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 treatment, but leaf sheath blight severity did not. Our findings suggest 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), anastomosis 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 (N) management (Castilla et al. 1996; Slaton et al. 2003; Tang et al. 2007) and water management (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 (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 randomised complete block design with four replicates where irrigation was the main plot and 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 N were N0 (no N 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) (Tab. ??).

### Crop Establishment

Trays of NSIC Rc222 were seeded on 19 December 2014. NSIC Rc222 is an inbred variety released by the Philippine Rice Research Institute (PhilRice), with a 114 day maturity when transplanted, were established. The variety is commonly grown by farmers in the area, having moderate resistance to brown plant hopper, green leaf hopper and yellow stem borer, but susceptibility to tungro. Plots were established by manually transplanting seedlings on 9 January 2015 in hills with six to eight seedlings per hill and a distance of 20cm within and between rows.

### 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 N treatments, N60 (60 kg per ha as urea split into two applications) and N180 (180 kg per ha in three splits) being applied (Tab. ??).

### Crop Establishment

Nurseries of NSIC Rc222 were established on 7 January 2016 experiments. Seedlings were transplanted by hand from 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

In both experiments, two sample areas, sized 1m x 1m, per plot were assessed. the total number of tillers per hill and number of tillers with ShB (incidence) were measured for nine hills per sample area. Tiller ShB severity was measured for four tillers per hill and six leaves tiller using a disease assessment rating scale for field evaluation developed at IRRI. The scale is an unequally spaced categorical scale 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%. Severity was considered to be the amount of leaf or sheath tissue covered by ShB lesions. Leaves were rated as green (living) having at least XXX% living tissue or dead, defined as having less than XXX% living tissue. The same rating methodology was used in both experiments. Five disease assessments were made in the 2015 experiment and four disease assessments were made in the 2016 experiment, respectively.

## Statistical Analysis

Area under the disease progress stairs (AUDPS) (Simko and Piepho 2012) was calculated for both disease incidence and severity using the R package agricolae (de Mendiburu 2017; R Core Team 2018). The severity data were converted to the midpoint percent value of the scale range.

The correlations between tiller sheath ShB incidence and tiller and leaf ShB severity were tested using Spearman’s correlation test, cor.test, (R Core Team 2018). No correlation was found, so the analysis was completed for each variable independently with no assumed interaction.

As most of the data’s residuals did not meet assumptions for normality, the analysis was carried out using Bayesian multivariate generalised linear mixed models implemented in the R package MCMCglmm (Hadfield 2010). Six models were created where the the dependent variables were 2015 tiller ShB incidence, 2015 tiller ShB severity, 2015 leaf ShB severity; 2016 tiller ShB incidence, 2016 tiller ShB severity; 2016 leaf ShB severity, respectively. The independent variables were the irrigation management and N rate with replicate treated as a random variable. The base levels (control treatments) for the analyses for 2015 were N rate - N0; irrigation management - FLD and for 2016, N rate - N60; irrigation management - FLD.

Four MCMC chains were run for 55,000 steps with the first 5000 discarded as burn in. The remaining 50,000 samples were used to determine the posterior distribution of the parameters of the model. The coda (Plummer et al. 2006) package was used to provide utilities to check MCMC chain convergence using visual inspection of resulting trace graphs and the Gelman-Rubin test. 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).

# Results

## 2015 Experiment

### Tiller Sheath Blight Incidence

In 2015 the incidence of tiller ShB remained low throughout the growing season (Fig. 1a, 2a). Water management was not significantly different (Fig. 3a, 5a). However, the N treatments, N100 and N120, were both significantly different when compared with the control N0 treatment (Fig. 4a, 5a).

### Tiller Sheath Blight Severity

Tiller ShB severity remained below 2% (Fig. 2c, 1c). Both the N100 and N120 treatments were significantly different than the control N0 treatment (Fig. 4c, 5c). However, the AWD water management was not significantly different from the FLD treatment (Fig. 3c, 5c).

### Leaf Sheath Blight Severity

Severity of leaf ShB remained low, less than 0.4% across all treatments (Fig. 1e, 2e). Both the N100 and N120 treatments were significantly different than the N0 treatment (Fig. 4e, 5e). However, the AWD water management was not significantly different from the FLD treatment (Fig. 3e, 5e).

### The Interaction of Irrigation and N Management

## 2016 Experiment

### Tiller Sheath Blight Incidence

The changes to the inoculation methodology resulted in a higher rate of infection in 2016, with the N180 treatment reaching a maximum value of 98% incidence at the third observation (Fig. 2b). The N treatment N180, was significantly different than the control N60 treatment (Fig. 4b, 5b). As in the 2015 study, water management did not significantly differ (Fig. 3b, 5b).

### 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 treatment (Fig. 2d). In 2016 the N180 treatment was significantly different from the N60 treatment, with N180 severity being higher (Fig. 4d, 5d). The AWD water management, which was lower than the FLD treatment, was also significantly different (Fig. 3d, 5d).

### Leaf Sheath Blight Severity

In 2016 the neither of the treatments, N rate or water management, were significantly different from the control treatments for leaf ShB severity (Fig. 3f, 5f, 4f, 5f).

### The Interaction of Irrigation and N Management

# 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. In the 2016 experiment the tiller ShB severity was significantly lower for AWD than FLD (Fig. 3d, 5d), indicating a possible adverse effect of using AWD on tiller ShB severity under conditions where there is high sheath blight pressure.

The findings of the effects of N rates on sheath blight were to be expected, where higher rates of N caused an increase in disease incidence and severity in 2015 and in tiller incidence in 2016. However, in 2016 tiller and leaf severity had no detectable differences due to the N rate. However, it should be noted that the levels of leaf severity remained low (< 1%) throughout the growing season in all treatments for both years.

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 (Fig. 1a:b, 2c:d, 3a:b, 4c:d). The rice establishment method is known to affect the spread of sheath blight (Willocquet et al. 2000). It is possible that the mechanical transplanter could increase ShB spread in the canopy as compared with traditional manual transplanting. This however was not investigated as a part of this study but could bear further research.

# Notes

## Acknowledgments

The authors wish to thank the IRRI Biometrics group for their input in the design of the experiments and Rachel King of the University of Southern Queensland Statistical Consulting Unit for her insightful comments on the analysis of this paper. We would also like to thank Dale Amozola, Paul Escandor and P. Lapis for their technical support in the field. Lastly, we would like to remember Michael Noel, who was a part of the plant disease management team at IRRI and who helped design and manage the first year of the project but passed away in September 2016.

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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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# Figures

![Figure 1 Sheath blight progress for 2015 and 2016 experiments. Disease 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/eps;base64,)

Figure 1 Sheath blight progress for 2015 and 2016 experiments. Disease 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.

##### 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 N treatments were applied to split plots depending on the experiment. In the 2015 experiment three N 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 N 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/eps;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/eps;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 N treatments were applied to split plots depending on the experiment. In the 2015 experiment three N 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 N rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180).](data:application/eps;base64,)

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##### Tiller estimates plots

![Figure 5 Posterior means and 95% credible intervals for the explanatory variables used in models of alternate wetting and drying irrigations (AWD) and N rate (NRTE) on sheath blight tiller incidence and tiller severity. Five different N treatments were applied to split plots depending on the experiment. In the 2015 experiment three N 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 N rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180).](data:application/eps;base64,)

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##### Leaf estimates plots

![Figure 6 Posterior means and 95% credible intervals for the explanatory variables used in models of alternate wetting and drying irrigations (AWD) and N rate (NRTE) and the interaction of the two treatments on sheath blight leaf severity. Five different N treatments were applied to split plots depending on the experiment. In the 2015 experiment three N 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 N rate treatments were applied: 60 kg per ha N (N60) and 180 kg per ha N (N180).](data:application/eps;base64,)

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### Colophon

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#> R6 2.3.0 2018-10-04 cran (@2.3.0)   
#> Rcpp 0.12.19 2018-10-01 cran (@0.12.19)   
#> reshape2 1.4.3 2017-12-11 CRAN (R 3.5.1)   
#> rice.awd.pests \* 0.0.0.9000 2018-09-18 local   
#> rlang 0.2.2 2018-08-16 CRAN (R 3.5.1)   
#> rmarkdown 1.10 2018-06-11 CRAN (R 3.5.1)   
#> rprojroot 1.3-2 2018-01-03 CRAN (R 3.5.1)   
#> scales 1.0.0 2018-08-09 CRAN (R 3.5.1)   
#> stats \* 3.5.1 2018-09-21 local   
#> stringi 1.2.4 2018-07-20 CRAN (R 3.5.1)   
#> stringr 1.3.1 2018-05-10 CRAN (R 3.5.1)   
#> tibble 1.4.2 2018-01-22 CRAN (R 3.5.1)   
#> tidyselect 0.2.4 2018-02-26 CRAN (R 3.5.1)   
#> tools 3.5.1 2018-09-21 local   
#> utils \* 3.5.1 2018-09-21 local   
#> withr 2.1.2 2018-03-15 CRAN (R 3.5.1)   
#> xfun 0.3 2018-07-06 CRAN (R 3.5.1)   
#> yaml 2.2.0 2018-07-25 CRAN (R 3.5.1)

The current Git commit details are:

#> Local: master /Users/adamsparks/Development/rice\_awd\_pests  
#> Remote: master @ origin (https://github.com/openplantpathology/rice\_awd\_pests.git)  
#> Head: [788bd70] 2018-09-18: Fixes analysis document