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

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## 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 recourses

- 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)*

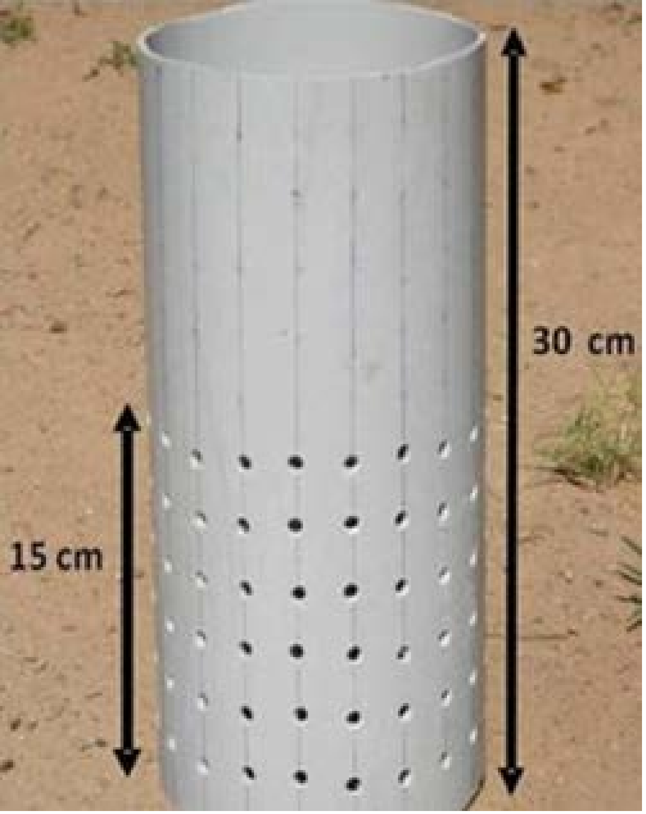
- Widely promoted water-saving technique introduced by the International Rice Research Institute (IRRI)

- 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




A field water tube in flooded field

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

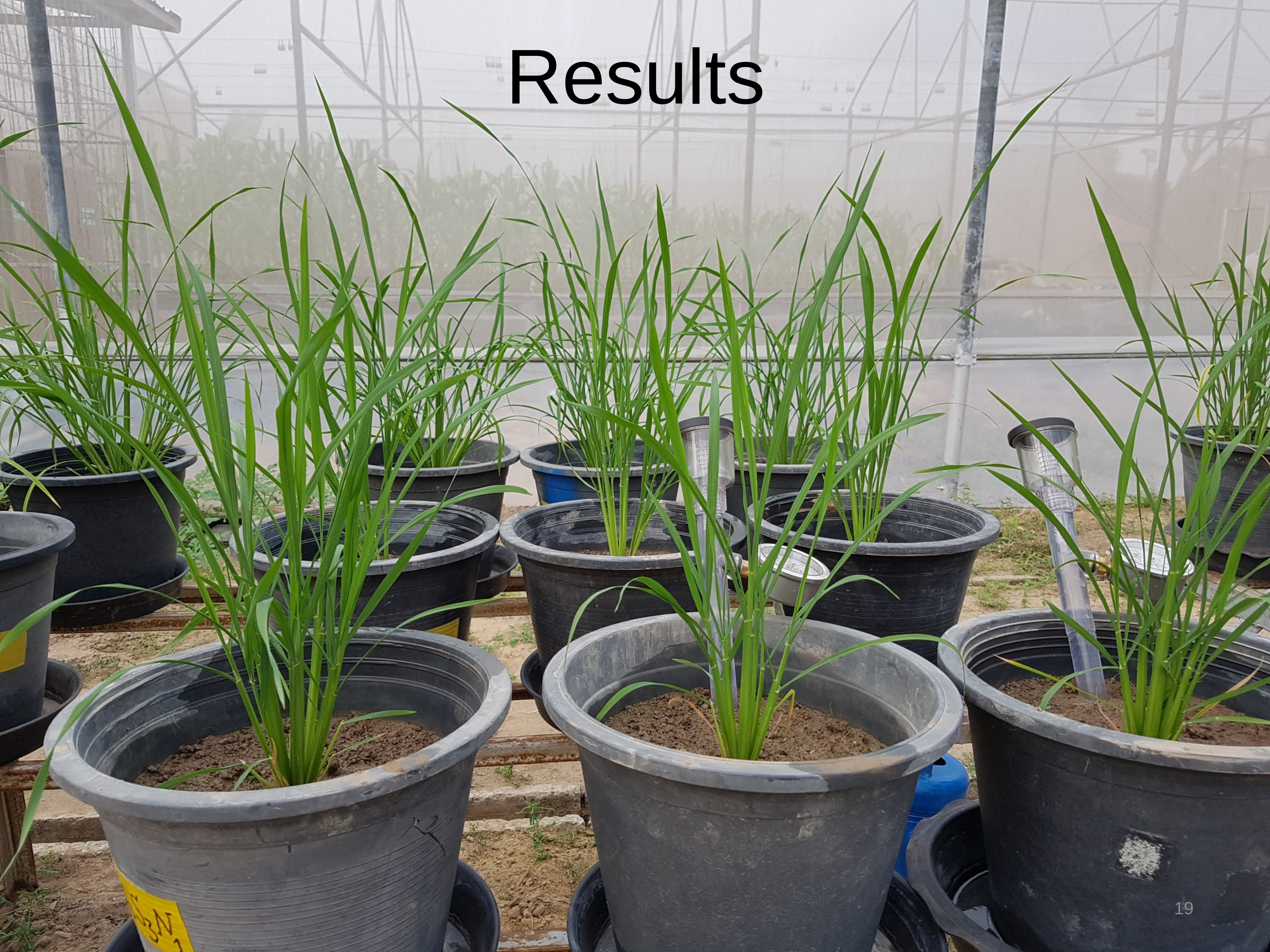
Ullah, Mohammadi, Datta. 2018. Ann. Appl. Biol. 173, 302–312

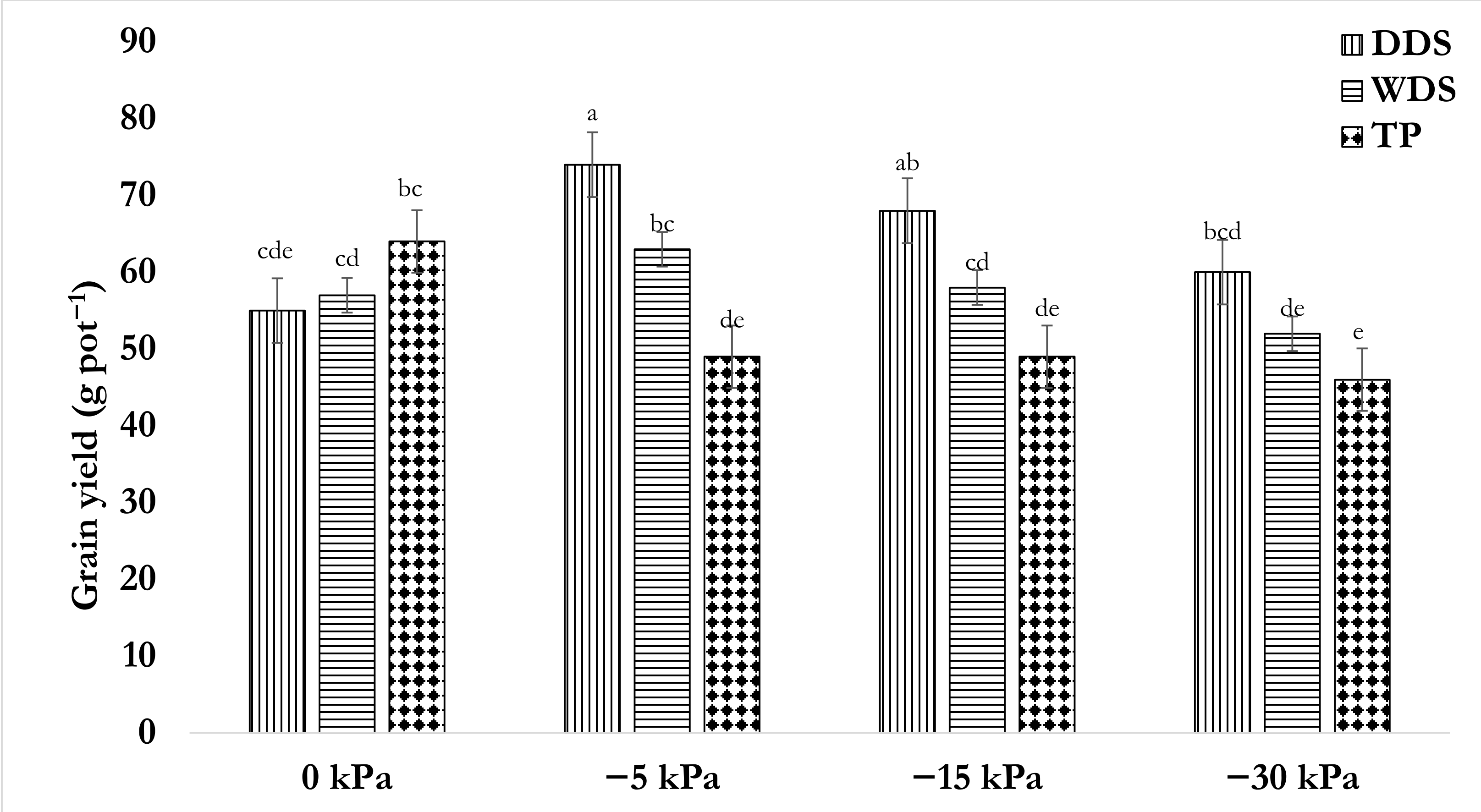
- A pot experiment was conducted to evaluate the performance of selected lowland Thai rice varieties grown under different cultivation methods subjected to AWD irrigation

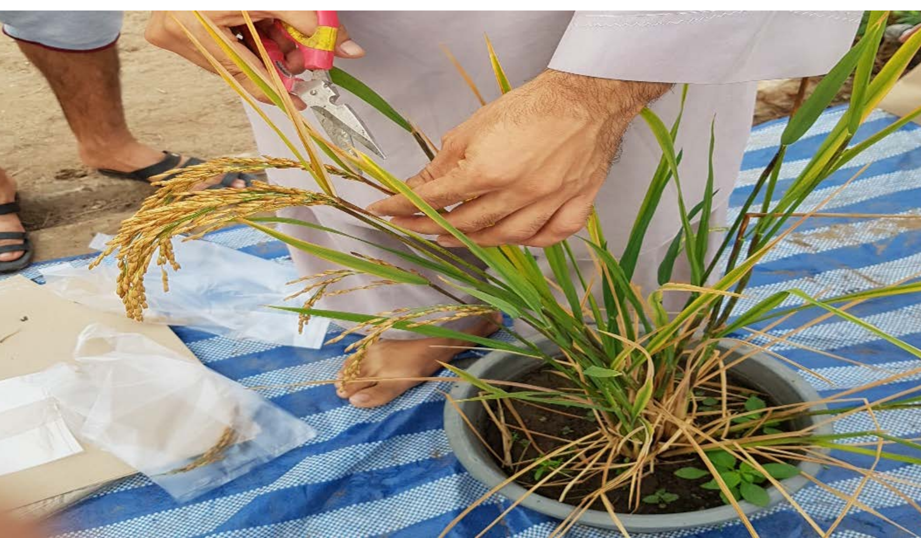
Treatments:

- ❑ 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

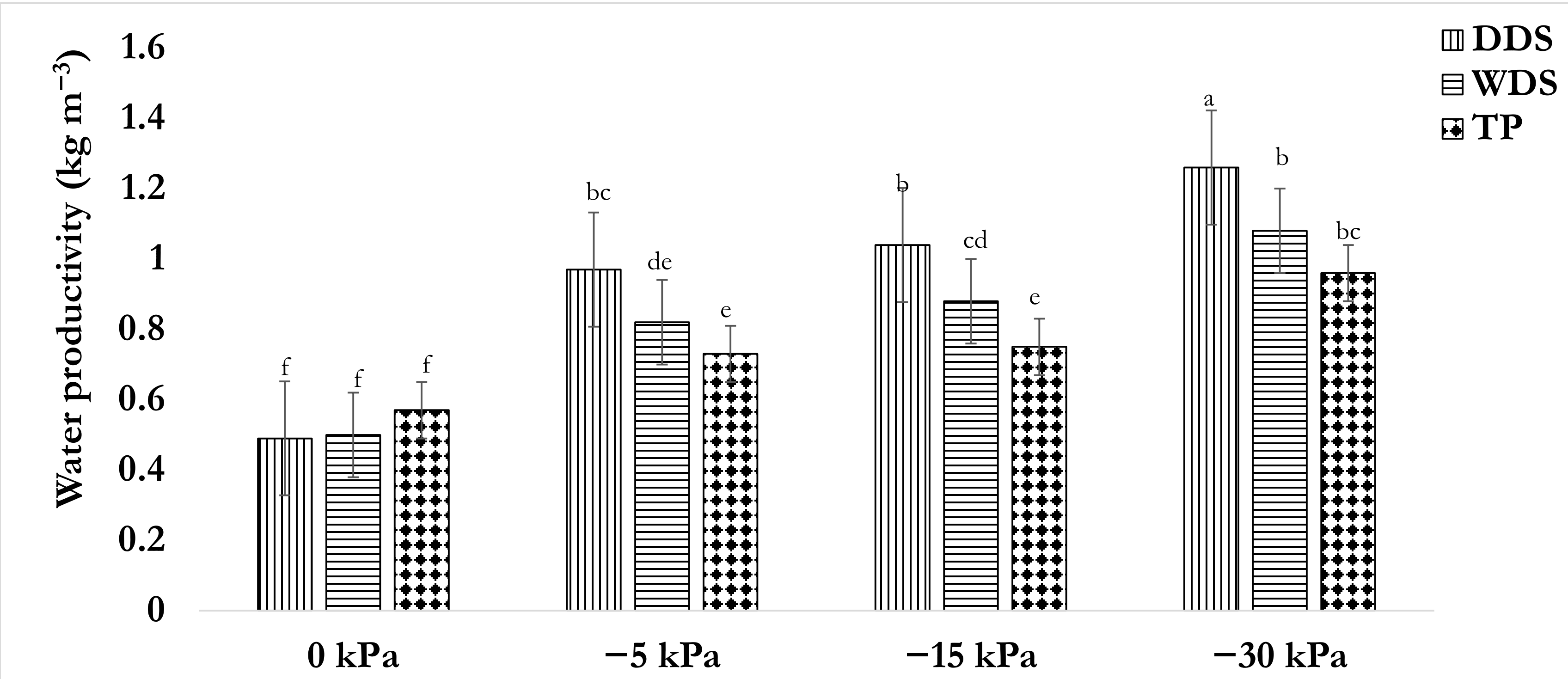



Grain yield (g pot⁻¹)
90
80
70
60
50
40
30
20
10
0
DDS
WDS
TP
cde
cd
bc
a
bc
de
ab
cd
de
bcd
de
e
0 kPa
−5 kPa
−15 kPa
−30 kPa



## 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)
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
DDS
WDS
TP
f
f
f
bc
de
e
b
cd
e
a
b
bc
0 kPa
−5 kPa
−15 kPa
−30 kPa

## 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 $kg/m^3$, respectively) than WDS (0.88 and 1.08 $kg/m^3$, respectively) and TP (0.75 and 0.96 $kg/m^3$, 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

| Cultivar | Establishment method | Grain yield ($kg\ ha^{-1}$) | | | Water productivity ($kg\ m^{-3}$) | | |
|---|---|---|---|---|---|---|---|
| | | CF | AWD15 | AWD30 | CF | AWD15 | AWD30 |
| **Pathumthani 1** | DDS | 3240 ± 638b A | 3750 ± 120b A | 2850 ± 634a A | 0.62 ± 0.01c B | 0.83 ± 0.05c A | 0.65 ± 0.04b B |
| | TP | 4830 ± 423a AB | **6240 ± 330a A** | 3330 ± 638a B | 0.89 ± 0.03b B | **1.32 ± 0.03b A** | 0.72 ± 0.03ab C |
| **RD57** | DDS | 4710 ± 482a A | **5610 ± 840a A** | 2820 ± 624a B | 1.11 ± 0.03a B | **1.58 ± 0.08a A** | 0.82 ± 0.07a C |
| | TP | 4830 ± 760a A | **5520 ± 876a A** | 2910 ± 79a B | 1.09 ± 0.01a B | **1.47 ± 0.07a A** | 0.80 ± 0.05a C |

## 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

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THANK YOU
QUESTIONS