the RICE TUNGRO VIRUS DISEASE

A Paradigm in Disease Management

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CHAPTER 11

COMPONENT TECHNOLOGIES FOR MANAGEMENT OF RICE TUNGRO DISEASE

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Disease management is achieved by the application of appropriate techniques to suppress disease to a tolerable level (Fry, 1982). Past efforts by plant pathologists to eradicate pathogens to control diseases have rarely been successful. As long as hosts for pathogens are cultivated, the pathogens usually can survive and the disease would persist. Thus, keeping the population of the pathogen under check so as not to cause economic losses to the crop is the present thrust in disease management (Chaube and Singh, 1991).

Strategies of disease management should be established based on the farmer's knowledge and on the cultural, genetic, economic, and environmental factors that influence crop production. The most appropriate management options should be determined within the framework of the crop production system.

Farmers in developing countries have difficulties in managing plant diseases. Because of their limited understanding on the disease processes, the management measures they adopt are often ineffective (Nagaraju et al., 2002, Nelson et al., 2001, Bentley and Thiele, 1999). Since disease management should be viewed in the context of crop production, scientists have to work with farmers to improve rice production through available management options. The measures should be simple, inexpensive, and within the limited technical and financial capability of the farmers. Available technologies for rice tungro disease (RTD) management are presented here for farmers, researchers, and extension workers in the tropics where RTD is a substantial threat in rice production.

Host Plant Resistance

Rice plants can show resistance to RTD if they are resistant to either the leafhopper vector or tungro viruses. Screening for RTD resistance and breeding for resistant varieties started in the 1960s. The first generation of resistant cultivars had only vector resistance because proper screening methods for virus resistance have not yet been established. Breeding materials were generally evaluated in the field. Cultivars resistant to leafhopper often escaped infection, and those which had a very low RTD incidence were selected as resistant cultivars (Hibino et al., 1987). Through the field screening, several resistant cultivars like Peta, Intan, Sigadis, TKM6, HR21, Malagkit Sungsong, Gam Pai15, Ptb18, Pankhari 203, and BJ1 were identified and used as donor parents for resistance (Khush, 1977). In the late 1960s and early 1970s when severe RTD epidemics occurred in Bangladesh, India, Indonesia, Malaysia, Philippines, and Thailand, the vector-resistant cultivars played a critical role in conditioning the outbreaks (Sogawa, 1976). Although leafhopper-resistant cultivars are still planted to manage RTD in many countries, the development of virulent leafhopper population (Rapusas and Heinrichs, 1982) and the breakdown of leafhopper resistance in some cultivars (Dahal et al., 1990; Hibino and Anjaneyulu, 1991) cast doubts on the durability of vector resistance.

Identification of two viruses causing RTD (Saito et al., 1975; Hibino et al., 1978) facilitated the development of cultivars resistant to tungro viruses. Sources of resistance to tungro viruses were identified (Hibino et al., 1990; Cabunagan et al., 1993, Koganezawa and Cabunagan, 1997) and genetic characteristics of tungro virus resistance in some cultivars were examined (Imbe et al., 1995, Sebastian et al., 1995, Zenna et al., 2006). Advanced breeding lines were developed utilizing the most promising sources of virus resistance (Angeles et al., 1998). The major advantage of breeding for resistance to viruses is that once a resistant cultivar is developed, the farmer virtually needs no further effort to control the diseases. Also, host resistance to viruses is selective and environmentally sound as compared to control by insecticides. Because of the successes in using resistant cultivars in managing RTD in different countries, current research for RTD management is primarily focused on virus resistance, which is assumed to be more effective and durable.

Cultivars and lines resistant to RTSV have been developed in the Philippines through conventional breeding. Virus infection in breeding lines was usually evaluated by serological tests (Tiongco et al., 1986; Hibino et al., 1988; Angeles et al., 1998). Several varieties confirmed to be resistant or tolerant to tungro viruses in multilocation trials have been deployed in Indonesia, India, and the Philippines (Cabunagan et al., 1999). These varieties have also been used in breeding RTD-resistant varieties in India (Chowdhury, 1999; Subramanian et al., 1999).

Table 1. RTSV resistant and RTBV tolerant varieties in the Philippines.

Variety	Line No.	Sourceofresistance	Reactiontotungroviruses
Matatag 1	IR69726-116-1-3	Utri Merah	Resistant to RTSV
Matatag 2	IR69726-29-1-2-2-2	Utri Merah	Resistant to RTSV
Matatag 3	IR68305-18-1-1	Balimau Putih	Tolerant to RTBV
Matatag 4	IR68305-18-1-2	Balimau Putih	Tolerant to RTBV
Matatag 9	IR73885-1-4-3-2-1-6	*O. rufipogon*	Tolerant to RTBV
NSIC 112	IR72102-159-1-3-3-3	*O. barthii*	Resistant to RTSV
NSIC 140	IR77298-5-6	Aday Sel.	Resistant to RTSV

These varieties were developed by crossing RTD-resistant cultivars/wild rice species with IR1561-118-3-3 and/or IR64 which have good eating qualities (Table 1). NSIC 112 and NSIC 140 were released to farmers in 2002 and 2006, respectively. The "Matatag" (a Pilipino word meaning durable) lines were distributed in RTD-affected areas as stop-gap cultivars to suppress the disease. Despite their resistance to RTD, Matatag 1 to 4 have unfavorable characteristics such as long maturity periods, tall stature, and low yields when RTD incidence is low. To overcome such drawbacks, Matatag 9 and NSIC 110, which have resistance to RTD as well as higher yield and good eating quality, were developed.

No true resistance to RTBV has been identified in any germplasm sources (Hibino et al., 1990; Koganezawa, 1998; Koganezawa and Cabunagan, 1998), probably due to the lack of a proper evaluation method for RTBV resistance. Application of the *Agrobacterium*-mediated transmission of RTBV (Sta. Cruz et al., 1999) may be of great use in the future to identify germplasm sources resistant to RTBV.

Development of virus resistance by transgenic approaches in rice (Hayakawa et al., 1992) and in other crops (Stark and Beachy, 1989; Dinant et al., 1993) has encouraged researchers to introduce resistance to tungro viruses by a similar approach. However, no transgenic rice plants showing reliable levels of resistance to tungro viruses have been developed (Azzam and Chancellor, 2002).

Leafhopper Vector Control

There are six leafhopper species that can transmit tungro viruses. The rice green leafhopper, *Nephotettix virescens* (Distant), is considered most important. Although, tungro viruses do not persist in the leafhopper vectors and are not transmitted transovarially, they are acquired and inoculated within a few minutes of feeding by the insects (Ling, 1966; Hibino, 1989). The short acquisition and inoculation feeding periods create a condition favorable for the rapid spread of the disease. For these reasons, vector control becomes an important means of managing the disease.

Controlling insects as vectors of plant viruses is a different and more difficult problem than controlling them as pests. To control insects as pests, their population should only be reduced below the damaging level. On the other hand, the presence of relatively few viruliferous leafhoppers may cause substantial spread of diseases in the fields (Satapathy, 1998). Direct damage due to feeding of leafhoppers is seldom significant in nature. Therefore, control is directed to leafhoppers that can transmit tungro viruses from diseased plants.

a. Insecticide application. Application of insecticides is the most common method of RTD management after crops are planted in the fields. In many countries where tungro is prevalent, farmers commonly apply highly toxic broad-spectrum insecticides that are targeted at a range of pests (Heong et al., 1994). Initial researches on RTD management used insecticides; various compounds were evaluated for their effectiveness in controlling leafhoppers (IRRI, 1974; 1975; Macatula et al., 1987). In the early stage of the Green Revolution, the use of insecticides was widely seen as an integral component of a package of inputs to successfully cultivate modern cultivars. Calendar spraying of insecticides was recommended in most countries. Sometimes insecticides were applied up to six times irrespective of the level of insect pest infestation (Teng, 1994).

The efficacy of a wide range of insecticides using different intervention strategies has been studied. In general, foliar insecticide applications that rely on contact action and show low persistency have limited effect in reducing RTD incidence (Chancellor et al., 1997). Applying chemicals in trap crops has been proposed (Saxena et al., 1988), but this approach has not been widely adopted by farmers. The use of granular applications to protect a healthy crop from primary infection has been advocated by some researchers. It was observed that application of compounds such as carbofuran and isoprocarb were most effective in reducing RTD infection because of their rapid activity and long persistency (Satapathy and Anjaneyulu, 1986). Insecticides were also applied to seedlings in the seedbed to avoid primary infection. However, such application was found to be ineffective because of very low infection rates in the seedbed (Tiongco et al., 1993).

The approaches to control leafhoppers with insecticides fall into two categories. The first is to eradicate the leafhopper vectors in infected fields to prevent them from migrating to neighboring fields. The second approach is to protect healthy crops from infection by killing immigrant viruliferous leafhoppers. Despite intensive efforts, however, controlling the vectors by insecticides is often not effective due to (1) the rapid spread of the disease because of the efficiency of leafhoppers as vectors, (2) the very short acquisition and inoculation feeding time of leafhoppers for tungro viruses, and (3) the continuous movement of leafhoppers from surrounding fields.

b. Biological control. Growing public awareness of insecticide hazards has led to the search for alternate or complementary strategy for leafhopper control. It was observed that various wasps and flies parasitize the leafhopper eggs, nymphs, and adults (Kiritani et al., 1971; IRRI, 1978; Chandra, 1979; Mieura et al., 1979). A number of predators, such as spiders and coccinellid beetles, were also reported to prey on the leafhopper nymphs and adults (IRRI, 1974; 1978; Bottenberg et al., 1990; Heong et al., 1992). Entomopathogens *Beauveria* and *Entomophthora* infect both nymph and adult of the leafhoppers in nature (Nayak and Srivastava, 1979; Li, 1988).

Although various natural enemies and biocontrol agents are teeming in the rice ecosystem, their role in regulating the population of leafhoppers is disturbed by the crop management decisions of the farmers. Their abundance in the field is influenced by practices such as time of planting, field sanitation, cropping space and density, and use of pesticides Because of the field activities that disrupt their population growth mechanisms, biological control agents may become sparse when they are needed.

Various attempts have been made to augment the population of biological control agents (Collier and Vansteenwyk, 2004). However, physical and financial constraints in raising their population in controlled conditions are common. Reports of unequivocal success after their release to the environment also remain in question. Because of such limitations, researchers adopt the preservation approach to maintain the natural population of biocontrol agents in the field. Preserving the field population of the natural enemies of leafhoppers involves knowing their seasonal abundance relative to the crop growth stages and management practices and to the judicious use of pesticides.

Cultural Management

Disease management by cultural methods is defined as the modification of certain farm operations to make the environment least favorable for the development of the disease but favorable for crop cultivation. The cultural practices of modern agriculture should not only cope with the plants' requirements but also affect the abundance of RTD and the leafhopper vector. Nevertheless, a range of cultural practices have been recommended for RTD management.

a. Synchrony of planting and provision of fallow period. When all farmers in an area plant rice at nearly the same time, a definite fallow period is observed between cropping seasons. The fallow periods can limit the spread of RTD because of reduced carry-over of inoculum sources and leafhoppers to the next crop (Loevinsohn, 1984). The leafhoppers can retain tungro viruses less than a week, thus a dry fallow period after harvest reduces the abundance of virus inoculum and vectors in the next crop. Fields planted very late relative to the neighboring fields face a high risk of RTD (Cabunagan et al., 2001; Chancellor et al., 2006) because of the build-up of infection in the crops planted earlier. Affected fields would then pose a threat to early plantings in the next season.

The adoption of synchronous planting has been successful in controlling RTD in South Sulawesi, Indonesia (Sama et al., 1991) and in Sabah, Malaysia (Hirao and Ho, 1987). Unfortunately, the implementation even in a limited area can be difficult due to various social and economic constraints. The demand for irrigation water, seeds, farm equipment, and labor force within a specific period in the cropping calendar puts severe pressure on the effective implementation of synchronous planting. Hence, farmers should plan and coordinate farm activities ahead of the planting period.

b. Time of planting. The seasonal patterns of leafhopper abundance and tungro incidence are important factors in determining the most appropriate planting time to avoid the disease. Figure 1 shows the relationship among the planting time, leafhopper abundance, and level of RTD incidence in Maros and Lanrang, South Sulawesi, Indonesia to avoid high RTD incidence. In Maros, planting was set from December to January for the wet season, and from June to July for the dry season. In Lanrang, planting was from mid-April to mid-June for the wet season, and from mid-October to mid-December for the dry season crop (Sama et al., 1991). Though planting at certain months of the year seems effective in reducing RTD incidence, circumstances such as late monsoon, shortage of irrigation water, flood, and typhoon may compel farmers to plant late.

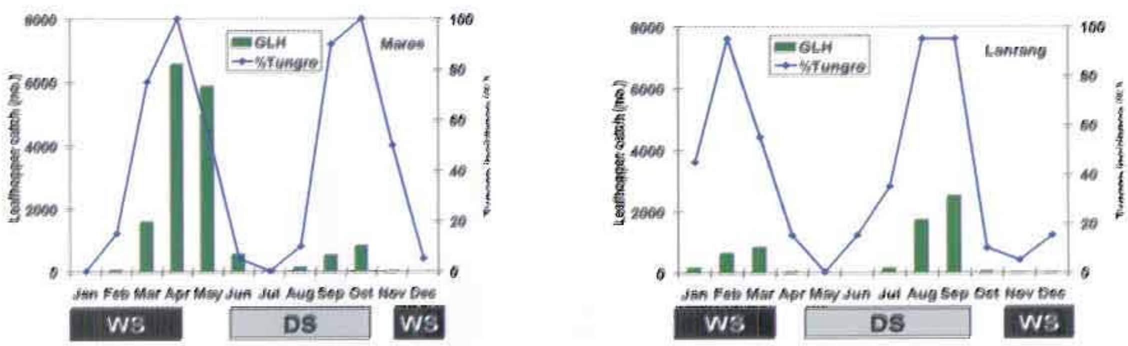

Fig. 1. Cropping pattern for the wet (WS) and dry seasons (DS) in Maros and Lanrang, South Sulawesi, Indonesia based on RTD incidence and leafhopper population.

c. *Crop space and density.* RTD incidence is usually lower in direct-seeded than in transplanted rice (Tiongco et al., 1990) because of the dense plant population that reduces the chances for the leafhoppers to find and feed on diseased plants.

d. *Sanitation.* To reduce inoculum sources and to destroy the eggs and breeding sites of leafhoppers, plowing under of stubbles/ratoons and volunteer rice is recommended especially when the previous crop was infected. Plowing should be done immediately after harvest or before seedbed establishment. The practice may be difficult for some farmers because it involves extra expenses and it depends on the availability of water.

While removing of diseased plants (roguing) to reduce foci of infection is commonly recommended, this practice is not effective if the incidence is already high (Tiongco et al., 1998). Removing diseased plants is generally ineffective because other plants may be latently infected. Pulling out infected plants may disturb leafhoppers and make the disease spread faster.

e. *Cultivar diversification.* Planting of different proportions of an RTD-susceptible (TN1) and a tolerant (IR20) cultivar in the same field have shown that RTD incidence in IR20 increased as the population size of TN1 increased (Shukla and Anjaneyulu, 1982). Cabunagan and Choi (2005) assessed the effects of mix-planting of a resistant (Matatag 9) and a susceptible (IR64) cultivar on the RTD incidence in the Philippines. Their results showed that the reduction of RTD incidence in the mix-planting was greater than that expected from the proportion of resistant component in the mixture (Fig. 2).

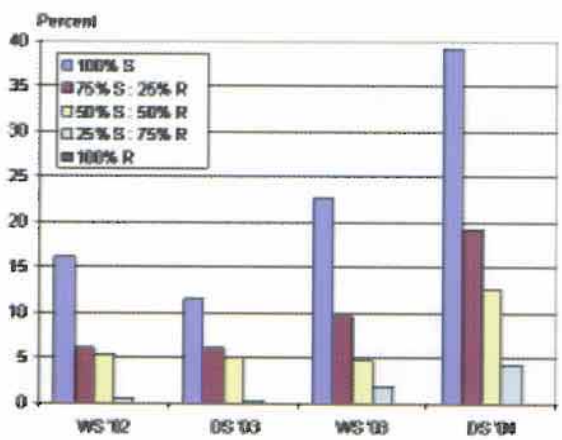

Fig 2. Percent RTD incidence in monoculture and mixed planting of a resistant line (Matatag 9) and a susceptible (IR64) variety in Iloilo, Philippines, wet (WS) and dry seasons (DS) from 2002-2004.

A Case Study - Integrated RTD Management in South Sulawesi, Indonesia

In 1972-1975, serious outbreaks of RTD occurred in South Sulawesi, Indonesia. An integrated management scheme was developed and first practiced in 1983 (Sama et al., 1991). The strategy had three components: (1) appropriate planting time for wet and dry seasons, (2) rotations of varieties with resistant genes to green leafhoppers (GLH), and (3) use of insecticides.

Because of the fairly uniform fluctuation in GLH population and RTD incidence observed in the area, year to year recommendations on the planting dates could be formulated. The planting dates were set so that the rice plants would be in the late tillering or flowering stage and less susceptible when high GLH population may develop in the field. The time of planting was further adjusted on the time for the variety to reach maturity so that harvesting occurs almost simultaneously.

The range of recommended planting dates to ensure uniform synchronous planting in an ecological area was about three weeks for a wide area (e.g., town). However, the range could be as short as 10 days in a small area (e.g., village). Under such recommendations, 90% or more of the farmers in wide areas practiced synchronous planting at the appropriate time. Thus, there were fewer areas planted late, and dry fallow periods between crops were established in the areas.

GLH-resistant varieties were rotated to avoid the emergence of virulent biotypes of *N. virescens*. Varieties were grouped into four based on resistance traits to *N. virescens* and reaction to RTD. Varieties under the different categories were deployed in an appropriate rotation cycle depending on the RTD situation in an area. After the rotation scheme was implemented, the use of insecticides was drastically reduced. Insecticides were only applied to eradicate GLH in the infected field so that they will not migrate to neighboring fields.

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