Climate Change Adaptation in the Agricultural Sector: Strategies for Rice Cultivation in Asian Context

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29 January 2019
Nutritional importance of rice

- Important staple food crop to meet the demand for food

- Main source of carbohydrates with a lower percentage of proteins, lipids, and fibers
  - also contains vitamins (B1, B2, and B6) along with some natural antioxidants and minerals

- Rice was the staple food crop of 3.23 billion people in the year 2004
  - followed by wheat (1.55 billion people) and maize (288 million people)
Food security and role of rice in Asia

- > 90% of rice is produced and consumed in Asia

- > 3 times increase in production during the last 4 decades

- Per capita consumption increased from 85 (1960) to 100 kg (2010)

- Based on UN 2010 projections, population of Asia will reach to ~ 5 billion by 2035 and 5.15 billion by 2050

- To fulfill the growing global needs for rice, an increase of 1.2–1.5% per year is required to be maintained by 2020 and 1.0–1.2% per year beyond 2020
Major problems in rice production

- Rapidly increasing population and trends towards urbanization
- Competition for land and water resources
- Constantly declining soil fertility and excessive use of agrochemicals
- Existing technologies are no longer sufficient
  - to meet the constantly increasing global food demand due to shrinkage of natural resources
Water issues in rice production

- World food security is dependent on irrigated lowland rice
  - largest consumer of freshwater in the agricultural sector
  - 2500-3400 liters of water are needed to produce 1 kg of rice

- ~75% of global and 80% of Asian existing water resources are devoted to its production

(Source: IRRI)
Water issues in rice production

- Global freshwater resources
  - rapidly declining due to CC and heavy extraction

- Serious threat to agricultural productivity, especially in Irrigated rice
  - with long-term consequences for regional and global food security

- By 2025
  - 2 mha of Asia’s irrigated dry-season rice and 13 mha of its irrigated wet-season rice may experience “physical water scarcity”
Opportunities

- More rice needs to be produced with less water
  - need alternative ways to increase water productivity in irrigated rice production system

- In Asia, WUE of rice is very low

- Yield gap in this area is very high
  - this gap could be narrowed through efficient use of resources and increasing WUE of rice
Opportunities

- Popular water-saving techniques
  - alternate wetting and drying (AWD)
  - aerobic rice system
  - direct seeding method of cultivation
    - dry direct seeding
    - wet direct seeding
  - system of rice intensification (SRI)
Agricultural water management to cope with CC

Direct Seeding Method of Cultivation

Direct seeding of rice

— a process of rice crop establishment from seeds directly sown in the field rather than by transplanting seedlings raised from the nurseries. Three methods:

1) **Dry seeding** – dry seeds are directly sown into dry soil

2) **Wet seeding** – sowing pre-germinated seeds on soil that is wet and puddled

3) **Water seeding** – sowing seeds in standing water
Transplanting (Source: IRRI)
Dry direct seeding (Source: IRRI)
Wet direct seeding (Source: IRRI)
Water seeding (Source: IRRI)
Agricultural Water Management to Cope with CC

Alternate wetting and drying (AWD)

- Widely promoted water-saving technique introduced by the International Rice Research Institute (IRRI)

- Irrigation water of ~ 2–5 cm is applied after an interval of between 2 and 7 days
  - depending on soil type and environmental conditions
  - followed by disappearance of ponded water from the soil surface

- Can reduce water demand by ~ 40 % with no adverse impact on yield
Field water tube made up of PVC. Note the holes on all sides (Source: IRRI)

Irrigation should be applied to re-flood the field to a depth of ~ 5 cm

— when the water level has dropped to ~15 cm below the surface of the soil
Experimental Findings
Polyhouse Experiment
Growth, yield and water productivity of selected lowland Thai rice varieties under different cultivation methods and alternate wetting and drying irrigation

A pot experiment was conducted to evaluate the performance of selected lowland Thai rice varieties grown under different cultivation methods subjected to AWD irrigation

Treatments:
- 3 varieties (Pathumthani 1, RD57, and RD41)
- 3 cultivation methods (DDS, WDS, and TP)
- 4 AWD irrigation levels (re-watered when soil water potential reached at 0, −5, −15, and −30 kPa)
Results

[Image of potted plants in a greenhouse]
Grain yield

- DDS resulted in higher grain yield at −5 and −15 kPa (74 and 68 g/pot, respectively)
  - respective reduction of 15 and 34% under WDS and TP at −5 kPa, and 15% and 28% at −15 kPa

- Grain yield was the highest (74 g/pot) at −5 kPa under DDS
  - reduced by 26% at 0 kPa (55 g/pot) and 19% at −30 kPa (60 g/pot)

- Grain yield between −15 and −30 kPa was similar under the same cultivation method
Water productivity (kg m$^{-3}$)

- 0 kPa
- -5 kPa
- -15 kPa
- -30 kPa

Symbols:
- DDS
- WDS
- TP

Legend:
- f
- bc
- de
- e
- a
- b
- bc
Water productivity

- The highest water productivity was recorded at −30 kPa under DDS
  - reduced by 17–61% for other soil water potentials irrespective of varieties
  - grain yield was also reduced by 12–19% at −30 kPa

- At −15 and −30 kPa
  - DDS had higher water productivity (1.04 and 1.26 kg/m³, respectively) than WDS (0.88 and 1.08 kg/m³, respectively) and TP (0.75 and 0.96 kg/m³, respectively)
Conclusions

- All the tested three varieties showed similar response to water-saving management practice of direct seeding (dry) cultivation method and AWD irrigation
  
  - they are equally suitable for growing under these water-efficient techniques

- Among four soil water potentials
  
  - most of the yield contributing characters and grain yield were higher at −5 kPa, whereas water productivity was higher at −30 kPa
Conclusions

- Defining the threshold level for AWD should be based on soil texture and soil type
  - $-15$ kPa could be a threshold level as there was a combination of higher grain yield and water productivity

- DDS had better performance for grain yield and water productivity
  - could be recommended as a potential cultivation method for these lowland Thai rice varieties
Field Experiment
Yield and water productivity of tropical lowland rice as affected by establishment method and water management

Ullah, Giri, Attia, Datta. 2018. Agricultural Water Management (Under Review)

Treatments:

- 2 Thai rice cultivars (Pathumthani 1 and RD57)
- 2 establishment methods (DDS and TP)
- 3 irrigation levels (continuous flooding [CF], 15 cm threshold water level below the soil surface for irrigation [AWD15], and 30 cm threshold water level below the soil surface for irrigation [AWD30])
Results
<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Establishment method</th>
<th>Grain yield (kg ha(^{-1}))</th>
<th>Water productivity (kg m(^{-3}))</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>CF</td>
<td>AWD15</td>
</tr>
<tr>
<td>Pathumthani 1</td>
<td>DDS</td>
<td>3240 ± 638b A</td>
<td>3750 ± 120b A</td>
</tr>
<tr>
<td></td>
<td>TP</td>
<td>4830 ± 423a AB</td>
<td>6240 ± 330a A</td>
</tr>
<tr>
<td>RD57</td>
<td>DDS</td>
<td>4710 ± 482a A</td>
<td>5610 ± 840a A</td>
</tr>
<tr>
<td></td>
<td>TP</td>
<td>4830 ± 760a A</td>
<td>5520 ± 876a A</td>
</tr>
</tbody>
</table>
Grain yield and water productivity

- The highest grain yield and water productivity of Pathumthani 1 was observed at AWD15 under TP.

- The highest grain yield and water productivity of RD57 was observed under both establishment methods at AWD15 irrigation.

- AWD15 saved 26% and 32% irrigation water under TP and DDS, respectively, compared with TP-CF treatment combination.
Conclusions

• RD57 had higher grain yield and water productivity than Pathumthani 1 for most of the treatments combinations, especially under DDS

• AWD15 could be safely recommended in maintaining yield stability and improving water productivity for both of the tested cultivars along with either establishment method for RD57 and TP for Pathumthani 1

• These results were confirmed by an average irrigation water saving of 26–32% pooled over years by AWD15 compared with TP-CF combination
Recommendations

- Adoption of water-efficient cultivation systems based on direct seeding method of cultivation (either dry or wet) and AWD should be encouraged among the farmers
  - to save water and labor input and increase the profit margin of the farmers

- Dose and timings of N application should also be focused in future studies along with different combinations of organic manure under AWD and DS
  - to find more farmer friendly options
References


