

Estimation of Rice Yield Loss Using a Simple Linear Regression Model for Bacterial Blight Disease

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ABSTRACT

Field experiment was carried out in hot and humid summer (Transplanted Aus) season to realize the yield loss of a susceptible rice variety Purbachi inoculated with bacterial blight (BB). Treatments consist of BB inoculations at different crop growth stages like maximum tillering (MT), panicle initiation (PI), booting (Bt), flowering and heading stages differently including a control (no BB inoculation). Disease severity index (DSI) was measured at 14 days after inoculation (DAI) and harvest. Data on 1000-grain-weight and yield was recorded at harvest. Significant variation on DSI was observed among different BB inoculated crop growth stages. MT, PI and Boot stage inoculations showed similar (DSI 7.1-8.0) but higher DSI than flowering and heading stages inoculation (3.2-5.3) even control (0.00) at 14 DAI. However, all the treatments showed similar DSI 9.0 at harvest. Bacterial blight can affect the grain weight to some extent although it was insignificant among the treatments (0.1-4.5%). DSI showed negative correlation with 1000-grain weight ($r=-0.77^*$) and similarly with the yield ($r=-0.97^{**}$). The yield ranged from 2.4-3.4 t/ha among the treatments. The yield loss was observed 5.8-30.4% in the BB inoculated treatments. MT, PI and Boot stages inoculation affected the yield much resulting 21-30.4% yield loss. It could be concluded that a susceptible variety can be affected with significant yield loss up to 30.4% with severe outbreak of B B. A simple regression equation $Y = 4.09 - 0.211X$ ($Y =$ Yield, $X =$ BB severity score) is suggested for the prediction of yield loss in susceptible variety in summer season.

Key words: Rice variety, bacterial blight, disease severity, yield loss

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the staple food crops in the world, feeding about half of the world population (Anon. 2016). It is the staple food crop of Bangladesh and the symbol of food security. Worldwide 40% rice crop is lost every year due to biotic stresses including pathogen, insects and weeds (Hossain 1996). During the growing period, rice is always vulnerable to different major diseases like blast (*Pyricularia oryzae*), sheath blight (*Rhizoctonia solani*), sheath rot (*Sarocladium oryzae*), bacterial blight (*Xanthomonas oryzae* pv. *oryzae*) and tungro that affects the yield. Among the diseases, bacterial blight (BB) is one of the most serious threats to the rice crop in irrigated and rainfed areas of the world (Mew 1987). The disease BB, has been reported globally from Asia, Africa, northern Australia, the United States of America (USA) and some Latin American countries (Ronald 1997). The

disease was identified first in Japan in 1884 (Tagami and Mizukami 1962) and considered as the oldest rice disease of Asia (Jeung *et al.* 2006).

In the last few decades BB of rice is considered as a major bacterial disease in Bangladesh. It is caused by a Gram-negative bacterium *Xanthomonas oryzae* pv. *oryzae* (*Xoo*). It is a vascular disease and cause systemic infection (Mew 1987). BB symptoms appear at the tillering stage and disease incidence increases with plant growth and reached peak at the flowering stage (Mew 1992). Virulent races of bacterial blight pathogen exist in tropical environment (Buddenhagen and Reddy 1971). Hot and humid environment in tropical Asia enhance the bacterial blight incidence and severity. Therefore, virulence races and disease favourable environment enhance the disease incidence and losses are thought to be significant in tropical Asia than sub-tropical (Mizukami and Wakimoto 1969, Ou 1972).

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Reports from several Asian and Southeast Asian countries indicated that crop losses could be occurred 10-20% in moderately susceptible cultivars in moderate conditions and up to 50% in very susceptible cultivars in conducive conditions due to bacterial blight disease (Ou 1985, Mew *et al.* 1993). Bacterial blight causes reduction in total dry matter, grain weight, and increase in the number of sterile grains. It also results in poor maturation as well as broken grain in milling. Generally, the extent of damage depends on the time of infection during growing period and the severity of the disease. In current years, BB incidence is increasing due to extensive use of nitrogen fertilizers in modern varieties and due to changing scenario of climate in different parts of the world including Bangladesh (Anon., 2016, Anon. 2017, Anon. 2018, Bashir *et al.* 2010, Ali *et al.* 2009, Akhtar 2003). Introduction and intensive cultivation of modern varieties with high dose of nitrogen also enhances the disease severity and thereby yield loss in susceptible varieties.

The disease management strategies need to evaluate the impact of disease severity on crop yield. Evaluation of disease severity and crop loss assessment help in reliable estimation of yield loss and thereby determine the economic impact (James 1974). The yield loss varies depending on the location, season, weather conditions, rice cultivars, management factors like nitrogen and the crop stage at which the infection takes place. Therefore, estimation of yield loss under local host-pathogen-environment interrelationship condition is necessary. Further, estimation of yield loss based on the relationship of disease severity and attributed yield may provide a way or method of yield loss assessment. Field experiments were conducted in summer (Transplanted Aus) season to find the relation of BB (*Xoo*) severity at different crop stages and yield losses in the susceptible variety.

MATERIALS AND METHODS

Location, season and plant materials. The experiment was conducted in the research field of Bangladesh Rice Research Institute (BRRI) during hot and humid summer (T. Aus) season. A susceptible variety Purbachi was evaluated for yield loss estimation under artificial bacterial blight (BB) inoculation following leaf clipping method (Kauffman *et al.* 1973).

Field management. Land was prepared with four cultivations for seedling transplanting and growing. Basal fertilizers and furadan (@ 20 kg/ha) were applied following the standard recommended dose during final land preparation. Rice seedlings were transplanted at 25 days. Seedlings were planted spaced with 20 cm in rows and 15 cm in between plants in a row. Individual plot size was 3 m × 2 m. The crop was fertilized with 120 kg N/ha in three splits following BRRI recommendation (BRRI 2015). Other management practices were also followed as the BRRI recommended production practices.

Treatments and Design. Plants were inoculated at different growth stages. BB inoculation was done separately at maximum tillering (MT), panicle initiation (PI), booting (Bt), flowering (Fl) and heading stages. Therefore, there were six treatments including a control (no inoculation). The experiment was laid out in RCB design with three replications.

Isolation and culture of Bxo9 isolate. A virulent isolate of bacterial blight Bxo9 were isolated from the bacterial blight infected leaf. BB infected leaf samples were collected from the research field of BRRI. Infected samples were surface sterilized with 70% (v/v) ethanol for one minute and rinsed. Then sterilized samples were cut into small pieces of 3-4 mm in size and rinsed twice in sterilized water for 2-3 minutes. After that the leaf pieces were soaked in 5 ml sterile sterilized water for 30 min at room temperature to allow bacteria to disperse into the surrounding liquid in the

laminar air flow. The water became cloudy which indicated the presence of a high number of bacteria. A loopful of the washings (bacterial suspension) was streaked onto Potato-sucrose-agar (PSA) medium and wrapped with cellophane tape to minimize the contamination risk. Plates were incubated at 30 °C in an incubator. After 48 hours, several yellowish or light-yellow watery colonies appeared on the medium of the plate. Further streaking on PSA petri plates allowed single colonies and pure cultures was obtained. Finally, single bacterial colony was cultured in a considerable number of slants and preserved at -20 °C for further use at different crop growth stages inoculation in a season.

Inoculation of Bxo9. Fresh culture of Bxo9 isolate were done again using the slant prepared and preserved earlier before inoculation in any stage of the crop. Bxo9 was grown in PSA petri plates or bottles under room temperature for 48 hours. Then distilled water was added in each petri plate/bottle and make the bacterial suspension. The concentration of inoculum was adjusted approximately 10^8 cfu/ml. Plants were inoculated with 48 hours old culture inoculum of Bxo9 at different growth stages singly. All the plants in each plot were inoculated following leaf clipping method (Kauffman *et al.* 1973). Almost all the leaves were cut 2-3 cm from the leaf tip with scissors dipping in bacterial suspension immediate before cutting leaves.

Disease estimation and data collection. In order to estimate the disease severity, 10 plants were selected from each replicated plot following diagonal method of sampling. Disease scoring was done at 14-day after inoculation (DAI) at the time of harvesting. Disease severity index (DSI) was estimated from all infected leaves in the selected plants based on leaf lesion spread following standard evaluation system (SES) for rice (IRRI 2002). Data were recorded on fertile tiller, 1000 grain weight (g) and yield ($t\ ha^{-1}$) at the time of harvesting. The yield was taken

from the whole plot. Number of effective tillers was estimated counting the number of panicles per hill from 10 randomly selected hills in a plot. Yield loss was calculated using the following formula:

$$\% \text{ Yield loss} = \frac{\text{Healthy plot yield} - \text{Diseased plot yield}}{\text{Healthy plot yield}} \times 100$$

RESULTS AND DISCUSSION

Disease severity index

The disease severity index was the highest at MT stage inoculation which was similar to PI and boot stage inoculation (Table 1). Disease development in MT and PI was significantly higher than those of flowering and heading stage inoculation. The lowest disease severity was observed in control (no inoculation). Disease severity in flowering and heading stage inoculation showed similar disease spread as control. Disease severity index indicated a decreasing trend with the increase of leaf maturity with advancement of plant age at different crop stages (Fig. 1). This was due to gradual increase of lignification into the cell wall in expanded leaves which supports Reimers *et al.* (1992). However, disease severity in all the treatments including control reached to 9.0 due to severe outbreak of the disease. Natural disease incidence in control treatment starts at flowering and reached at the highest at harvesting.

Effect of bacterial blight on grain weight. The 1000-grain weight did not vary among the treatments which ranged from 22.2-23.3 g. Correlation between BB disease index and 1000-grain weight showed a negative relationship (Fig. 2). This means that there was a trend of decreasing grain weight with increase of disease severity. Grain weight pattern among the treatments indicated that BB can affect the grain weight to some extent although it was insignificant among the treatments (0.1-4.5%). The losses were more at or before boot stage inoculation (2.0-4.5%) which might indicate a considerable amount of losses as a whole throughout the country.

Table 1. Effect of BB disease on the yield of Purbachi during T. Aus.

Crop stage of BB inoculation	BB disease index at 14d ^a	BB disease index at harvesting	1000 grain weight (g)	Yield (t ha ⁻¹)
MT	8.00 a	9	22.22 a	2.43 c
PI	7.77 a	9	22.85 a	2.37 c
Booting	7.13 ab	9	22.80 a	2.70 c
Flowering	5.33 bc	9	23.24 a	2.80 bc
Heading	4.27 cd	9	22.95 a	3.23 ab
Control	3.27 d	9	23.27 a	3.43 a

^a14-day after inoculation. In a column figures with common letters did not significantly differ at the 5% level by DMRT. BB: Bacterial blight, MT: Maximum tillering (Seven days before panicle initiation), PI: Panicle initiation and Control: No inoculation

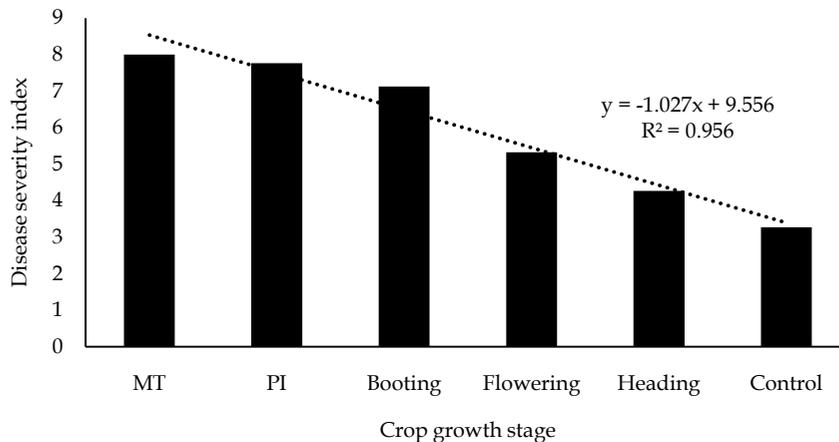


Fig. 1. Disease severity level decreases with advancement of crop stage (MT: Maximum tillering, PI: Panicle initiation, Control: No inoculation).

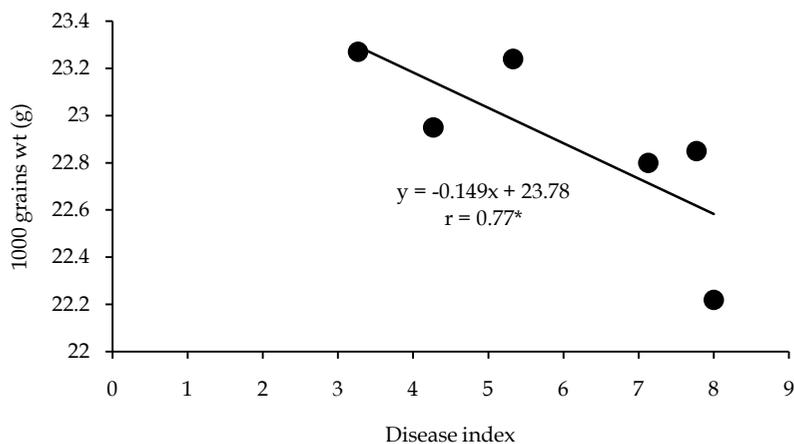


Fig. 2. 1000-grain weight of Purbachi at different disease severity levels in T. Aus.

Yield and yield loss.

The yield ranged from 2.4-3.4 t ha⁻¹ among the treatments (Table 2). The highest yield was recorded in the control (3.4 t ha⁻¹) followed by heading (3.2 t ha⁻¹) and flowering (2.8 t ha⁻¹) stage inoculation with corresponding their lower disease severity. Similar yield at heading stage inoculation and control treatments were due to natural incidence of BB in control treatment occurred at heading and progress similarly until harvesting. BB inoculation in other three stages showed similar yield (2.4-2.7 t ha⁻¹) which was significantly lower than the

rest of the stages. Lower yield in MT, PI and booting stages was due to higher disease severity in these stages compared to the rest of the crop stages. Crop loss assessment is often reported as percent of the yield in comparison with the control plot. The yield loss was observed 5.8-30.4% in the BB inoculated treatments (Table 2). MT to Booting stages inoculation affected the yield much resulting 21-30.4% yield loss. Whereas later stage inoculation of BB at flowering or heading resulted considerably lower yield loss.

Table 2. Prediction of yield loss on the basis of estimated yield using regression equation.

Crop stage of BB inoculation	Actual yield (t ha ⁻¹)	Yield loss (%)	Estimated yield (t ha ⁻¹)	^a Predicted yield loss(%)
MT	2.43	29.2	2.40	30.2
PI	2.37	30.4	2.45	28.7
Booting	2.70	21.4	2.59	24.6
Flowering	2.80	18.6	2.97	13.1
Heading	3.23	5.8	3.19	6.4
Control	3.43	0.0	3.40	0.0

^aBased on equation $Y=4.09-0.211X$, BB: Bacterial blight, MT: Maximum tillering (Seven days before panicle initiation), PI: Panicle initiation and Control: No inoculation

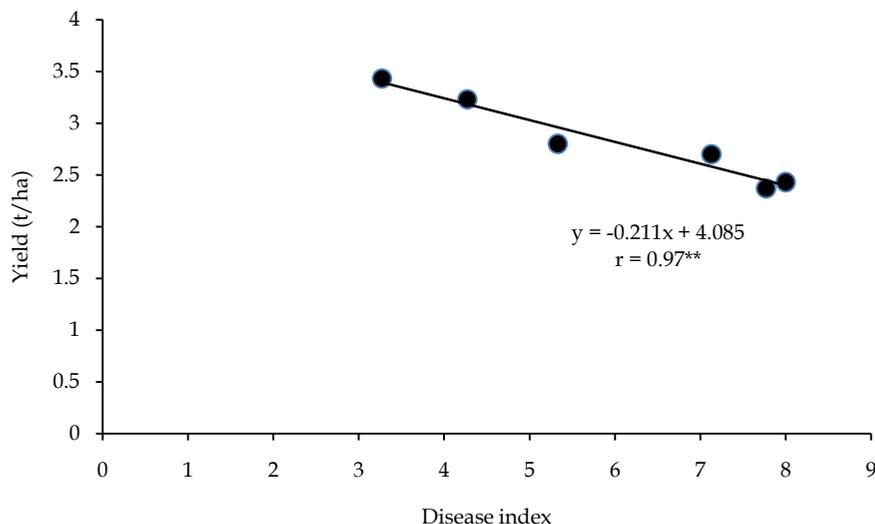


Fig. 3. Rice grain yield at different disease severity levels in Purbachi, during T. Aus.

Yield loss assessment. The yield trend indicated the increase of yield loss with higher disease severity (Fig. 3). A relationship between DSI and yield was estimated by a linear regression as $Y = 4.09 - 0.211X$ (Coefficient of determination $R^2 = 94.5\%$). The equation could be expressed as $Y = a - bX$ where Y is the predicted rice yield at X level of BB severity, a is the expected yield in the absence of disease, X is the disease severity index or diseased leaf area (%) and $-b$ is the regression coefficient that expresses the linear loss in an amount per unit area associated with specific levels of BB on susceptible rice variety (Reddy *et al.* 1979). Considering the yield loss data as a percentage of the corresponding y -axis intercept (here $a = 4.09$), a theoretical expected rice grain yield could be attributed in absence of BB.

The estimated or predicted yield was calculated on the basis of the above equation based on a constant Y axis intercept value 4.09 (Table 2). The results showed that the predicted yield was similar to the actual yield. Similar results were also found for predicted yield loss and this predicted loss assessment was more harmonious to the disease severity. Therefore, the equation with Y axis intercept value 4.09 could be used in yield loss assessment in the BB susceptible varieties with similar yield potential. However, further studies including a considerable number of cultivars in this regard is needful for confirmation of this study.

CONCLUSION

BB inoculation at early stages (MT, PI and boot) produced the highest diseases corresponding to lower yield than the BB severity at flowering and later stages. Therefore, control measures are necessarily important when crop infected with BB at early stages. The results indicated that a susceptible variety can be affected with significant yield

loss up to 30.4% with severe outbreak of BB. The suggested regression equation $Y = 4.09 - 0.211X$ could be used for the prediction of yield loss in susceptible variety in summer season.

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