90 kg N ha⁻¹ urea + 45 kg K ha⁻¹ KCl + 75 kg P ha⁻¹ P₂O₅; Tillering fertilizers -- 54 kg N ha⁻¹ urea + 60 kg K ha⁻¹ KCl; Panicle initiation fertilizer -- 36 kg N ha⁻¹ urea + 45 kg K ha⁻¹ KCl.
**Sampling**

- CH$_4$ and N$_2$O fluxes were monitored using the static chamber technique.
- Soil temperature at 0.05 m depth was measured with a hand-carried digital thermometer.
- Depth of the water layer in the field was measured manually.
- Unhulled rice grain yields were determined from a 1 m$^2$ area in each replicate plot and adjusted to 14% moisture content.
Seedling nursery
Applying fertilizer
Transplanting
Harvest
Results and Discussion

- CH₄ emission peaks in the late half early rice season: Precipitation; Soil temperature.
- CH₄ emission peaks early in the late rice season: CH₄ production; CH₄ transport efficiency.

Fig. 1. Temporal variation of CH₄ flux, soil temperature (0.05 m in depth) and rainfall in paddy fields under double rice cultivation in Yingtan, Jiangxi, China.
Fig. 2. Seasonal CH$_4$ emission

%Reduction = (CH$_4$ emission of Continuous flooding – CH$_4$ emission of Early aeration/Normal aeration/Late aeration)/CH$_4$ emission of Continuous flooding
Results and Discussion

Many N$_2$O fluxes were triggered by the midseason drainage episode.

Fig. 3. Temporal variation of N$_2$O flux and water layer depth in paddy fields under double rice cultivation in Yingtan, Jiangxi, China
### Results and Discussion

#### Seasonal N$_2$O emission

<table>
<thead>
<tr>
<th>Year</th>
<th>Treatments</th>
<th>N$_2$O Emission (g N$_2$O-N ha$^{-1}$)</th>
<th>Relative to continuous flooding:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>Continuous flooding</td>
<td>13.3</td>
<td>13.3</td>
</tr>
<tr>
<td></td>
<td>Early aeration</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td></td>
<td>Normal aeration</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Late aeration</td>
<td>2.1</td>
<td>2.1</td>
</tr>
<tr>
<td></td>
<td>MSA and reflooding</td>
<td>1.3</td>
<td>1.3</td>
</tr>
</tbody>
</table>

#### Early rice

- Continuous flooding: 13.3
- Early aeration: 5.5
- Normal aeration: 3.1
- Late aeration: 2.1
- MSA and reflooding: 1.3

#### Late rice

- Continuous flooding: 2.6
- Early aeration: 2.4
- Normal aeration: 4.1
- Late aeration: 3.4

*Fig. 4. Seasonal N$_2$O emission*
Results and Discussion

Fig. 5. 100-year GWP (CH$_4$+N$_2$O)

%Reduction = (GWP of Continuous flooding – GWP of Early aeration/Normal aeration/Late aeration)/GWP of Continuous flooding
Results and Discussion

Fig. 6. Rice yield
## Results and Discussion

Table 1  A three-way ANOVA for the effects of water management, season and year on CH$_4$ and N$_2$O emissions, 100-year GWPs (CH$_4$+N$_2$O) and grain yields in rice paddies

<table>
<thead>
<tr>
<th>Factors</th>
<th>df</th>
<th>CH$_4$ emission</th>
<th>N$_2$O emission</th>
<th>100-year GWP (CH$_4$+N$_2$O)</th>
<th>Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(kg CH$_4$ ha$^{-1}$)</td>
<td>(g N$_2$O-N ha$^{-1}$)</td>
<td>(t CO$_2$-eq ha$^{-1}$)</td>
<td>(t ha$^{-1}$)</td>
</tr>
<tr>
<td></td>
<td>SS</td>
<td>F</td>
<td>p</td>
<td>SS</td>
<td>F</td>
</tr>
<tr>
<td>WM</td>
<td>3</td>
<td>86477</td>
<td>51.816</td>
<td>0.001</td>
<td>55576</td>
</tr>
<tr>
<td>Season</td>
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<td>0.031</td>
<td>0.861</td>
<td>19372</td>
</tr>
<tr>
<td>Year</td>
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<td>9474</td>
<td>17.03</td>
<td>&lt;0.001</td>
<td>12731</td>
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<tr>
<td>Model</td>
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<td>101895</td>
<td>36.632</td>
<td>&lt;0.001</td>
<td>91177</td>
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<tr>
<td>Error</td>
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<td>20027</td>
<td>101552</td>
<td>12</td>
<td>5.39</td>
</tr>
</tbody>
</table>

Note: WM: water management.

100-year GWP (CH$_4$+N$_2$O) = 25 × CH$_4$ + 298 × N$_2$O.
Conclusions

- Early rice season: Normal aeration.
- Late rice season: Early aeration.
Thanks!

Welcome your comments and suggestions!