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Major Diseases Affecting Sugarcane Production in Indonesia

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ABSTRACT

Although a large number of sugarcane pathogens have been recorded in Indonesia, the current major sugarcane diseases affecting sugar production in Indonesia are ratoon stunting disease, smut, mosaic and leaf scorch. A new type of mosaic disease caused by *Sugarcane streak mosaic virus* is now widely distributed in most commercial sugarcane areas in Java (Indonesia). An integrated management strategy is used for controlling the disease and minimizing their impact on sugar production.

Keywords: control, leaf scorch, ratoon stunting disease, SCMV, SCSMV, smut

Abbreviations: CP, coat protein; **DNA**, deoxyribonucleic acid; **EB-EIA**, evaporative-binding enzyme-linked immunoassay; **HWT**, hot water treatment; **IPM**, integrated pest management; **ISRI**, Indonesian Sugar Research Institute; **PBST**, phosphate buffer saline tween; **RNA**, ribonucleic acid; **RSD**, ratoon stunting disease; **RT-PCR**, reverse transcription polymerase chain reaction; **SCMV**, *Sugarcane mosaic virus*; **SCSMV**, *Sugarcane streak mosaic virus*; **SDT**, simple direct tube

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INTRODUCTION

Sugarcane is one of important industrial crops in Indonesia, covering approximately 400.000 ha of land area with an average yield of 60-70 tonnes of cane per ha. Sugarcane is mostly cultivated under rain-fed conditions contributing to more than 60% of the sugar production. The sugar industry is spread across North Sumatera, South Sumatera, Java, South and North Sulawesi. Java is still the main area for commercial sugarcane contributing to around 65% of total cane production. In 2009, the 61 sugar factories crushed more than 30 million tonnes of cane, producing a sugar yield of 2.62 million tonnes (Anonymous 2010b), and in 2010 sugar production reduced to 2.56 million tonnes due to the wet climate during 2010 (Anonymous 2011).

Historically, disease of sugarcane cannot be separated with the development of sugar research in Indonesia. One of the causes for establishment of the Indonesian Sugar Research Institute (formerly *Het Proefstation Oost Java*) was the epidemic of sereh diseases in the 1880s which severely damaged sugarcane plants all over Java. After the introduction of the wonder cane - POJ 2878, that was resistant to sereh disease, there was a decline in the disease incidence (Handojo 1982).

More than 30 diseases of sugarcane caused by fungi, bacteria, viruses, nematodes and unknown causal agents have been recorded in Indonesia. During the last three decades, the major diseases affecting sugarcane production in Indonesia are ratoon stunting disease (RSD), smut, mosaic and leaf scorch. A new type of mosaic disease caused by *Sugarcane streak mosaic virus* (SCSMV) is now widely distributed in most of the commercial sugarcane areas in Java. Other diseases such as leaf scald, chlorotic streak disease, pokkah boeng and other foliar spot diseases are considered as minor diseases due to low level of incidence in the fields or no significant impact to sugar production.

RATOON STUNTING DISEASE

Ratoon stunting disease (RSD), caused by the bacterium *Leifsonia xyli* subsp. *xyli*, is the most prevalent disease in all commercial sugarcane fields in Indonesia, particularly on ratoon cane in the rain-fed areas. The disease was first reported in 1960 by Han (1960) and he gave it a local name "*Penyakit Pembuluh*". A survey by Legowo *et al*. (1978) indicated that RSD was found in most of the sugarcane plantations throughout Java in which 55% of all stalk samples showed RSD symptom. Commercial cane fields on the outside Java were also infected.

RSD is difficult to be diagnosed in the field due to no easily visible symptoms except stunting, which can also arise from other biotic and abiotic factors. The only other visible symptoms are red-orange dots or commas in vascular bundles in the nodal tissue, which can be seen when

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stalks are sliced open with a sharp knife. The symptoms generally occur in relatively matured stalk and less commonly in young stalks. The difficulties of RSD detection cause the occurrence of the disease in the fields, which is often neglected by cane growers.

RSD is mainly transmitted through infected cane cuttings and contaminated cutting tools and harvesters. The keys to control the disease are planting disease-free cane cuttings and preventing re-infection by disinfecting cutting tools and harvesting equipments. Provision of disease-free plant materials plays an important role in controlling RSD, because there are no commercial varieties that are resistant to the disease. RSD-free cane cuttings could be mainly obtained by subjecting cane cuttings to long hot water treatment at 50°C for 2 h (Gillaspie and Teakle 1989). Handojo *et al*. (1975) reported that the application of hot water treatment 50°C for 2 h on cane cuttings of first to third stage of cane nurseries can increase cane yield more than 12%, when compared with untreated cuttings. Furthermore, Irawan *et al.* (1985) in their study found that sugarcane crops will be free from RSD until the second ratoon cane, if the planting materials were hot water treated at 50°C for 2 h. The main problem for applying such method of control is a lack of hot water treatment units, particularly for farmers where their cane nurseries are far away from sugar factory and unfortunately not all sugar factories have the tank facility. This problem complicates successful management of RSD.

A survey conducted in 2000, revealed that the majority of commercial sugarcane areas in Java were still affected by RSD with an infection rate of 1.5-74% and mainly the disease infected cultivar M 442-51 in rain-fed areas (Putra *et al.* 2000). A further survey of RSD on cane nurseries conducted in 2003/2004 showed that the disease was detected using EB-EIA (evaporative-binding enzyme-linked immunoassay) technique in most cane nurseries in Java with the disease incidence 3-54% and most commercial cane varieties was infected by the bacteria (Putra *et al.* 2005). The results also revealed that during more than three decades, RSD has not been properly controlled and it was advised that serious efforts need to be undertaken in order to minimize the incidence of RSD in the fields.

To improve the management strategy, an integrated pest management (IPM) program for RSD which involves replacement of M 442-51 with other tolerant varieties, provision of disease-free planting materials, disinfection of cutting tools, inspection of plant sources for disease, improving certification scheme for seed cane and application of hot water treatment technique especially for first to fourth stage of cane nurseries had been implemented. Supported by the government in 2003, a program for varietal replacement, called *Bongkar Ratoon* (Ploughing Ratoon Cane) was launched as part of the acceleration program for increasing sugar production. By means of this program, farmers were subsidized by the government to plough their ratoon canes and replanting them with new varieties. In 2006, the Indonesian Sugar Research Institute (ISRI) distributed a moveable hot water treatment tank to ISRI's experiment stations to help farmers for obtaining RSD-free cane cuttings. The tank capacity is one tonne cane cuttings per day and can be operated in the fields using a portable electricity generator. Putra *et al*. (2009) proved that the application of such technology on the fourth stage of cane nurseries in three sugar factories effectively controlled RSD and can improve the quality of plantings materials.

To enhance the IPM program of RSD, a serological diagnostic technique, called evaporative-binding enzyme-linked immunoassay (EB-EIA), was applied to assist inspection and selection of the disease in cane nursery and to support a certification scheme of cane cuttings. The technique can also be used to monitor spread of RSD in the commercial fields. For the successful IPM of RSD, those approaches are socialized intensively to cane growers through a regular extension program. With those approaches, the RSD incidence in the first and second stage of cane nurseries seem to be gradually reduced (Marjayanti *et al*. 2009).

SMUT

Smut (*Ustilago scitaminea* Syd.) was first observed in Java in 1881, but the disease was not important here. In 1929, two samples of POJ 2878 with smut symptoms were sent to *Proefstation Oost Java* Pasuruan, and after that the disease was not reported again in Java (Handojo 1982). Since its disappearance for about half a century, smut incidence was recorded again in 1979 in the North of central Java. Within a few years, the infection rate of the disease was more than 40% in the centre of the affected area (Tjokrodirjo 1981). After 10 years, Suwarno *et al*. (1990) stated that the presence of smut in this area was considered minor due to the use of resistant clones. However, Putra (1995) reported that during 15 years after the outbreak in 1979, smut had extensively spread to all Indonesian sugarcane plantations except North Sulawesi. The disease commonly occurred in rain-fed areas and predominantly infected var. M 442-51, the most popular cultivar which occupied more than 60% sugarcane areas. In the 1990s, smut was considered to be the most important disease affecting sugar production in Indonesia.

The use of resistant varieties is the best approach for controlling smut disease. Since 1979, ISRI routinely carried out resistance evaluation trials against smut disease in Trangkil Central Java. For inoculation a dipping method was used by dipping two-budded cane cuttings in a teliospore suspension 5×10^6/ml water for 10 min. In view of lower incidence of smut incidence, since 1990 the trials were moved to Jatitujuh West Java, the new endemic area of smut disease. The trials resulted in several high yielding sugarcane varieties, which are relatively resistant or tolerant against smut such as PS 79-82, PS 864, PS 891, PS 951 and PSJT 941 (Putra and Irawan 1997; Wahyudi 2005).

A great effort through extension activities was conducted to socialize the control methods of smut disease. A special guide book informing how to identify, observe and control the smut disease was also distributed to cane growers. The main approach of smut control was the replacement of the susceptible varieties with more resistant varieties. To minimize the source of infection, an intensive rouging was recommended to remove and destroy infected stools. The use of fungicides was also suggested especially in endemic area by dipping cane cuttings in Score 250 EC or Bayleton 250 EC at 0.5 g a.i/l water for 45 min. This application protects the cane plants from smut infection for six months (Suwarno *et al.* 1991; Putra *et al.* 1995; Putra 1997). The main objective of such methods is to reduce the initial inocula and decrease the rate of disease development. Since the early 2000s, several new high yielding varieties were introduced to cane growers. Furthermore, with the program of ploughing ratoon cane conducted since 2003, several new resistant varieties such as PS 864 and PSJT 941 are now widely planted in rain-fed areas substituting the dominancy of M 442-51.

Based on a survey in 2000, it was reported that smut incidence in sugarcane plantations reduced gradually and high level of smut infection occurred only in a few sugarcane fields (Putra *et al*. 2000). An inspection on several cane nurseries in Java conducted by Putra *et al.* (2005) also indicated that the infection rate of smut disease was less than 2%. The recent survey in 2008 revealed that the average of smut incidence in commercial sugarcane plantations in Java was less than 5% and the disease could be observed throughout the year (Kristini *et al.* 2008).

MOSAIC DISEASE

There are two types of mosaic disease infected sugarcane plantations in Indonesia. They are an old mosaic disease caused by *Sugarcane mosaic virus* (SCMV) and a new type of mosaic disease known as a streak mosaic disease caused by *Sugarcane streak mosaic virus* (SCSMV), which was first observed in 2005.

Sugarcane mosaic virus

Mosaic disease is a viral disease of sugarcane first recognized in 1892 as an abnormality of sugarcane by Musschenbroek in Java. He named it "*gelestrepenziekte*" or yellow stripe disease (Abbott 1961). The disease is characterized by a pattern on the leaf lamina of contrasting shades of green, pale green or yellow areas. Mosaic patterns are more recognizable on younger leaves, particularly in the basal portion of the leaves, and tend to disappear on older leaves (Irawan 1993).

In the 1970s mosaic became a serious disease in most of the sugarcane plantations in Indonesia. At that time, POJ 3016, POJ 3067 and Ps 41, the major varieties planted were severely affected by SCMV. Consequently, the three varieties were gradually replaced by another resistant variety-M 442-51. It was estimated that the disease could reduce sugar yield by 10-22%, when the infection rate was more than 50% (Handojo *et al*. 1978).

SCMV can be transmitted mechanically through sap, infected seed cane and in a non-persistent manner by aphids. Transmission of mosaic through infected seed cane and by aphids plays an important role in the spread of the virus in field. The use of infected seed cane can cause the disease to spread rapidly and widely (Koike and Gillaspie 1989). In Java, *Rhopalosiphum maidis* Fitch. has been reported as the most important vector of SCMV. Several plants of the Poaceae such as maize, *Saccharum spontaneum* L., *Cynodon dactylon* Pers., *Dactyloctenium aegypticum* Willd. were also reported to be alternative hosts of SCMV (Handojo 1982).

Currently mosaic disease is present in all Indonesian sugarcane plantations. Three strains of the SCMV had been reported that infect sugarcane in Indonesia, namely strain A, B, and E (Gillaspie *et al*. 1986). There was no further report of any other new strains of SCMV in Indonesia. Until present, the three strains of SCMV are used for inoculation in the routine mosaic resistance evaluation trials using Sein leafslip method. The use of resistant varieties is the best method for controlling SCMV (Putra *et al.* 2007). Recently, most sugarcane varieties planted by cane growers were observed to possess a good resistance to SCMV. Compared to the new type of mosaic disease (SCSMV), the incidence of SCMV in the sugarcane fields are considerably lower.

Sugarcane streak mosaic virus (SCSMV)

Based on field surveys conducted by ISRI in 2005 and in 2007 (joint survey with Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural University (IPB)), a new type of mosaic disease with different symptoms of SCMV was reported. The typical streak mosaic along the leaf lamina is more obvious on upper leaves and milder on lower leaves (**Fig. 1**). The similar typical symptoms were observed in almost 59 sugarcane fields in Central and East Java. The mosaic disease predominantly infects sugarcane variety PS 864, that is known as a high yielding sugarcane variety, because of its high sugar content and high tiller numbers. Interestingly, the occurrence of the disease is higher in irrigated areas than rain-fed areas (Damayanti and Putra 2011).

It was suspected that new emergence of the mosaic disease might be as a risk of introducing varieties from different origin. Alternatively, the streak mosaic disease might already present previously, however it remains symptomless on widely cultivated sugarcane varieties and being undetectable. The streak mosaic symptom first recognized and more pronounce after variety PS 864 widely distributed in Java Island and outside Java since a few years ago. In Indonesia streak mosaic disease is considered to be a new disease. Therefore, to mitigate the impact of the disease on sugarcane production, studies related with its identification, bio-ecological characters and attempts to manage the disease are under progress.

Studies of transmission modes showed that the streak mosaic disease was transmitted by either mechanically or vegetative propagation through cane cuttings (sett-borne), suggesting the causal agent is a virus. Furthermore, the virus was also able to be transmitted *via* contaminated cutting knife during preparation of planting materials or harvesting. However, the virus was unable to be transmitted *via* insect vectors corn aphid (*Rhopalosiphum maidis*) and sugarcane wholly aphid (*Ceratovacuna lanigera*). The host range of the virus was narrow; with limited infection on some members of *Poaceae* such as sorghum, maize and weed growing in proximity to sugarcane fields *Dactyloctonium aegypticum* (Damayanti and Putra 2011).

RT-PCR (reverse transcription polymerase chain reaction) was used to determine the causal agent of the disease. There was no DNA fragment amplified by RT-PCR using primer specific to the coat protein (CP) gene of SCMV (data not shown), however a partial 500 bp DNA was successfully amplified by using a primer specific to SCSMV CP gene (**Fig. 2**). It is indicating that the streak mosaic disease on sugarcane in Indonesia caused by SCSMV rather

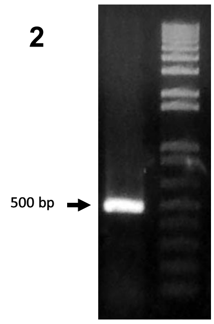

Fig. 1 Streak mosaic symptom on infected sugarcane var. PS 864.
Fig. 2 Electrophoresis of RT-PCR product of partial CP gene of SCSMV (lane 1), and a 100 bp DNA marker (InVitrogen) (lane 2). Arrow indicates a 500-bp DNA size.

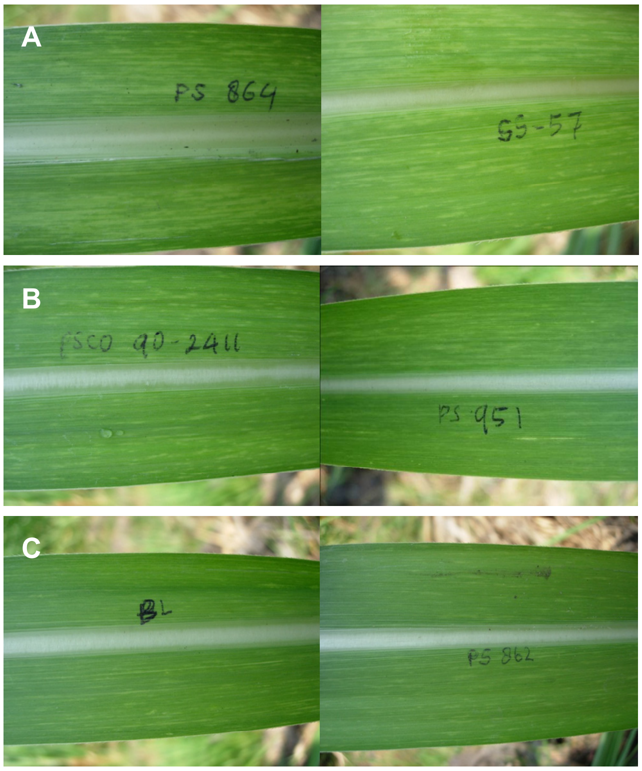

Fig. 3 Symptom variation of SCSMV Indonesian isolate on several sugarcane varieties. (**A**) Straight streak on var. PS 864 and SS-57 (Kenthung); (**B**) Moderate streak on var. PSCO 90-2411 (PSCO 902) and PS 951; (**C**) Mild streak on var. BL and PS 862.

than SCMV. The CP sequences alignment showed that SCSMV Indonesian isolate (AB563503) had highest CP nucleotide and amino acid homology to Pakistan isolate (U75456) up to 92.1 and 97.5%, respectively (Damayanti and Putra 2011). This was the first report of SCSMV in Indonesia. Recently, Li *et al.* (2011) identified the presence of a new strain of SCSMV in China in imported cutting-cane from Japan and Indonesia. The Indonesia isolate of SCSMV (ID) had CP gene homology up to 85.93% to that of Pakistan isolate. These suggested the presence of different strains of SCSMV from Indonesia. The same virus has been previously reported in several Asian countries such as Pakistan, India, Bangladesh, Sri Lanka, Vietnam and Thailand (Hall *et al*. 1998; Hema *et al*. 1999; Chatenet *et al*. 2005).

Based on the response of 10 commercial sugarcane varieties in Indonesia against SCSMV incidence and severity, it was concluded that PSCO 902 was resistant variety; PS851, PS 862, PS 951 and BL as moderately resistant varieties, while Kenthung (SS 57), PS 881, PSJT 941 and PS 921 were susceptible and PS 864 was considered as very susceptible variety against SCSMV infection. The study also revealed that there were three different phenotypes of streak mosaic symptoms: (1) straight streak type, (2) moderately streak and (3) mild streak (**Fig. 3**). It indicated that the intensity of symptom expression was related with the level of resistance in varieties. These data will valuable to develop resistance variety against SCSMV with high sugar content either through conventional plant breeding or *via* producing transgenic mother plant. Further, information of symptom variations on infected plants might be important for farmers or field supervisors to facilitate earlier diagnosis by recognizing the symptoms during field monitoring.

The data of recent survey conducted during milling season 2008/2009 showed that the majority of sugarcane areas in Java Island were infected by SCSMV except two sugar plantations in West Java i.e. Jatitujuh and Subang. The average of streak mosaic incidence in commercial sugarcane plantations ranged from 1 to 20%. Several fields were severely affected by the disease with infection rate of more than 50% (Anonymous 2010a). A site observation carried out in 2011 revealed that streak mosaic was found in sugarcane plantations in Jatitujuh West Java and Merauke Papua (Putra, unpublished data). The information on the impact of streak mosaic to sugarcane production is very limited. A preliminary study revealed that streak mosaic could reduce sugarcane yields to a tune of about 20% when infection rate is more than 50% (Asnawi 2009).

Some efforts were conducted to study the effectiveness of several control methods including the development of rapid detection method for routine detection and monitoring of the disease in the field. It is difficult to distinguish between healthy and infected canes visually. Since specific antibody is not available commercially yet, RT-PCR is the best detection method. However, for routine detection, a rapid and easy method in releasing total RNA from sugarcane tissues needs to be explored. Extraction of total RNA to get enough virus titre is a critical step in RT-PCR detection, as the total RNA extraction from sugarcane leaf, sheath and stalk was hampered by physical and chemical properties of sugarcane tissue. A comparison of several methods to get sufficient of total RNA from sugarcane tissues was tested. It was found that the simple direct tube (SDT) method adopted from Suehiro *et al*. (2005) with minor modification is the best method for extracting total RNA from leaf, stalk and sheath. The plant tissues were grinded in phosphate buffer saline tween (PBST). This method is easy, simple, cheap and results in reliable detection either one-step or two-step RT-PCR comparable as commercial kits for nucleic acid extraction (data not shown).

The following are the recommended practices for effectively managing the disease: 1) Detection of the virus in all sugarcane parts/tissues and from suspected reservoir plants like weeds using SDT method; 2) Avoidance of intercropping between maize and sugarcane, which is a very common cultivation practice in Indonesia (Damayanti and Putra 2011); 3) Use of disinfectant Lysol to disinfect cutting knife during preparation of planting materials or harvesting time. This practice effectively reduces the virus spread and infection; 4) Utilizing the rhizosphere, endophytic, decomposer bacteria isolated from sugarcane tissues and soils in combination application. It was able to attenuate symptom expression and decreased severity significantly in compared with untreated plants (Damayanti *et al*. 2011); 6) Application of hot water treatment (HWT) on cane cuttings, which could considerably reduce the disease severity (Damayanti *et al.* 2010). As with all plant diseases, virus diseases are often most effectively managed through a combination of strategies (Schuman and D'Arcy 2006). At the present, it is hard to find SCSMV-free cutting canes in Java, Indonesia. Thus, producing SCSMV-free sugarcane via *in vitro* meristem tip culture with additional anti-necrotic compound (Subba and Sreenivasulu 2011) must become a prominent effort to be addressed to manage the SCSMV. We are now studying the effective strategy for managing SCSMV by combining those methods of control.

LEAF SCORCH

Leaf scorch, a fungal disease caused by *Stagonospora sacchari* Lo and Ling, was first found in Indonesia at Gunung Madu Sugar Factory, South Sumatera in 1986. At that time, the varieties Ragnar and and SP 70-1284 were heavily infected (Handojo dan Irawan 1986). In the same year the disease was later also found at neighboring sugar factories such as Gula Putih Mataram, Bungamayang and Cintamanis (Kuntohartono *et al.* 1986). Leaf scorch was then reported in Aceh in 1995 (Anonymous 1995), in South Kalimantan in 1999 and in West Java in 2001 (Irawan and Putra 2002). In 2007 the disease was observed in North Sumatera and in 2008 was found in Central Java (ISRI, unpublished data). This data implied that the disease gradually became important. A progressive spread of the disease is related with the movement of cane cuttings among sugarcane plantations. Leaf scorch is not a systemic disease, but the habit of cane growers leaving the leaf sheath and leaf lamina when they are transporting cane cuttings causes the fungus on infected leaves could be transmitted to other areas.

Leaf scorch can cause significant yield losses especially in case of susceptible varieties. Suranto (1988) and Suranto and Harsanto (1989) reported that sugar losses due to this disease on some susceptible varieties such as Ragnar and SP 70-1284 could range from 17 to 37%, depending the age of the plants when they were infected. The use resistant variety is the most effective way to control leaf scorch and many resistant varieties are available such as PSBM 901 and *Kenthung* (SS-57). The incidences of leaf scorch in Sumatera are currently maintained in low to moderate level due to the cultivation of resistant varieties. However, the disease incidence could potentially become an outbreak especially when the climate is suitable for disease development. Meanwhile, in West Java the disease is now considerably disappearing after the replacement of susceptible varieties with the resistant varieties. Other methods of control are also suggested such as planting of disease free cane cuttings, field sanitation and application of fungicide. Several fungicides had been recommended for controlling leaf scorch namely: Benomil, Karbendazim and Mankozeb (Suranto and Harsanto 1989).

DEVELOPMENT OF DISEASE STATUS

Disease is one of our great concerns in affecting sugarcane productivity. Sugarcane diseases not only cause yield losses but also have a major impact in variety development program. Historically, planting susceptible varieties in a large area encouraged the outbreak of a certain diseases in a particular period of time. The shift in disease status often occurred because of the replacement of the susceptible variety with the more resistant ones. When a resistant variety can

Table 1 Major diseases and varieties during three decades.

Decade	Major diseases[1)]	Major varieties
1971-1980	Mosaic	POJ 3067
	Leaf scald	POJ 3016
	Ratoon stunting disease (RSD)	Ps 41
1981-1990	RSD	M 442-51
	Smut	F 154
	Leaf scorch (in certain area)	Ps 61
1991-2000	Smut	M 442-51
	RSD	F 154
	Leaf scorch (in certain area)	PS 77-1553
		PS 80-1424
2001-2011	Streak mosaic	PS 851
	RSD	PS 864
	Smut	PS 862
	Leaf scorch (in certain area)	PSJT 941
		BL

[1)] listed from the most important disease

suppress a certain disease, another disease would probably emerge as a new major disease. **Table 1** shows the development of sugarcane disease in Indonesia during four decades (1970-2010) in relation with the composition of the major varieties, and **Table 2** informs the rate of diseases resistance of the main varieties along the decades.

It can be seen from the two tables, during 1971-1980 mosaic (caused by SCMV), leaf scald and RSD were the major diseases of sugarcane. The main commercial clones planted in that decade i.e. POJ 3016, POJ 3067 and PS 41 were susceptible to SCMV and leaf scald, and it caused an outbreak of the two diseases in the field. The varieties were then withdrawn from commercial production and replaced by M 442-51 and F 154. As a result, SCMV and leaf scald gradually disappeared from commercial canes in the next period. Comparing with the previous period (data not shown), in this decade RSD was more prevalent in the fields indicating that the disease could become a considerable threat for sugarcane plantations.

Within years 1981-1990, RSD became the most widespread disease in sugarcane plantations due to an extensive cultivation of the highly susceptible variety M 442-51. During that period sugarcane was more commonly grown in the rain-fed areas and variety M 442-51 was the most popular and suitable cane for those areas. This situation caused RSD incidence was more widespread and cane growers commonly ignored the presence of the disease in their plantations. In line with the dominancy of variety M 442-51, smut incidence also increased rapidly and the disease became more rampant. This was a case that the substitution of the planted varieties could trigger the change of disease dominancy.

In the next decade (1991-2000), smut became the most prevalent sugarcane disease in Indonesia, because the major cane varieties planted by growers such as M 442-51, PS 77-1553 and PS 80-1424 were susceptible against smut disease. In this period M 442-51 was still dominant and it caused RSD and severe smut infection in nearly all sugarcane areas in Indonesia. Because of the more serious disease problem, a progressive effort to socialize and conduct integrated management for controlling the diseases was started in the end of this period. The replacement of the susceptible varieties was the main approach to overcome the disease problem.

In the period of 2000-2011 the program for disease management was continued. In line with the acceleration program to increase sugar production, a program for replacement of varieties known as *Bongkar Ratoon* (Ploughing Ratoon Cane) was launched by the Indonesian government in 2003. The main objective of this program is to replace the disease susceptible varieties such as M 442-51 with the new high yielding varieties combined with disease resistance. Through this program, cane growers are "forced" to cultivate the new varieties that have a good resistance against major disease particularly for smut and RSD. Combining with other methods of disease control such as intensive rouging, hot water treatment of cane cuttings, maintenance of disease-free nurseries and certification, inspection and monitoring program, smut and RSD incidence in the fields were observed to be considerably decreased. However, a new type of mosaic disease caused by *Sugarcane streak mosaic virus* emerged in the middle of this period. The disease infects most commercial varieties and predominantly on variety PS 864. A comprehensive research to investigate and control the disease is now under progress. To obtain high yielding varieties resistant to SCSMV, a resistance screening against SCSMV will be integrated into sugarcane breeding program started in 2012.

CONCLUSIONS

Sugarcane disease is one of our great concerns due to their impact on sugarcane productivity. More than 30 diseases have been reported in Indonesia, but only few diseases are classified as major diseases. The current important diseases affecting sugarcane production are ratoon stunting disease, smut, mosaic and leaf scorch. A new type of mosaic disease caused by *Sugarcane streak mosaic virus* is recently reported in most of the sugarcane plantations in Java. A concerted effort has been made to control the diseases and it is expected that the disease management would help in sustaining the sugarcane production in the country.

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Table 2 The rating* for disease resistance in major sugarcane varieties.

Variety	The rate of disease resistance
POJ 3016	Susceptible to SCMV and leaf scald, and considerably susceptible to RSD
POJ 3067	Susceptible to SCMV and leaf scald, and considerably moderate to RSD
Ps 41	Moderately susceptible to SCMV, resistant to leaf scorch, resistant to smut
M 442-51	Resistant to leaf scald, very susceptible to smut and leaf scorch, and considerably highly susceptible to RSD
F 154	Resistant to SCMV and leaf scald, moderate to smut, considerably moderate to RSD
Ps 61	Considerably susceptible to RSD, and susceptible to leaf scorch and smut
PS 77-1553	Very susceptible to smut
PS 80-1424	Susceptible to smut, resistant to SCMV and leaf scald
PS 851	Resistant to leaf scald and SCMV, and moderately susceptible to smut
PS 864	Very susceptible to SCSMV, moderately resistant to smut, resistant to leaf scald
BL	Considerably resistant to smut, susceptible to leaf scorch, moderately resistant to SCSMV
PSJT 941	Resistant to smut and leaf scald, susceptible to SCSMV
PS 862	Moderately resistant to SCSMV and smut, resistant to leaf scald, considerably moderate to RSD

* Rating is based on a quantitative data of resistance trials. A routine resistance trial is conducted yearly in ISRI to evaluate the response of cane clones against major diseases before releasing as commercial/high yielding varieties. Each disease has a certain scale or measure. RSD = Ratoon stunting disease; SCMV = *Sugarcane mosaic virus*; SCSMV = *Sugarcane streak mosaic virus*

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