



## REVIEW ARTICLE

### Current Status of Bacterial Leaf Blight in Malaysian Rice Plants

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#### ABSTRACT

Bacterial leaf blight (BLB) of rice is among the most devastating pathosystem of rice in nearly all the rice-growing localities in tropical and temperate regions. In Malaysia, the disease was initially detected in paddy fields of Peninsular Malaysia in 1967, with yield losses reaching 70%. Devastating BLB spread was in 2013 at Sekinchan, Selangor with 80% infection involving varieties of MR220, CL2, MR263 and MR 269, while at Northwest Selangor, 40% of the planting area involved MR284, MR220, CL2 and MR219 varieties. The country produced 71% of the rice after the Second National Agriculture Policy (NAP) in the year 2000 and only increased by 72% at the end of 2010, passing the target of 65% of SSL. Malaysia announced its intention to reach self-sufficiency level (SSL) by the year 2020, but has been extended to the year 2050. In general, several factors favour the BLB disease's development, particularly in irrigated and rainfed lowland areas, with temperatures of 25-34°C and humidity above 70 instead of high nitrogen levels and absence of resistant varieties. This disease could be overcome through practising a few control methods to prevent the disease's development.

**Keywords:** Bacterial leaf blight, yield loss, statistics, self-sufficiency level

## INTRODUCTION

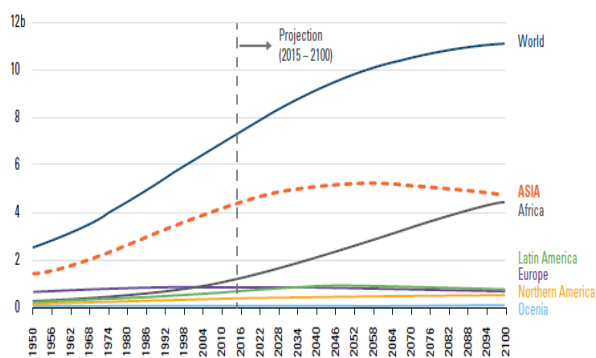
Rice is a staple food for Malaysia and a defining feature of our culture (Sarena et al., 2019). It is a global food source for over 3.5 billion people in the world. Asia is championed as the top rice-consuming and producing area (Herman et al., 2015). In Malaysia, rice is classified as a primary crop with regards to cultivation area and production (Wahab, 2018). The rapid growth of the human population in Asia has led to an estimation of a 70% rice production increase required to meet future demands (Rajamoorthy et al., 2015). Rice plants were severely affected by bacterial leaf blight (BLB) in wetland areas with heavy rainfall in the monsoon (Yasmin et al., 2017), warm temperatures (25 to 30°C), high humidity, and deep water (Sharma et al., 2017). Severe wind that could cause wounds to rice plants also contributes to the disease's infectivity (Sharma et al., 2017). In addition, the susceptibility of rice varieties under high nitrogen fertilisation also favours BLB severity (Kiran et al., 2015). The spread of this bacterium is via plant-to-plant contact, water, windblown or splashing, handling techniques during transplanting and transplanting tools (Sharma et al., 2017). A rice plant may be infected at any growth stage, which may begin from the seedling to mature plant stages. Bacterial leaf blight caused yield reduction of 20–50% at the tiller stage in severe cases (Kim et al., 2015; Pranamika et al., 2017; Patra et al., 2018; Du et al., 2022). *Xanthomonas oryzae* pv. *oryzae* (Xoo) infected rice plants demonstrate visible symptoms either by leaf blight or kresek (Pranamika et al., 2017). The bacterium invades plants through wounds or water pores. Lesions with wavy margins begin from the tip of the leaf as the water pores are located at the margins of the upper parts of the leaf. These water-soaked lesions enlarged in size, turn yellow, and ultimately lead to the death of plant (Du et al., 2022).

Biotic stresses such as pathogens, weeds, and insect pests annually contribute to the world's rice crop losses (Patra et al., 2018). The causal agent of BLB disease of rice, *Xanthomonas oryzae* pv. *oryzae*, is considered the oldest and most serious disease of rice (Chukwu et al., 2019). Historically, BLB was initially reported in Japan during 1884–1885 and subsequently reported in other rice-growing countries (Gnanamanickam, 2009). The first BLB infection in Malaysia was reported on a small scale in the rice fields of Peninsular Malaysia in the early 80s (MOA, 2018). To date, this disease has spread more

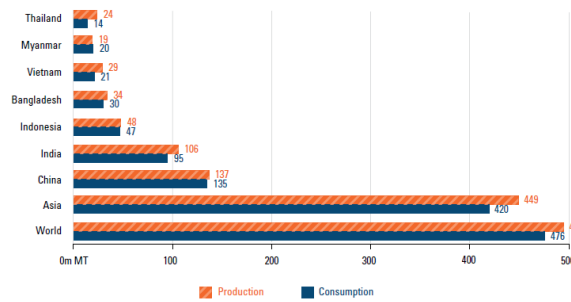
vigorously, with 10-20% crop losses being observed under moderate prevailing conditions (DOA, 2019). Whereas under a conducive environment, up to 50% crop losses were recorded (DOA, 2019). Peninsular Malaysia recorded an increase in BLB disease incidence in a 12,080-hectare (ha) rice-growing area including Melaka (less than 1 ha), Kelantan (1 ha), Johor (5 ha), Perlis (141 ha), Pahang (46 ha), Perak (174 ha), Negeri Sembilan (291 ha), Terengganu (440 ha), Pulau Pinang (620 ha), Kedah (4,415 ha), and Selangor (5,945 ha) (DOA, 2019).

### The world Rice Situation

The United Nations in 2017 estimated the global population to reach 7.5 billion, with the biggest proportion in Asia (Figure 1; Special Aggregates: Geographical groups: Total population – Both sexes, World Population Prospects 2017) (UNDESA, 2015). As rice is the staple food for most countries in Asia, the region consumes more than 80% of the world's rice (Figure 2; Food balance sheets: Production quantity & Domestic supply quantity) (FAOSTAT, 2021). In fact, the world's five largest rice producers are also the world's five largest rice consumers, namely China, India, Indonesia, Bangladesh, and Vietnam. Future demand for rice is expected to rise from the already high level of rice consumption as the population continues to grow. As such, countries in Asia have always been concerned with acquiring an adequate supply of rice to meet this increasing demand. This is further motivated by concerns about spikes in rice prices, which have been shown to be correlated with social unrest (OECD & FAO, 2017). (Figure 3; World: Prices & Forecasts: Monthly Data, IMF Primary Commodity Prices)



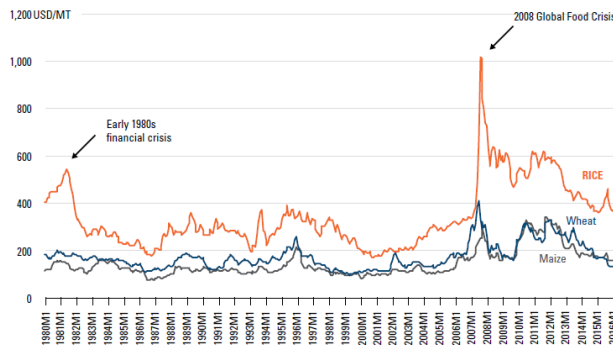
**Figure 1.** Total population estimates, by region, 1950-2100 (billion). Source: Special Aggregates: Geographical groups: Total population – Both sexes, World Population Prospects 2017 (UNDESA, 2015).



**Figure 2.** World's top producers and consumers of rice, by country and region, 2013. Source: Food balance sheets: Production quantity & Domestic supply quantity (FAOSTAT, 2021).

*Note:* 1. The most recent data on production and consumption in FAOSTAT are up to the year 2013. OECD-FAO Agricultural Outlook 2018-2027, although provides data up to 2018 (and projection up to 2027), is limited in the number of countries covered.

2. Based on OECD-FAO Agricultural Outlook 2018-2027, the worlds and Asia's rice production in 2016 is 502m MT and 453m MT respectively, whereas rice consumption is 498m MT and 434m MT, respectively.



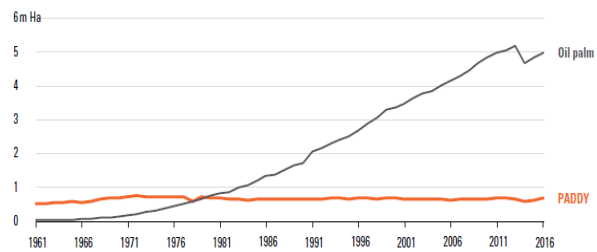
**Figure 3.** World monthly cereal prices, by commodity, 1980-2016 (USD/MT). Source: World: Prices & Forecasts: Monthly Data, IMF Primary Commodity Prices.

*Notes:*

1. Rice: Rice, 5 per cent broken milled white rice, Thailand nominal price quote (USD/MT)
2. Maize: Maize (corn), U.S. No.2 Yellow, FOB Gulf of Mexico, U.S. price (USD/MT)
3. Wheat: Wheat, No.1 Hard Red Winter, ordinary protein, Kansas City (USD/MT)

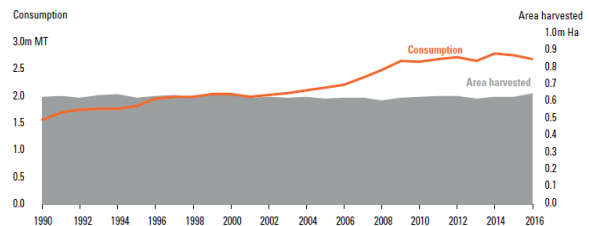
## Rice Statistics In Malaysia

In 2016, Malaysia's Gross Domestic Product (GDP) was RM1, 196.4 billion (b), whereby the agriculture, forestry, and fisheries sectors contributed only RM106.5 b (8.9%) (National Accounts from Time Series Data: Malaysia Economic Statistics - Time Series 2016, DOSM website). Within agriculture, palm oil was the biggest contributor at RM 41.9 billion (40.2%), while paddy contributed only RM 2.4 billion (2.3%). Indeed, palm oil has always been a bigger contributor to the national GDP and this can be seen over time as the oil palm harvested area has increased tremendously while the paddy harvested area remained relatively constant (Figure 4; Crops: Area harvested: Oil palm fruit & Rice, paddy) (FAOSTAT, 2021).



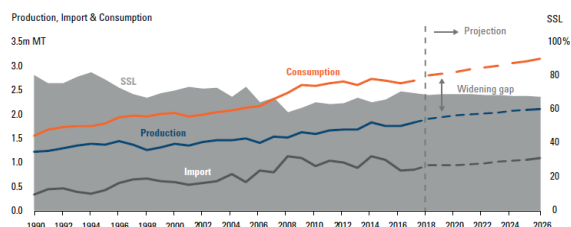
**Figure 4.** Total area harvested for oil palm and paddy in Malaysia, 1961-2016 (m Ha). Source: Crops: Area harvested: Oil palm fruit & Rice, paddy (FAOSTAT, 2021).

Despite the paddy and rice industries having a small contribution towards the nation's GDP, they have garnered much interest from policymakers given their complex relationship with food security, culture, and socio-economic factors. This is motivated by the increasing national demand for rice (Figure 5; OECD-FAO Agriculture Outlook 2018-2027) at the back of a constant size of the harvested area. In fact, the OECD-FAO Agricultural Outlook report projected a widening gap between Malaysia's production and consumption of rice (Figure 6; Production, consumption, import and export data from OECD-FAO Agricultural Outlook 2018-2027).



**Figure 5.** Rice consumption and total harvested in Malaysia, 1990-2016 (m MT & m Ha). Source: OECD-

FAO Agriculture Outlook 2018-2027 (OECD & FAO, 2017).



**Figure 6.** Malaysia's rice production, consumption, import (m MT) and self-sufficiency level (SSL, percentage), 1990-2026. Source: Production, consumption, import and export data from OECD-FAO Agricultural Outlook 2018-2027 (OECD & FAO, 2017).

### Status of Bacterial Leaf Blight in Malaysia

Bacterial Leaf Blight (BLB) was initially detected in the paddy fields of Peninsular Malaysia in 1967 and on the 'Seribu Gantang' variety during the early 80s, but it was in a limited widespread (Anim, 2017 and MOA, 2018). In favourable environments, yield losses due to this disease could go up to 70% when susceptible varieties of rice are grown (Febri et al., 2019). In brief, if the disease was infected at younger stages of the rice plant, higher yield losses were recorded. In more critical cases, BLB was capable of affecting as much as 50% to 70% of the production; therefore, it is important to discover the solution to this problem (Rafidah et al., 2018).

In an article entitled "BLB kurangkan berat bijirin padi" written by Kogeethavani (2017) it was stated that serious BLB infection had occurred between 1988 and 1994, with the cultivation of susceptible varieties causing yield losses of up to 50%. While in 2013, devastating BLB spread was reported again in the rice field at Sekinchan Selangor with 80% of infection involving varieties of MR 220 CL2, MR 263 and MR 269. Severe BLB infection spread was also reported to occur at a rice field in Northwest Selangor (Barat Laut Selangor-BLS), infecting 7,800 ha or 40% of the planting areas involving varieties of MR 284, MR 220, CL2 and MR 219.

Portal Rasmi Pejabat Daerah dan Tanah Sabak Bernam (2016) reported that 1,500 ha of rice plant in Sabak Bernam, Sekinchan, Selangor was badly infected by BLB since November 2016, causing the rice production in that area to decrease compared to the previous year. It was also noted that the MR 284 variety that has been used is susceptible to the causal pathogen. One of the farmers, Pa Kin Kuang, 43, said that almost all of the 1.6 ha of paddy fields in

Sekinchan were damaged and experienced a decline in paddy yield from 11 metric tonnes to only 4 metric tonnes per season due to the devastating BLB severity. Farmers could only earn an income of approximately RM 4,800, compared to RM 10,000 or more previously for 0.4 ha of land. Another farmer, Lee Loy Fong, 76, said his paddy production was severely affected and he described the bacterial attack as the worst he had ever experienced since cultivating the crop more than 40 years ago.

Apart from Sekinchan, a survey in several paddy cultivation areas around Sabak Bernam district found that most of the farmers complained about BLB disease attacks, which are also spread in their production areas. A farmer in Sungai Haji Dorani, Ahmad Salihin Selamat, 45, said that a total of 8.4 ha of his paddy fields were affected due to the spread of the pathogenic bacteria. The farmers explained that this variety of rice (MR 284) is indeed good in producing high yield, and unfortunately it was not resistant to BLB. A young farmer, Alifi Hijas, 29, said the government needs to help farmers, especially those who have suffered due to BLB, besides reviewing the use of MR 284 rice varieties.

Farmers in the affected area have received federal government aid amounting to RM 110 million in 2017. An addition of RM 3.7 million was provided to ease the burden of 3000 farmers in the North West of Selangor that has been affected by BLB. The Ministry of Agriculture and Agro-based Industry said the blight had destroyed about 7,700 ha of paddy cultivation in the affected areas. He stated that the funds were used for the purchase of fertilizers, fungicides, and seeds. The Malaysian Agriculture Research and Development Institute is currently conducting research to identify the factors of epidemiology contributing to blight attacks on rice crops in Malaysia. Besides that, the Minister also mentioned that the studies were also extended to look for new resistant paddy seeds and suitable pesticides to combat and ensure the blight does not recur.

### Self-Sufficiency Level (SSL) of Rice

Self-sufficiency, from the word self-sufficient, is defined as needing no outside help in satisfying one's basic needs especially with regard to the production of food (Oxford Dictionaries, 2016). The self-sufficiency status of a food item can be measured using the SSL, also known as the self-sufficiency ratio (Sarena et al., 2019). The ratio is the total domestic production divided by the total available supply, measured in percentage. However, there are variations in the way this ratio is calculated. Unless

otherwise stated, this report will assume the formula as stated in the FAO (FAO, 2015).

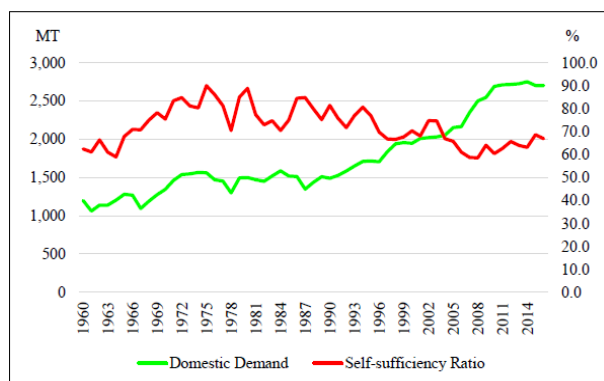
$$SSL = \frac{\text{Production}}{(\text{Production} + \text{Import} \pm \text{Stock} - \text{Export})} \times 100$$

Source: Agrofood Statistics, MOA (2015)

$$SSL = \frac{\text{Production}}{(\text{Production} + \text{Import} - \text{Export})} \times 100$$

Source: FAO Statistical Pocket Book (2015).

Self-sufficiency has been brought to the world's attention and has moved to the higher policy agenda, particularly to address food security concerns in most rice-staple and rice-deficit regions among developing countries (Ali, 2017). Malaysia announced its intention to pursue self-sufficiency by the year 2020 and has recently been extended to the year 2050 (National Transformation 2020-2050). Domestic demand for rice is growing, and self-sufficiency goals have become more challenging (Figure 7; Production, Supply and Distribution (PS&D), USDA). Currently, the crop intensity of rice is considerably high, ranging between 170% and 180%, yet domestic production remains constrained by its marginal productivity (Ali, 2017). Pursuing self-sufficiency with a constrained supply of land requires significant gains in productivity, or else it will lead to higher market prices and consequently reduced consumer welfare (Ali, 2017).



**Figure 7.** Trends of domestic demand and self-sufficiency ratio for rice in Malaysia, 1960-2014.

Source: Production, Supply and Distribution (PS & D), USDA.

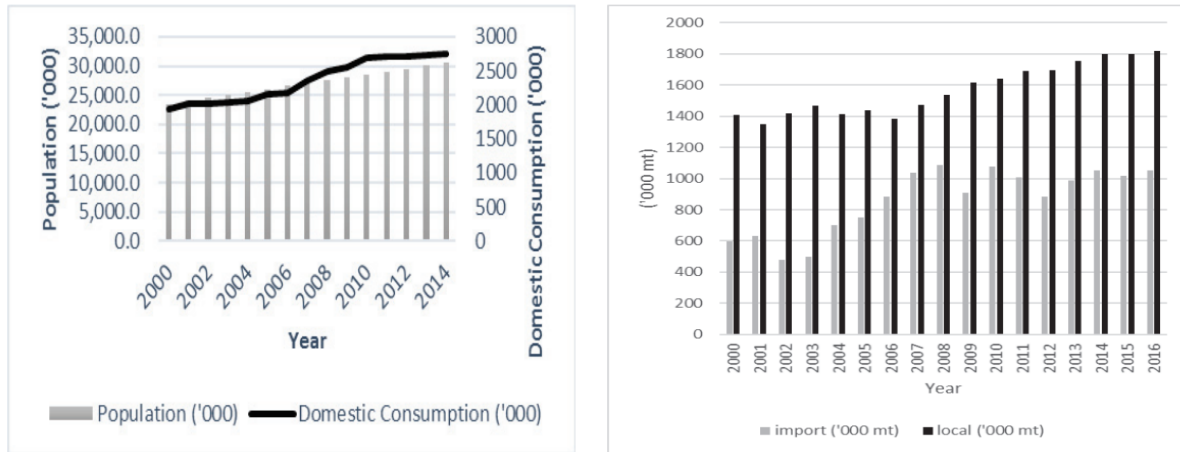
According to Statistic Booklets of Plant (Food Crops of Sub-Sector) in Malaysia (2015), to date, Malaysia is able to produce rice with 71.6% self-sufficiency. No change in rice productivity has been made for the past 16 years; Malaysia produced 71% rice after the

Second National Agricultural Policy (NAP) or 7<sup>th</sup> Malaysian Plan was implemented in the year 2000 (Eight Malaysia Plan). The percentage of rice productivity only increased by 72% in 2010 (Tenth Malaysia Plan) even though this Third NAP (1998-2010) was outlined with the purpose to enhance the farmers income through increases in food production.

While according to data from Farah et al. (2018) published in Malaysia is currently 65 to 75% sufficient in rice, with the remainder coming from Southeast Asian imports like Thailand, Cambodia, and Vietnam. As the majority of Malaysians use rice as their main staple meal, it is crucial to preserve its independence. The government's efforts to ensure Malaysia's rice self-sufficiency through the implementation of various policies and strategies in the rice production system are greatly assisting in maintaining the continuity of the rice supply to the nation's expanding consumer base and demand.

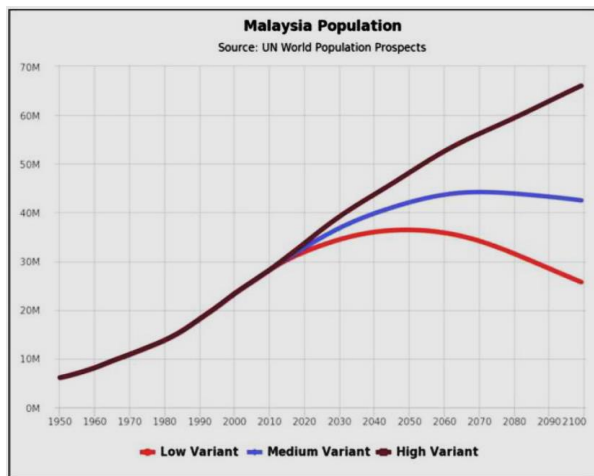
Malaysia's growing population is to blame for the rise in domestic consumption. In order to meet the demand for rice from the expanding population, as illustrated in Figure 8 (a) (Najim et al., 2007), it is imperative to maintain rice output. Currently, Malaysia produces about 75% of the rice needed for domestic consumption each year, with the remaining 25% coming from other nations like Thailand, Vietnam, and Pakistan. However, at slightly over 3 tonnes per hectare, the national average output is low. Thus, only 65 to 75% of domestic needs can be met by local production (Ministry of Agriculture & Agro-based Industry Malaysia, 2015). Therefore, imported rice is used to make up the difference, as indicated in Figure 8 (b).

To restore the remaining grain needed for domestic consumption, the nation cannot only rely on rice imports. This was demonstrated by the 2008 global food crisis that hit Asian nations and raised concerns because importers were reluctant to transfer their production outside of the region (Rashid and Dainuri, 2013). The significance of rice production in Malaysia has prompted our nation to develop policies on the sustainability of domestic rice production rather than relying on imports from abroad. The effects of the crisis on the rice production industry cannot be ignored by the government. In order to avoid dependence and guarantee an adequate supply for local consumers, Malaysia needs to have a strong policy in the rice production system if history is to be repeated (Farah et al., 2018).



**Figure 8:** (a) The trend of the population and domestic rice consumption; (b) The trend of local and import rice.

In 2015, Malaysia recorded a population of 30 million and is projected to continuously grow to reach approximately 43 million by the end of 2050, as shown in Figure 9 (UNDESA, 2015). Malaysia's population is growing at 2.7% per year. Therefore, an estimation of 45,000 tonnes of rice is required each year as stated by Chang (1983) to maintain the consumption, which is about 180,000 tonnes of rice per month. Two factors affecting the increasing demand for food supply are world population growth and rising domestic incomes (Azizan and Hussin, 2015). Through the New Economic Model (NEM) (2010-2020), Malaysia targets to increase self-sufficiency level by 85% to fulfil the nations demand (Ismail and Ngadiman, 2017).



**Figure 9.** Malaysia projected population 2005-2100. Source: UNDESA (2015).

The first National Agricultural Policy (NAP) in 1984 was focused on maximising agricultural income

by optimising rice productivity. Table 1 shows that at this time, the self-sufficiency level in the paddy sector had dropped to 65% from 90% (1976-1980). Concentration on food security encouraged Malaysia to focus on rice production during the first and second Malaysia Plan, through the New Economic Plan and the First Outline Perspective Plans (1960-1975). Malaysia successfully achieved 95% self-sufficiency in rice production in 1975 (Arshad, 1996). However, the Malaysian paddy market was forced to compete with other low-cost producing countries after globalisation and trade liberalisation agreements, which resulted in the rice imported from other countries being cheaper than the locally produced rice (Ismail and Ngadiman, 2017). No new changes introduced in First NAP (1984-1995), while in the second NAP (1992-2000), it was drafted to balance agricultural and manufacturing sector, developing food industry to the comprehensive and higher level, and sustainable agriculture sector. The rice self-sufficiency level was maintained at 65% with the argument to save cost with cheaper imported rice. The NAP was also introduced to private agencies to reduce government intervention in the paddy market.

In the third NAP (2001-2010), rice policies such as fertiliser and price subsidies were instituted to secure food security. At the end of 2010, Malaysia achieved 72% self-sufficiency, surpassing the target of 65% self-sufficiency. The NEM was drafted in 2010 to achieve a higher self-sufficiency goal of 85% by 2020. Table 1 report the self-sufficiency of rice in Malaysia from the year 1956 to 2010 (Arshad et al., 2010).

**Table 1.** Rice self-sufficiency in Malaysia (Arshad et al., 2010).

Malaysia Plan/ National Agricultural Policy (NAP)	Years	Self- sufficiency level (%)	Self-sufficiency achievement (%)
First Malaysia Plan	1956-1960	-	54.0
Second Malaysia Plan	1961-1965	-	60.0
First Malaysia Plan	1966-1970	-	80.0
Second Malaysia Plan	1971-1975	-	87.0
Third Malaysia Plan	1976-1980	90	92.0
<i>First National Agriculture policy</i>	<i>1984-1991</i>	65	75.9
Fourth Malaysia Plan	1981-1985	65	76.5
Fifth Malaysia Plan	1986-1990	65	75.0
Sixth Malaysia Plan	1991-1995	65	76.3
<i>Second National Agriculture policy</i>	<i>1992-2010</i>	65	65.0
Seventh Malaysia Plan	1996-2000	65	71.0
<i>Third National Agriculture policy</i>	<i>1998-2010</i>	65	71.0
Eight Malaysia Plan	2001-2005	65	71.0
Ninth Malaysia Plan	2006-2010	65	72.0
<i>Food Security Policy</i>	2008-2010	80	72.0
<i>New Economic Model</i>	2010-2020	85	75.0

Therefore, the policy changes were one of the actions that led to the success of the rice sector. For example, the World Bank and the Malaysian government together invested in the Federal Land Consolidation and Rehabilitation Authority (FELCRA) Seberang Perak Project where the government made policy changes in land planning, land reform, and resource allocation (Ismail and Ngadiman, 2017). The National Paddy and Rice Board (established in 1971) made a corporate body renamed as BERNAS in 1994 to improve the efficiency of processing and marketing of rice. BERNAS is involved in rice manufacturing, monopolising the import sector, licencing the paddy and rice traders, managing farmers' subsidies and transferring payments in the form of price subsidies to farmers (Ismail and Ngadiman, 2017).

### Factors Favouring Disease Development

The disease is also most likely to develop in areas that have weeds and stubbles of infected plants. It can occur in both tropical and temperate environments, particularly in irrigated and rain-fed lowland areas. In general, the disease favours temperatures of 25-34°C, with relative humidity above 70%. It is commonly observed when strong winds and continuous heavy rains occur, allowing the disease-causing bacteria to easily spread through ooze droplets on lesions of infected plants. Bacteria blight can be severe in susceptible rice varieties

under high nitrogen fertilization (Rice Knowledge Bank).

In addition, the disease could also be spread through the splashing of rainwater, especially when the leaves are injured due to the strong wind. Nevertheless, improper irrigation systems, flooding, infected farm equipment, contaminated seeds, and poor hygiene of field workers also contribute to the spread of the disease (Kogeethavani, 2017). Since all the existing rice varieties are moderately susceptible or susceptible to BLB disease, and the development of new resistant varieties is still in progress (MARDI), this could be the factor contributing to the severe BLB attack. Nonetheless, the use of illegal seeds that may have been contaminated with BLB also contributes as the inoculum source (Kogeethavani, 2017).

### Management Practices of Bacterial Leaf Blight (BLB) of Rice

#### *Cultural control*

Cultural practises are normally the removal of weeds and straw, diseased stubbles from the field, the use of healthy seeds, keeping the nursery beds above water level, avoiding the excessive use of fertiliser (NPK) and nitrogenous compounds using modern irrigation systems and proper drainage system (Tabei and Mukoo, 1960; Tabei, 1967).

### Physical control

The eradication of 95 to 100% of the bacterial blight pathosystem was attained in rice seed by twelve hours of soaking in a 0.07% solution of agrimycin, then moving the seeds into a 54°C water bath for 30 minutes followed by 8-10 hours of pre-soaking in water would give better results as compared to the control treatment (Srivastava and Rao, 1963). Besides, Jain (Jain, 1970) reported that physical control is normally carried out for seed disinfection before nursery sowing. For example, hot water treatment of rice seeds for about 30 minutes at 52°C followed by 8-10 hours of pre-soaking in water was found to be the most effective against BLB of rice. Zhang et al. (1996) reported that 2 to 3 washings of paddy seeds in distilled water after cleaning with either brine solution or 50 ppm suspension of zhongshengmycin could minimise the disease incidence of BLB in a field experiment, thus enhancing the germination percentage of the crop. Haq et al. (2006) also determined the effectiveness of paddy seed washing to reduce the frequency of deadly pathosystem of rice. An experiment conducted showed a significant reduction of BLB incidence in the field by washing the seeds with simple distilled water or with the brine solution.

### Chemical control

Ali et al. (2016) stated that an ideal agent for chemical control should be one that functions at low concentration by either killing or inhibiting the multiplication of the pathogen by blocking its important metabolic pathway. It should also be readily translocated and stable in the plant system with minimal damage to the environment.

In a study conducted by Nasir et al. (2019), the comparative efficacy of 3 antibiotics, namely Flare 72 WP (streptomycin sulphate), Cordate 4 WP (kasugamycin) and Castle 50 WP (kasugamycin + copper oxychloride) along with four fungicides; Copper oxychloride 50 WP (copper oxychloride), Nativo 75 WDG (Tebuconazole + trifloxystrobin), Gem Star Super 325 SC (azoxystrobin + difenconazole) and Bordeaux mixture, were studied as foliar spray applications against *Xanthomonas oryzae* pv. *oryzae* (Xoo) under natural environmental field conditions at a farmer's field at Faisalabad for 2 years (2012-2013). In general, all the treatments significantly reduced the incidence of BLB disease and improved rice yield higher than untreated control treatments (Nasir et al., 2019).

Halima et al. (2017) conducted a series of studies on the comparative efficacy of different chemical

treatments to control paddy blast, brown leaf spot, and bacterial blight in rice. The application of different fungicides to control the disease and their effects on paddy yield under field conditions were evaluated. The results demonstrated that the application of fungicide not only controlled the disease but also improved the paddy yield as compared to control. Application of Amistar Top 325 SC performed best to control the paddy blast. Switch DF 80 WG revealed the lowest incidence of disease along with the highest protection value of brown leaf spot, while Nativo was the most effective at controlling BLB infection.

### Biological control

Biological control is an environmentally friendly and cost-effective alternative to chemical control (Ali et al., 2016). It is the control of disease by the application of biological agents to a host animal or plant that prevents the development of disease by a pathogen (Philip, 2017). Biological control agents (BCAs) are used on crops to control pathogens through a variety of mechanisms, including interaction via plants metabolism (induce resistance or priming plants), indirect interaction with pathogens (nutrient competition), and direct interaction with pathogens (hyperparasitism and antibiosis by antimicrobial metabolites) (Jürgen et al., 2019). Bacterial antagonists of Xoo have received particular attention as biocontrol candidates, largely because of their rapid growth, easy handling, and effective colonisation of the rhizosphere (Vasudevan et al., 2002).

Abdallah et al. (Abdallah et al., 2019) conducted a study on the effects and mechanisms of *Paenibacillus polymyxa* Sx3 on growth promotion and suppression of BLB in rice. The results from a plate assay indicated that Sx3 inhibited the growth of 20 strains of Xoo, while rice seedling experiments indicated that Sx3 promoted plant growth and suppressed BLB. In 2018, a study carried out by Yadav et al. (2018) reported the efficacy of *Trichoderma* spp. to control major diseases of rice. In 2017, Pranamika et al. (2017) reviewed the potential role of *Pseudomonas fluorescens* in the suppression of the Xoo pathogen for management of bacterial blight. From laboratory and field assays, it is evident that *P. fluorescens* is an effective biocontrol agent against Xoo (Pranamika et al., 2017).

Yasmin et al. (2017) demonstrated that secondary metabolites produced by rhizospheric *Pseudomonas aeruginosa* strain BRp3 showed consistent pathogen suppression of different strains of BLB pathogen in rice. When it was used as an inoculant in a field trial,



this strain enhanced the grain and straw yields by 51% over the non-inoculated control (Yasmin et al., 2017). The results from the study provide evidence that novel secondary metabolites produced by BRp3 may have contributed to its activity as a BCA against Xoo and its potential to promote the growth and yield of Super Basmati rice. A study done by Noor et al. (2016) stated that several strains of actinomycetes are also capable of protecting plants against plant disease. In the study, a total of 8 isolates positively demonstrated the capability of controlling Xoo *in vitro* and 4 isolates significantly reduced the disease severity of BLB (Noor et al., 2016). According to Ahmed et al. (2015), *Bacillus* strains also showed efficacy in suppressing the growth of BLB and promoting the growth of rice plants. These *Bacillus* strains demonstrated a strong capability to produce indole3-acetic acid, siderophore, solubilize phosphate, and also colonise roots (Ahmed et al., 2015).

#### **Use of host resistance cultivars**

It is widely accepted to use resistant cultivars as a management strategy to reduce pests and diseases. In comparison to employing chemicals, this method is more affordable and safer for the environment. Varied *X. oryzae* individuals have been shown to exhibit different cultivar-specific infectivity patterns. (Mew et al., 1979; Eamchit and Mew, 1982). Using markers linked to the gene, (Naveed et al., 2010) identified the BLB disease resistance gene (xa5) in a single rice cultivar. Utilizing rice resistant variants is both more productive and economical. Using molecular methods, it is of utmost importance to find and include bacterial blight resistant or tolerance gene donors in commercial cultivars (Sayma et al., 2022).

#### **DISCLOSURE STATEMENT**

No potential conflict of interest was reported by Authors.

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#### **Natural harvests or botanicals extracts use**

Controlling BLB disease with natural remedies or plant extracts can be extremely important in preventing rice disease. Numerous botanical plant extracts were hostile to and considerably effective against *X. oryzae* (Xoo) (Sayma et al., 2022). The disease primarily affects nursery seedlings after transplantation and afterwards at the flowering stage. Its Kresek phase angle lasts for a longer time and is more destructive. Only a small number of chemical substances can effectively block the Xoo, but they are not economically advantageous and have negative long-term effects on soil and plant life. When Nutrient Agar well-plated technique is applied, (Manav and Thind, 2002). Manav and Thind's experiments from 2002 demonstrated that the botanical and novel chemical have antagonistic action against earlier isolates of BLB illness. The management of rice disease must include both novel chemical controls for BLB and botanical extracts (Singh et al., 2010). According to (Madhiazhagan et al., 2002), *Curcuma longa*, *Allium cepa*, *Prosopis juliflora*, and *Azadirachta indica* are not as effective at reducing BLB disease prevalence as *Adhatoda vasica* leaf extract. *Neemzal*, *triculture* (neem-based), ahook, neemgold, wanis (*Cymbopogon* sp), ovis (*Lantana camara*), and spictaf are some botanical extracts that reduced BLB incidence by 20%. (Eswamurthy et al., 1993; Sunder et al., 2001).

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