Research Article

RESPONSE OF TECHNOLOGICAL OPTIONS FOR THE MANAGEMENT OF BACTERIAL LEAF BLIGHT DISEASE ON DISEASE INCIDENCE AND CROP ECONOMY

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KEYWORDS:

Integrated disease management (IDM), Bacterial leaf blight (BLB), Economics, Rice, *Xanthomonas oryzae* pv. *oryzae*

ARTICLE INFO

Received on: 27.08.2020
Revised on: 21.12.2020
Accepted on: 28.12.2020

ABSTRACT

Bacterial leaf blight (BLB) of rice, caused by *Xanthomonas oryzae* pv. *oryzae*, represents a significant phytopathological challenge affecting rice crop. The present investigation aimed to investigate the effectiveness of integrated disease management (IDM) in reducing the bacterial leaf blight incidence in rice and improving the crop economics thereby as compared to those under conventional and chemical control practices. Field trials were conducted in Mirzapur district, India, with three treatments: T_1 (conventional control), T_2 (chemical control) and T_3 (IDM). It was found that IDM significantly reduced BLB incidence (7.81%) compared to the other treatments (18.0% and 11.21% under T_1 and T_2, respectively). Crop yield was highest in the IDM treatment, followed by the chemical control and conventional control treatments. IDM also yielded in the highest net return and benefit-cost ratio, indicating its economic viability. These findings suggest that IDM is an effective and sustainable approach for managing BLB and improving rice production.

INTRODUCTION

After wheat, rice or paddy (*Oryza sativa* L.) is one of the most important foodgrain in the world (Matthews *et al.*, 1995; Banik, 1999). Asian countries being the primary supplier and consumption region (Gumma *et al.*, 2011) cultivate this crop widely. According to a market monitor released by Food and Agriculture Organization, paddy rice production is increasing yearly in rice-producing nations (FAO, 2017). Over 3.5 billion people worldwide directly depend on this cereal for their primary diet and source of daily energy (Cheng *et al.*, 2007).

Bacterial leaf blight (BLB) poses a significant constraint to rice cultivation for various regions of the world (Ishiyama, 1922; Swings *et al.*, 1990). Since the 1960s, *Xanthomonas oryzae* pv. *oryzae*, the infectious microbe that causes bacterial leaf blight (BLB) disease, has been one of the most common and severe pathogens affecting the rice industry in Asia (Ou, 1985). It causes heavy losses to the crop every year and is considered to be a dreadful menace to the crop. It is a significant vascular disease that affects rice grown under irrigation, is challenging to treat and can reduce production by up to 50% (Anonymous, 2007). Mew (1987), Reddy (1989) and Adhikari *et al.* (1994) claimed that *X. oryzae* pv. *oryzae* can result in yield decreases in rice up to between 30% and 50%. Although, there are a number of measures recommended for the management of the disease, a systems analytical method needs to be used to improve damage knowledge and create a tool that makes recommendations for managing diseases (Elings *et al.*, 1997). Bacterial leaf blight (BLB), attributed to *Xanthomonas oryzae* pv. *oryzae* (Xoo), is a destructive disease that impacts rice cultivation across numerous countries (Qian *et al.*, 2013; Tian *et al.*, 2014). First documented in Japan in 1884, BLB is currently widespread throughout the majority of Asia's rice-producing nations. Earlier, it only occurred in the warmer regions of southwest Japan. Wider areas were affected by the disease as agricultural techniques progressed and rice cultivars changed in search of greater yields. The crop decline may be the most reasonable indicator of the harm produced by a plant disease. Rice BLB caused by bacteria has long been known to seriously harm the crop. However, the damage assessment methodology has only been in place since 1950.

Although being reported much earlier, the disease was recognized to be of serious nature as late as in 1922 (Mew *et al.*, 1993).

Conversely, the development of symptoms or degree of infection on the plant has been used instead of yield reduction in evaluating rice's resistance to the disease, virulence of bacteria and effectiveness of agricultural pesticides. Furthermore, it is now evident how the levels of damage and infection at a given time relate to one another.

Bacterial leaf blight increases the volume of cast-off rice and the number of immature, sterile and broken grains. The disease also decreases the weight of straw, brown rice per unit capacity, weight of brown rice grains and milling rate. The degree of infection and the length of time the disease has been present determine how much harm is done. In general, the harm increases with the early onset of the disease. When the disease strikes rice plants later in their growth cycle, the damage is less than in years when the affected area is larger.

The disease exhibits symptoms in two clearly defined phases, *viz.* leaf blight and kresek or wilt phase, the latter being of more economic significance. Yellowish-colored, water-soaked streaks on leaf blades or wavy margins starting at the tips of leaves are indicative of leaf blight. The primary signs and symptoms are leaves with rolling, midrib-preserving, drying back from the tip and yellowish white or golden yellow marginal necrosis. Only some millimeters from the apex, where water vents are dispersed, the lesion first appears as little steaks drenched in water. It grows quickly in both length and width, resulting in a lesion that is yellow to greyish-white in colour and has a rippled border on the leaf's margin. Eventually, the leaf dries out completely (Agrios, 1997). Early in the morning, there is appearance of bacterial oozing on fresh lesions that resemble an opaque or milky dewdrop. Leaves with severe infection usually dry up rapidly. Grain yield could be reduced by as much as 60%. The wilting phase symptoms are noticed one to three weeks following transplantation. An early indication is a green, water-soaked layer along the leaf tip or the cut section. The leaves eventually wilt, fold up and turn from greyish-green to yellow. The plant entirely withers away. By differentiating stem borer damage from kresek signs, the symptoms can be confirmed. This can be accomplished by squeezing the diseased seedling's lower end between your fingers. There is a yellowish bacterial ooze that emerges from the cut ends. The sliced area can be seen in relation to light to reveal the bacterial slime that is dripping into the water from the cut ends. One to two hours later, the water turns turbid.

The Pathogen

The pathogen of BLB is a bacterium known as *Xanthomonas oryzae* pv. *oryzae*. The bacterium has a rod-like shape, measuring 1.2×0.3-0.5 µm in dimensions. They are usually single and may sometimes be found in twins but never form chains. The bacterium has a polar flagellum for motility (Tian *et al.*, 2015). They are negative in Gram reaction, do not form spores (non-spore-forming) and are lack of capsules. The bacterial colonies on nutritional agar have a smooth, round, pale yellow colour and a complete border. They are viscid and convex. The occurrence of bacteria in the rice paddy and irrigation canals, weeds, rice stubbles and ratoons of diseased plants, rain and deep water, high humidity, warm temperatures (ranging from 25 to 30 °C), *etc*. are among the known conditions that promote the expansion of the disease. Over-fertilization and strong winds, which can lead to wounds, are conducive conditions for the disease to grow. Rain that blows in from the wind or splashes on plants can spread the bacterium. New infections can also be brought on by handling and using trimming instruments for transplantation. Both weed hosts and rice stubble can harbor the inoculum. Although the pathogen may exist briefly on contaminated seed and in soil, these are not thought to constitute significant contributors of inoculum. Rain, irrigation water, human touch between plants and instruments used to move seedlings are all ways that the bacteria might spread. Rain, breeze, hail, weeds, plant straw, wild rice (Nino-Liu *et al.*, 2006), seeds and irrigation water (Nyvall, 1999) can all rapidly spread the disease. Typhoons and the quick spread of disease are related. Hydathodes and stomata on leaf blades, growth fractures created by new roots emerging underneath the leaf sheath and lesions on leaves and roots are all natural entry points for the bacteria into leaf tissues. Some bacteria may infiltrate the vascular system and proliferate to the point where they exude from hydathodes. While thiamine complex synthesis genes received a lot of attention, several recent studies on *Xoo* focused on examining additional unidentified genes linked to the organism's pathogenicity (Ryan *et al.*, 2011) interactions with the host. According to Yu *et al.* (2015), the thiG gene prevents cell accumulation, which is necessary for *Xoo*'s complete pathogenicity. Furthermore, it has been noted that iron increases *X. oryzae* pv. *oryzae*'s pathogenicity (Ansari and Sridhar, 2001).

Management of diseases and pests has a number of strategies involved. Apart from chemicals, several other measures for the management of such deterrents of crop productivity are available and biological control is one of the most promising methods to manage crop pests (Dey,

2016) and diseases. Cultural, mechanical, botanical (Seethapathy *et al.*, 2016) and genetic measures are some other relatively less effective measures available for a number of plant protection issues. Their integration in a complementary manner to obtain maximum impact is the strategy called integrated disease management.

Rice is an important food grain crop of District Mirzapur. Farmers cultivate several high-yielding and scented varieties of rice in Jamalpur Development Block of the district, along with improved rice varieties in other irrigated as well as rainfed parts of the district. However, in the recent past, a high emergence of Bacterial leaf blight disease has been noticed, resulting in yield loss of this important crop. The basic idea of the investigation was to identify the most effective strategy for managing the disease, reduce the yield losses from it and enhance the monetary gains in terms of BCR and ICBR. Although there are recommendations for the effective management of various diseases of plant, there is a need for assessment of the potential of location-specific technologies for better results.

The current investigation was, therefore, conducted with the objectives to assess the impact of integrated disease management of bacterial leaf blight on the following when compared to the conventional control methods and recommended chemical control.

1. Incidence of the Bacterial leaf blight
2. Crop yield
3. Returns (gross return and net return) from the crop
4. Economics of the crop (BCR and ICBR)

MATERIALS AND METHODS

An on-farm trial was carried out to assess the response of control measures in integrated form and the relative effect of the conventional practice (also called farmers' practice) that served as conventional check (control) and chemical control measures. The details of the treatments are hereunder:

T_1: No Seed Treatment, Spray of Mancozeb @ 0.2% (Farmers practice/ Conventional control).

T_2: Seed Treatment (with Streptocycline 4 g + Carbendazim 90 g in 45 litre water per 25 kg seeds) + Two sprays (of 15 g Streptocycline + 500 g Copper oxychloride in 600-800 litre water ha^{-1}) at 15 days interval in the standing crop (Chemical control).

T_3: Field sanitation + Judicious application of fertilizers after soil testing + Transplantation at recommended spacing (25 cm × 25 cm) + Seed treatment with Bleaching powder (@ 100 µg ml^{-1} of water) and $ZnSO_4$ (Zinc sulphate) (2%) (Integrated disease management - IDM).

The benefit cost ratio, or B:C or BCR, is the ratio that results from dividing the benefit stream by the present value of the costs. When the ratio is smaller than 1.0, there are more expenses than benefits. However**,** if the value of ratio is more than 1.0, the benefits outweigh the costs incurred (Gittenger, 1982; Jehanzeb, 1999). It reflects the gross monetary return for every unit of money incurred as the cost of the enterprise. The benefit-cost ratio was estimated using the following formula:

$$\text{B: C} = \frac{\text{Gross Return}}{\text{Gross Cost}}$$

The incremental cost-benefit ratio (ICBR) is the net monetary return or profit for every unit of money incurred as costs of the enterprise. ICBR was calculated using the following formula:

$$\text{B: C} = \frac{\text{Net Return}}{\text{Gross Cost}}$$

All the treatments were replicated four times. The statistical design used was simple randomized block design (RBD) and the data obtained were analyzed accordingly.

RESULTS AND DISCUSSION

Effect on Disease Incidence

The findings of the investigation on this parameter are presented in table 1 and figure 1. It is evident from a careful perusal of the data that the incidence (%) of bacterial leaf blight was decreased significantly as compared to the conventional control and chemical control. The disease incidence (%) recorded in the conventional control (T_1) was as much as 18%, which was reduced to 11.32% in chemical control (T_2) and it was recorded minimum (7.81) in the IDM module (T_3) being significantly lower than the other two treatments.

Effect on Crop Economics

The results on this parameter are presented in table 2 and figure 2 to 4. Crop yield (q ha^{-1}), gross return (Rs. ha^{-1}), gross cost (Rs. ha^{-1}), net return (Rs. ha^{-1}), BCR and ICBR were the parameters used for the assessment of crop economy and comparison of treatments.

Yield

The yield of crops under various treatments was negatively associated with the incidence of the disease. The conventional control yielded 37.52 quintals ha^{-1} and the chemical control yielded 40.63 q ha^{-1}, which had an increase of 8.29% over the conventional control. Integrated disease management (T_3); however, was found to be the most rewarding option, with a yield of 41.39 q ha^{-1} recording a huge 10.31% increase over the conventional control.

Table 1: Impact of integrated disease management on bacterial leaf blight in rice cultivation

Treatment	Incidence of BLB (%)
T_1 (Conventional Control)	18.00
T_2 (Chemical Control)	11.32
T_3 (Integrated Disease Management)	7.81

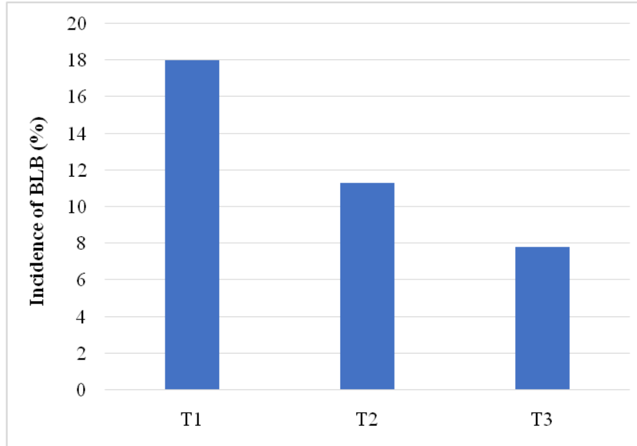

Figure 1: Impact of integrated disease management on the incidence (%) of bacterial leaf blight in rice cultivation

Table 2: Effect of integrated disease management on the economics of rice cultivation

Treatment	Yield of treatments (q ha^{-1})	Increase in yield (%)	Economics of Treatments				
			Gross Cost	Gross Return	Net Return	BCR	ICBR
			(Rs. ha^{-1})				
T_1	37.52	-	15,749.00	37,520.00	21,771.00	2.38	1.38
T_2	40.63	8.29	16,256.00	40,630.00	24,374.00	2.50	1.50
T_3	41.39	10.31	15,947.00	41,390.00	25,443.00	2.60	1.60

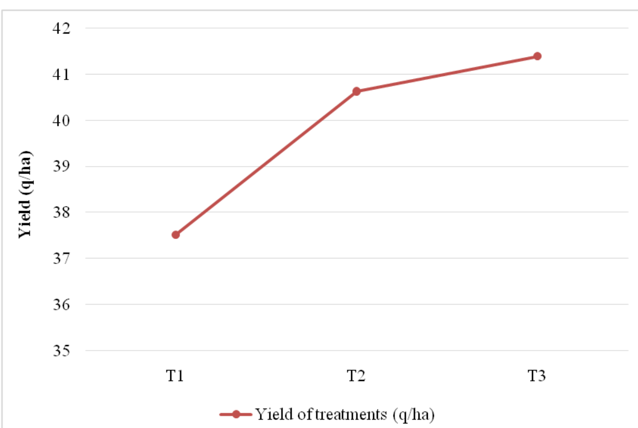

Figure 2: Impact of integrated disease management on the yield of rice crop

Cost of Cultivation and Returns from the Crop

Among the three treatments, chemical control (T_2) was the most expensive treatment for disease management with the gross cultivation cost being Rs. 16,256.00 ha^{-1}. It was followed by the Integrated Disease Management (T_3) with an average gross cost of Rs. 15,947.00 ha^{-1}. Conventional control or check (T_1) was the cheapest option for the management of BLB in rice.

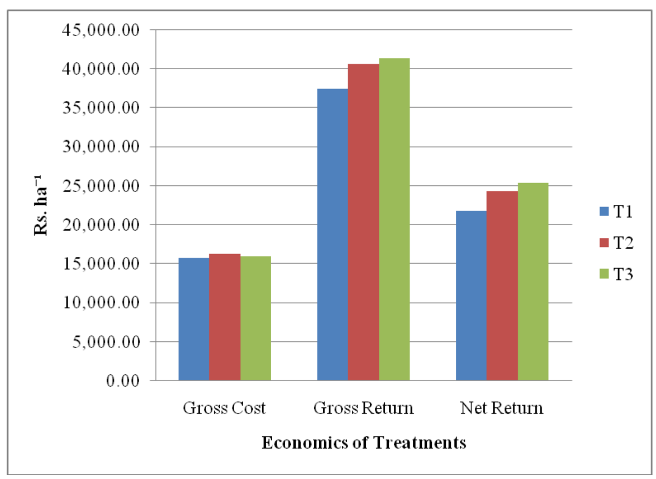

Figure 3: Impact of integrated disease management on the returns from rice crop

As much as gross returns of the treatments are concerned, integrated disease management (T_3) was the most rewarding among all the treatments with a gross return of Rs. 41,390.00 ha^{-1}. It was followed by chemical control (T_2) with the same being Rs. 40,630.00 ha^{-1}. Conventional control or check was; however, the least remunerative among all the three treatments with a gross return of Rs. 37,520.00 ha^{-1}.

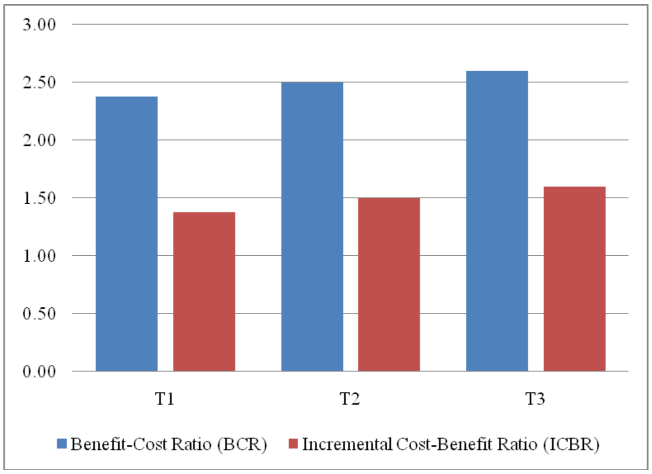

Figure 4: Impact of integrated disease management on the economics of rice crop

Among all the three treatments, the net return was maximum in the case of integrated disease management (T_3) with Rs. 25,443.00 ha^{-1} followed by chemical control (T_2) with Rs. 24,374.00 ha^{-1}. Conventional control or check (T_1) was, however, the least profitable among all the treatments.

The BCR and ICBR were calculated to assess the viability and profitability of the treatment options. Integrated disease management (T_3) was most remunerative for every unit of cost incurred in the cultivation of the crop with BCR and ICBR being 2.60 and 1.60, respectively. It was followed by chemical control (T_2) for which the values of above were 2.50 and 1.50, respectively. The conventional control (T_1), however, stood the least remunerative on this parameter.

According to Tagami and Mizukami (1962), applying a spray solution containing streptomycin and copper oxychloride can effectively suppress the growth of *Xoo*. When Srivastava (1972) evaluated the streptomycin mixture to decontaminate rice seeds, he recommended an appropriate course of treatment to combat the infection. Hori (1973) found that spraying a mixture of streptomycin and copper oxychloride prevented the development of bacteria. According to Chand *et al.* (1979), the lesions caused by the bacteria in rice were considerably diminished through the application of bleaching powder and 30% chlorine at a dosage of 2 kg ha^{-1}. Nasir *et al.* (2019) have reported a 76.48% reduction in the BLB over the untreated control with a corresponding 2.90% increase in the yield of rice crop. They also found streptomycin sulphate effective and reported 92.23% disease reduction over the untreated control with a 3.55% increase in the crop yield.

The goal of integrated disease management (IDM) is to effectively manage and control illnesses in humans and in different agricultural settings using a holistic strategy. Several tactics, including prevention, early detection, diagnosis, treatment and continuous monitoring, are used in this comprehensive strategy to reduce the impact of diseases on people, communities and agriculture (Gurjar *et al.*, 2018). IDM aims to maximize disease management efforts, improve people's general well-being and strengthen the sustainability of agricultural systems by combining different approaches and disciplines. IDM is essential for maintaining public health and our food systems' resilience and production in this age of rising disease burdens and new dangers. In order to control diseases of major importance, integrated disease management combines the implementation of sound agricultural practices with farming approaches that are socially, chemically and biologically acceptable (Khokhar and Gupta, 2014). Integrated management is a practice that relies on decisions and involves the coordinated use of several strategies to maximize disease control in an environmentally and financially sustainable way (Khokhar and Gupta, 2014). However, the application of integrated management techniques must be comprehensive in order to incorporate all available control strategies. The package ought to be designed such that farmers could readily comprehend and implement it (Ameyaw *et al.*, 2014). Integrated disease management has been shown to be highly effective in managing various plant diseases (Srivastava and Saksena, 1968; Locke *et al.*, 1985; Upadhyay and Rai, 1989). IPM reduces the amount of fungicides used to the minimum required to produce the desired results. This method does not, however, do away with the requirement for fungicides.

CONCLUSION

Bacterial leaf blight in rice or paddy crop is a serious threat to its cultivation and economics. Various strategies have been developed for its management to mitigate the losses attributed to the disease. Integrated disease management or IDM advocates the integration of all the available measures for the management of a given disease to obtain maximum reduction in the amount of disease with minimum efforts and investments. The present investigation aims to assess the available and adopted measures for controlling the bacterial leaf blight of rice in Mirzapur district of Uttar Pradesh (India) and it was found that IDM was superior to the conventional control methods (farmers practice as adopted in the region of investigation) and recommended chemical control, not only in terms of reducing the disease incidence (%), but also in improving crop economics with best BCR and ICBR.

Acknowledgements

The author acknowledges the financial and material support facilitated by the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture, Government of India and Banaras Hindu University, Varanasi.

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How to cite this article?

Rai, J.P., 2020. Response of technological options for the management of bacterial leaf blight disease on disease incidence and crop economy. *Innovative Farming* 5(4): 160-166.