Do Alternate Wetting and Drying Irrigation Technology and Nitrogen Rates Affect Rice Sheath Blight?

Water and nitrogen management play vital roles in rice production. However, the mismanagement of these two management practices may trigger sheath blight of rice, caused by *Rhizoctonia solani*, which is favored by wet conditions, high relative humidity, and high nitrogen fertilizer levels. To understand how different combinations of water and nitrogen management affect sheath blight epidemics, we conducted two separate split-plot experiments with a water saving (alternate wetting and drying) regime and traditional flood irrigation regime combined with differing nitrogen treatments in the dry seasons of 2015 and 2016. Disease was scored in the same way in both experiments using a sheath blight assessment scale for field evaluation developed at the International Rice Research Institute to assess the severity on infected sheaths and leaves while sheath blight incidence on tillers were counted per hill. We were unable to detect any difference in the incidence of tiller sheath blight due to irrigation, tiller and leaf sheath blight did differ significantly by irrigation treament but leaf sheath blight severity did not. Our findings suggests that farmers can adopt water saving technologies without risking increased sheath blight incidence. We suggest that further cross-cutting research in this area is warranted.

# Introduction

Sheath blight (ShB) disease (*Rhizoctonia solani* Kühn), anastamosis group 1 [(teleomorph: *Thanatephorus cucumeris* (A.B. Frank) Donk.] of rice is an economically important disease worldwide throughout tropical and temperate production areas. Under conducive conditions he disease can cause up to 50% yield losses (Marchetti and Bollich 1991). Studies by Savary et al. (2000) estimated normal yield losses in tropical irrigated lowland rice in Asia at 5-10%. The disease is best managed through an integrated disease management approach which includes resistance (Kumar et al. 2009, Srinivasachary et al. (2011)) fungicide applications where affordable (Groth 2008; Rush and Lee 1983), nitrogen management (N. P. Castilla et al. 1996; Slaton et al. 2003; Tang et al. 2007) and water management (N. P. Castilla et al. 1996).

Alternate wetting and drying (AWD) is an irrigation technique for irrigated rice (*Oryza sativa* L.) developed by the International Rice Research Institute (IRRI) and its partners that saves about 15-40% of irrigation water (B. A. Bouman and Tuong 2001; Liping et al. 2007). In AWD rice, fields are exposed to several dry phases during the growth period without exposing the plants to water stress. In order to avoid yield decline under AWD “safe” thresholds have been developed. Under safe AWD irrigation water is applied when the field water level reaches 15cm below the soil surface (Richards and Sander 2014). Fields are furthermore kept flooded during the flowering period. As an added benefit to saving water, AWD also reduces greenhouse gas (GHG) emissions of rice fields, which are a substantial factor in the GHG budget of rice producing countries, by around 50% (Sander et al. 2016; Yan et al. 2005).

The AWD technology has been identified as promising climate smart practice for different rice growing regions that can stabilize rice production in water scarce areas as well as help reduce the carbon footprint of rice production. Various countries, *e.g.*, Bangladesh, Vietnam, Thailand and the Philippines, plan to widely apply AWD to local rice production (Ministry of Environment and Forests (MOEF) Government of the People’s Republic of Bangladesh 2015). However, a change in water regime in rice fields on large scale might encompass different other effects, for example related to plant health.

Because of the well documented effects of irrigation and N on ShB, we established field experiments to study what effects AWD irrigation technologies and N could have upon ShB incidence and severity in tropical rice.

# Materials and Methods

Two experiments were conducted at the International Rice Research Institute’s (IRRI) Ziegler Experiment Station in Los Baños, Calabarzon, Philippines (latitude 14° 11’ N, longitude 121° 15’ E) in the 2015 and 2016 dry seasons. For 2016 changes were made to optimize the experiment based on findings from the 2015 experiment. Details were as follows.

## 2015 Experiment

### Experimental Design

The plot design was a split-plot design with four replicates where irrigation was the main plot and nitrogen (N) rate was the split-plot.

The main plot treatments were alternate wetting and drying (AWD) and continuously flooded (FLD) or farmers’ practice as the control treatment. The main plot size was 12m x 12m (144 sq m), with a split-plot size of 5m x 5m (25 sq m). Replication size was 12m x 24m (288 sq m) with a buffer of 1m per split-plot for a whole experiment size of 1,152 sq m.

Irrigation in AWD plots was determined by the water level in plots, *i.e.*, when the water level reached 15cm below the soil surface irrigation water was applied to a level of 5cm. In FLD plots a standing water layer of 3-5cm was maintained throughout the growing season.

The split-plot treatment rates of nitrogen were N0 (no nitrogen supply), N100 (100 kg per ha applied as urea in three splits at final harrowing, active tillering and panicle initiation) and N120 (120 kg per ha applied as urea in three splits at final harrowing, active tillering and panicle initiation) (Table 1).

### Crop Establishment

Trays of NSIC Rc222, a short-season inbred irrigated lowland rice variety with 114 day maturity when transplanted were established on 19 December 2014. Trays were randomised and transplanted using a mechanical transplanter on 9 January 2015.

### Inoculum Preparation and Application

An isolate of *Rhizoctonia solani* AG1-1a from infected rice was maintained on potato dextrose agar (PDA) medium in tubes. The isolate was transferred to 90mm Petri dishes containing PDA and incubated a room temperature (20 to 27°C). Glass bottles of autoclaved rice grain and hull substrate were prepared and plugs of the culture were transferred from Petri dishes to the autoclaved substrate and incubated at room temperature for two weeks.

The plots were inoculated 20 days after transplanting by spreading 151g of inoculum over the split-plot area with a 1m buffer on either end (4m x 11m).

## 2016 Experiment

### Experimental Design

The experiment followed the same split-plot design as described for the 2015 experiment. However, the plot size was increased and due to these changes, the replicate sizes are are not equal as necessitated by the use of a larger area for the experiment. The main plot sizes were: Block 1 (B1) 21m x 20.5m (412.5 sq m) and Block 2 (B2) 20.25m x 21.6m (437.4 sq m). The split-plot sizes were B1 21m x 10.25m (215.25 sq m), B2 20.25m x 10.8m (218.7 sq m). The replication sizes were B1 - 42m x 20.5m (861 sq m) and B2 - 40.5m x 21.6m (874.8 sq m). A buffer 0.5m per split-plot was used and the overall experiment size was 3471.6 sq m.

Split-plot N rates differed from the 2015 rates with only two nitrogen treatments, N60 (60 kg per ha as urea split into two applications) and N180 (180 kg per ha in three splits) being applied (Table 1).

### Crop Establishment

Nurseries of NSIC Rc222 were established on 7 January 2016 experiments. Seedlings were transplanted by hand 20 to 22 January 2016 in hills with six to eight seedlings per hill with a distance of 20 cm within and between rows.

### Inoculum Preparation and Application

Based on the 2015 results, the inoculation methods were modified in 2016 to increase the amount of inoculum applied to a smaller area. Plots were inoculated 41 days after transplanting using ten bottles per one sampling area (1m x 1m) per plot, where one bottle contained 151g inoculum. A total amount of 1,510g of inoculum was applied to a 1m x 1m area.

### Data Collection

Two sample areas per plot (1m x 1m) were assessed. For nine hills per sample, the total number of tillers per hill and number of tillers with ShB (incidence) were measured. Tiller ShB severity was measured for four tillers per hill and six leaves tiller using the rating scale. Leaves were rated as green (living) having at least XXX% living tissue or dead, defined as having less than XXX% living tissue. Five disease assessments were made in the 2015 experiment and four disease assessments were made in the 2016 experiment, respectively.

Disease rating was the same in both experiments using the same disease assessment scale for field evaluation developed at IRRI where 0 - no disease; 1 - trace to 1% severity; 2 - 1 to 5%; 3 - 5 to 15%; 4 - 15 to 50%; 5 - 50 to 100%. Where severity was considered to be the amount of leaf or sheath tissue covered by ShB lesions.

### Statistical Analysis

Because the severity data were collected on an unevenly spaced categorical scale, they were converted to the midpoint value of the percent range for severity. Area under the disease progress stairs (AUDPS) (Simko and Piepho 2012) was calculated for both disease incidence and severity.

As most of the data’s residuals did not meet assumptions for normality, the analysis was carried out using multivariate generalised linear mixed models implemented in the MCMCglmm package (Hadfield 2010) in the R programming environment (R Core Team 2018).

For each measurement, e.g. 2015 tiller incidence, 2016 tiller incidence, a single MCMC chain was run for 55,000 steps, with the first 5000 discarded as burn in. The remaining 50,000 samples were thinned by taking every tenth sample, resulting in 5000 independent draws from the posterior distribution of the parameters of the model. The model

# Results

## 2015 Experiment

### Tiller Sheath Blight Incidence

In 2015 the incidence of tiller ShB remained low throughout the growing season only reaching 15% in 2015 in the N120, flooded treatment (Figure ??). The nitrogen treatments, N100 and N120, were both significantly different when compared with the control N0 treatment (Figure ??). However, water management was not significantly different (Figure ??).

### Tiller Sheath Blight Severity

Tiller ShB severity remained below 2% (Figure ??). Both the N100 and N120 treatments were significantly different than the control N0 treatment (Figure ??). However, the AWD water management was not significantly different from the FLD treatment (Figure ??).

### Leaf Sheath Blight Severity

Severity of leaf ShB remained low, less than 0.4% across all treatments (Figure ??)). Both the N100 and N120 treatments were significantly different than the N0 treatment (Figure ??). However, the AWD water management was not significantly different from the FLD treatment (Figure ??).

## 2016 Experiment

### Tiller Sheath Blight Incidence

The changes to the inoculation methodology resulted in a higher rate of infection in 2016, with the N180, flooded treatment reaching a maximum value of 98% incidence at the third observation (Figure ??). The nitrogen treatment N180, was significantly different than the control N60 treatment (Figure ??). As in the 2015 study, water management did not significantly differ ??).

### Tiller Sheath Blight Severity

As with the tiller incidence, the tiller severity increased with the changed inoculation methods with a maximum of 7.6% for the flooded In 2016 the N180 treatment was significantly different from the N60 treatment, with N180 severity being higher (Figure ??). The AWD water management, which was lower than the FLD treatment, was also significantly different (Figure ??).

### Leaf Sheath Blight Severity

In 2016 the neither of the treatments, nitrogen rate or water management, were significantly different from the control treatments for leaf ShB severity (Figures ??, ??).

# Discussion

In both experiments we were unable to detect any significant effect of AWD on ShB that would cause increases in the disease, which could hinder adoption of the technology. In only one instance were we able to detect any effect of AWD on ShB (Figure ??). In the 2016 experiment the tiller ShB severity was significantly lower for AWD than the traditional FLD treatment, which may indicate a possible adverse effect of using AWD on tiller ShB severity.

The changes made for the 2016 experiment appear to have improved the experiment, increasing the incidence and decreased variability of sheath blight in the plots (Figure ??).

# Notes

## Data and Code Availability

All data generated from this project and code used for analysis are available as a reproducible research compendium from <https://github.com/openplantpathology/rice_awd_pests> (Sparks et al. 2018).

## Acknowledgments

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# Tables

Table 1 Nitrogen application rates for 2015 and 2016. Five different nitrogen treatments were applied depending on the experiment. In the 2015 experiment three nitrogen rate treatments were applied: no N (N0), 100 kg per ha N (N100) and 180 kg per ha N (N120). In the 2016 experiment, two nitrogen rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180). Treatments were applied in splits, basal, tillering and panicle initiation growth stages.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Year | Total N (kg/ha) | Basal N (kg/ha) | Tillering N (kg/ha) | Panicle Initiation N (kg/ha) |
| N0 | 2015 | 0 | 0 | 0 | 0 |
| N100 | 2015 | 100 | 60 | 20 | 20 |
| N120 | 2015 | 120 | 60 | 30 | 30 |
| N60 | 2016 | 60 | 30 | 30 | 0 |
| N180 | 2016 | 180 | 60 | 60 | 60 |

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Table 2 MCMC fit

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dependent Variable | Year | Predictors | Post Mean | Lower 95% CI | Upper 95% CI | P MCMC | DIC |
| Tiller Incidence | 2015 | WMGTAWD | 0.127 | -0.210 | 0.462 | 0.4644 | 332.82 |
|  | 2015 | NRTEN100 | 0.623 | 0.222 | 1.032 | 0.0028 |  |
|  | 2015 | NRTEN120 | 1.000 | 0.599 | 1.400 | 0.0002 |  |
| Tiller Severity | 2015 | WMGTAWD | 4.769 | -3.661 | 13.674 | 0.2716 | 1114.37 |
|  | 2015 | NRTEN100 | 26.214 | 15.868 | 37.041 | 0.0002 |  |
|  | 2015 | NRTEN120 | 41.113 | 31.312 | 52.316 | 0.0002 |  |
| Leaf Severity | 2015 | WMGTAWD | 0.038 | -1.152 | 1.298 | 0.9580 | 636.41 |
|  | 2015 | NRTEN100 | 4.548 | 3.026 | 6.015 | 0.0002 |  |
|  | 2015 | NRTEN120 | 4.985 | 3.540 | 6.457 | 0.0002 |  |
| Tiller Incidence | 2016 | WMGTAWD | 0.369 | -0.107 | 0.857 | 0.1408 | 185.92 |
|  | 2016 | NRTEN180 | 1.963 | 1.476 | 2.461 | 0.0002 |  |
| Tiller Severity | 2016 | WMGTAWD | -8.236 | -12.449 | -3.905 | 0.0012 | 465.9 |
|  | 2016 | NRTEN180 | 4.736 | 0.538 | 9.157 | 0.0288 |  |
| Leaf Severity | 2016 | WMGTAWD | 0.132 | -0.118 | 0.377 | 0.2932 | 99.2 |
|  | 2016 | NRTEN180 | 0.159 | -0.084 | 0.399 | 0.1964 |  |

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# Figures

![Figure 1 Sheath blight progress was measured in the 2015 experiment at five assessment points and 2016 experiment at four assessment points during the dry season both years. Main plot irrigation treatments were permanently flooded (FLD) and alternate wetting and drying (AWD). Points represent the mean of four replications.](data:application/postscript;base64,)

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##### Tiller ShB N progress

![Figure 2 Sheath blight incidence progress was measured in the 2015 experiment at five assessment points and 2016 experiment at four assessment points during the dry season both years. Five different nitrogen treatments were applied to split plots depending on the experiment. In the 2015 experiment three nitrogen rate treatments were applied: no N (N0), 100 kg per ha N (N100) and 180 kg per ha N (N120). In the 2016 experiment, two nitrogen rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180). Points represent the mean of four replications.](data:application/postscript;base64,)

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##### ShB boxplot - WMGT

![Figure 3 Sheath blight progress was measured in the 2015 at five assessment points and 2016 experiment at four points. Sheath blight incidence was rated as the number of infected tillers divided by the total number of tillers per hill and used to calculate the area under the disease progress stairs (AUDPS). Sheath blight severity was rated on an unevenly spaced categorical scale and converted to the mid-point percentage value to calculate the AUDPS. Main plot irrigation treatments were permanently flooded (FLD) and alternate wetting and drying (AWD).](data:application/postscript;base64,)

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##### ShB boxplot - NRTE

![Figure 4 Sheath blight severity progress was measured in the 2015 at five assessment points and 2016 experiment at four points. Sheath blight incidence was rated as the number of infected tillers divided by the total number of tillers per hill and used to calculate the area under the disease progress stairs (AUDPS). Sheath blight severity was rated on an unevenly spaced categorical scale and converted to the mid-point percentage value to calculate the AUDPS. Five different nitrogen treatments were applied to split plots depending on the experiment. In the 2015 experiment three nitrogen rate treatments were applied: no N (N0), 100 kg per ha N (N100) and 180 kg per ha N (N120). In the 2016 experiment, two nitrogen rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180).](data:application/postscript;base64,)

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### Colophon

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The current Git commit details are:

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