YIELD LOSS DUE TO RICE VIRUS DISEASES IN ASIAN TROPICS

P.S. Teng*,
H. Hibino and H. Leung****

ABSTRACT

The quantitative relationship between tungro infection and yield components of rice was evaluated using a modified single tiller approach. Yield loss per hill and per panicle varied depending upon the symptom severity and height reduction in infected IR64. Losses ranged from 1.1 to 99.1% per hill and 1.0 to 96.1 per panicle. Losses in 1000 grain- weight ranged from 13.5 to 57.8%. Field grain percentages were higher in healthy than infected plants. Yield loss per hill and panicle was positively correlated with height reducticn and symptom severity. Height reduction and symptom severity were significantly correlated with biomass. Regression equations were developed with different combinations of dependent and independent variables.

Grain yield reduction due to the tungro-associated viruses and ragged stunt virus in plants varied depending on the cultivars and growth stage when the plants were infected. The reduction was generally high when the plants were infected at 1-5 wk after soaking. The reduction was 17-97% in plants infected with both rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV), 12-90% with RTBV, 1-40% with RTSV, and 22-100% with rice ragged stunt virus. Cultivars with a lower yield reduction showed milder symptoms and contained a lower amount of virus in plants.

Introduction

Rice virus diseases have become increasingly important since the mid 1960s. Tungro, grassy stunt, and ragged stunt are the major virus diseases occurring in the Asian Tropics. Occurrence of dwarf, gall dwarf, transitory yellowing, and necrosis mosaic has been reported in these areas but the incidence has remained low. Of the three major virus diseases, tungro is the most important one in many countries. Tungro outbreaks occurred in 1969 in Bangladesh; 1969 and 1984-1985 in India; in 1969-1971, 1972-1975, 1980 and 1983-1984 in Indonesia; in 1969 and in 1992-1983 in Malaysia; in 1957, 1370-1971, and 1983-1984 in the Philippines, and in 1965-1970 and 1979 in Thailand. Grassy stunt oubreaks occurred in India, Indonesia, Philippines, and Thailand during 1972-1978. Ragged stunt outbreaks occurred in 1977-1979 in Indonesia and Philippines, and in 1980-1982 in Thailand. After 1982, grassy stunt and ragged stunt incidences declined to a low level and have not become economically important in some countries.

Grain yield loss due to tungro

Tungro can potentially cause total yield loss because of the lack of effective and corrective measures. Following outbreaks of the disease in Malaysia, surveys showed that the disease caused only localized damage, and when losses were averaged over production regions, the average loss was less than 1% during 1981-84 (Heong and Ho, 1986). Chang *et al.* (1985) estimated tungro induced losses at M$ 21.6 million from an affected area of 17,628 ha in 1982. Tungro had caused total crop loss in Indonesia (ca. 21,000 ha, 1969-71), 40%-60% loss in Bangladesh and about 50% in parts of Thailand

* Plant Pathologist,
** Plant Pathologist and Department Head,
*** Associate Plant Pathologists, Department of Plant Pathology, International Rice Research Institute, P.O. Box 933, Manila, Philippines.

(Reddy, 1973; Wathanakul and Weerapat, 1969). In the Philippines "aksip na pula" or "red disease" (Serrano, 1957) probably tungro, caused annual losses of about 30%, an equivalent of 1.4 million tons of rough rice every year in the 1940s. In 1971 yield losses due to tungro in the Philippines were estimated at 456,000 tons of rough rice (1971, IRRI Annual Report).

Tungro is known to cause differential losses in rice depending on the duration and onset of infection (Riessig *et al.*, 1986). Decreasing infection onset from about 10 days after sowing to about 75 days after sowing reduced losses from 70% to 5% (Ling and Falomar, 1966). A similar study in India using a susceptible variety showed yield losses of 83.3%, 74.1%, 59.3% and 40.7% with infection occurring at 30 days after transplanting, 45 DAT, 60 DAT and 75 DAT, respectively (John and Ghosh, 1980).

A critical point model developed by Valencia and Mochida (1985) estimated yield reduction from a potential uninfected hill as follows:

Yield (t/ha) = 4.04 - 0.04* (% infected hills at 40 DT).

In a recent study at IRRI, individual tungro-infested hills in close proximity to healthy plants were selected and labeled (Nuque *et al.*, 1988). Symptom severity and height of infected plants as well as healthy plants were recorded and compared. Data on tiller number, percentage of filled grains, 1000 grain weight, grain yield per hill, and biomass were recorded. Results showed that yield losses per hill and per panicle varied depending upon the symptom severity and height reduction of tungro infected IR64 plants (Nuque *et al.*, 1988). Losses ranged from 1.1-99.1% per hill and 1.0-96.1% per panicle. Losses in 1000 grain weight ranged from 13.5 to 57.8%. Filled grain percentages were higher in healthy than in infected plants. Yield losses per hill and per panicle were positively correlated with height reduction and symptom severity. Likewise, height reduction and symptom severity were significantly correlated with biomass.

The generalized regression model is Y = Bo + B1X + B2Z,
where X = 1000 grain weight and
Z = percent filled grains.
The specific models developed are:
LH (%) = 100.31 + 0.0007 (X) + (-0.51260 (Z)
where LH = Grain weight % loss/hill, and
LP (%) = 80.27 + 0.0039 (X) + (-0.9541) (Z),
where Lp = Grain weight % loss/panicle.

Grain field reduction in artificial infection

1 Tungro

Tungro is a composite disease associated with rice tungro bacilliform virus (RTBV) and rice tungro spherical virus (RTSV) (Hibino *et al.*, 1978; Omura *et al.*, 1983). RTSV spread as an independent disease in South and South-East Asia and Japan (Bajet *et al.*, 1986). In Japan, the disease was called rice waika disease (Furuta, 1977). RTBV is dependent on the presence of RTSV for its transmission by the leafhopper (Hibino *et al.*, 1978).

Generally, the symptoms are severe on plants infected with both RTBV and RTSV, milder on plants with RTBV alone, and almost inexistent on plants with RTSV alone (Hibino *et al.*, 1978; Hasanuddin *et al.*, 1988). Doubly infected plants show no clear symptoms in cultivar Balimau Putih, light green coloration in Utri Rajapan, mild yellowing in Sigadis and Palasithari, and a severe yellow-orange discoloration and stunting in the other cultivars (Hasanuddin *et al.*, 1988). RTBV-infected plants show no clear symptoms in Balimau Putih, Sigadis, and Utri Rajapan; mild discoloration and stunting in IR36, IR54 and TN1 and severe discoloratin and stunting in BW272-6B and FK135. RTSV-infected plants of all cultivars show no discoloration but very mild stunting.

Table 1 Symptoms and plant height reduction at 3 wk after infection and grain yield reduction in plants of 6 cultivars infected at one wk after soaking with both RTBV and RTSV, RTBV alone, or RTSV alone (Hasanuddin *et al.*, 1988)

Cultivar	Virus	Symptoms[y]	Height reduction (%)	Yield reduction (%)
Balimau Putih	RTBV + RTSV	-[z]	9.2	19.9
	RTBV	-	3.3	17.1
	RTSV	-	1.5	7.2
BW272-6B	RTBV + RTSV	S.Y.D.	62.6	94.2
	RTBV	S.Y.	59.4	81.9
	RTSV	-	16.3	14.5
FK135	RTBV + RTSV	S.Y.I.D	72.0	99.0
	RTBV	S.Y.I.D	68.2	98.0
	RTSV	-	2.9	19.5
Palasithari	RTBV + RTSV	S.Y.I.	36.9	33.5
	RTBV	S.Y.	34.6	20.6
	RTSV	-	4.5	10.1
Sigadis	RTBV + RTSV	S.Y.I.	16.9	30.7
	RTBV	-	13.5	23.9
	RTSV	-	11.2	9.1
Utri Rajapan	RTBV + RTSV	s.t.	29.4	28.8
	RTBV	-	21.8	16.8
	RTSV	-	2.3	1.6
TN1	RTBV + RTSV	S.Y.I.	71.8	97.4
	RTBV	S.Y.I.	49.1	94.7
	RTSV	-	3.7	19.5

[y]S, severe stunting; s, mild stunting; Y, yellow orange discoloration; y, mild yellowing; I, interveinal chlorosis; D, drooping of leaves; t, reduced tillering.
[z]No clear symptoms.

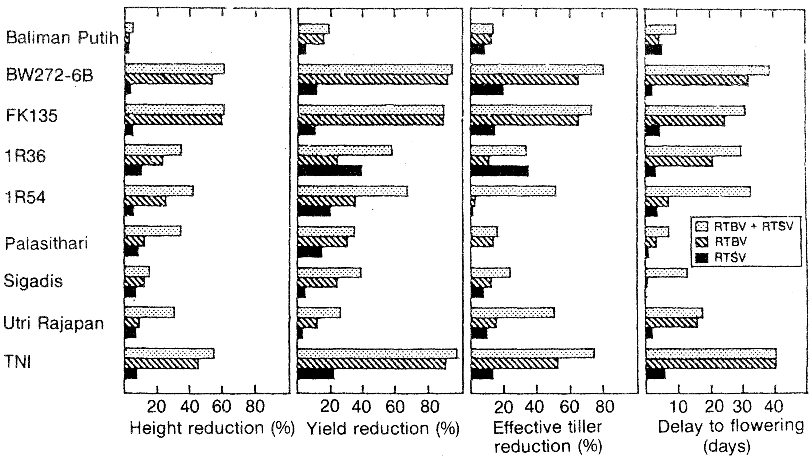

Fig. 1 Reduction in plant height and grain yield, and delay in days to first flowering in plants of 9 cultivars infected at 1 wk after soaking with both RTBV and RTSV, or RTBV or RTSV alone (Hasanuddin, 1987).

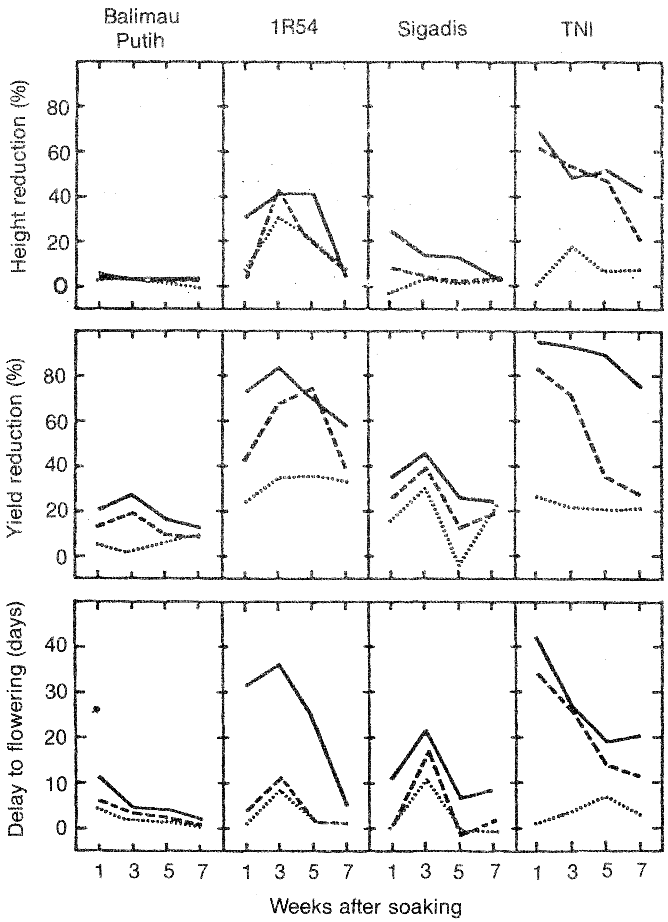

Fig. 2 Reduction in plant height and grain yield, and delay in days to first flowering in plants of 4 cultivars infected at 1, 3, 5, or 7 wk after soaking with both RTBV and RTSV, or RTBV or RTSV alone (Hasanuddin, 1987).

Symptom severity on seedlings at 3 wk after infection and grain yield reduction are correlated in tungro infected rice (Table 1).

Yield components and height reduction at 9 wk after infection in plants infected with either both viruses or RTBV or RTSV alone were compared (Hasanuddin, 1987). Yield reduction in infected plants resulted mainly from high reduction in effective tiller number, filled grain number per hill, and filled grain number per panicle, and from greater delay in days to flowering (Fig. 1). Irrespective of virus species in plants, Balimau Putih showed the least reduction in grain yield (Fig. 1), followed by Utri Rajapan, Palasithari and Sigadis. Grain yield reduction in plants of BW272-6B, FK135 and TN1 infected with RTBV and RTSV, or RTBV alone was as high as 90%. The reduction in RTSV-infected plants was 40% in IR36 and about 20% in IR54 and TN1. High yield reduction in RTSV-infected IR36 and IR54 resulted mainly from a high percentage of unfilled grains.

Grain yield reduction was generally higher in plants infected at 3 wk after soaking than in plants

Table 2 Absorbance at 405 nm in ELISA of extracts from plants of cultivars tolerant (upper 5) or non-tolerant (Lower 5) of tungro at 3 wk after infection with both RTBV and RTSV when tested for RTBV and RTSV antigen (Hasanuddin, 1987)

Cultivar	Plants tested (No.)	Absorbance at 405 nm RTBV	RTSV
Balimau Putih	7	0.27 ± 0.29	0.36 ± 0.09
Betriko	9	0.79 ± 0.41	1.04 ± 0.34
Tjempo Kijik	7	0.62 ± 0.40	0.37 ± 0.11
Utri Merah	2	0.32 ± 0.07	0.30 ± 0.03
Utri Rajapan	4	0.62 ± 0.15	0.30 ± 0.03
Cera Sentra	11	1.73 ± 0.56	0.32 ± 0.08
FJ135	5	0.96 ± 0.57	0.22 ± 0.09
IR54	4	1.75 ± 0.22	0.60 ± 0.03
Tjempo Kamali	7	1.43 ± 0.22	0.44 ± 0.04
TN1	9	2.19 ± 0.42	0.48 ± 0.03

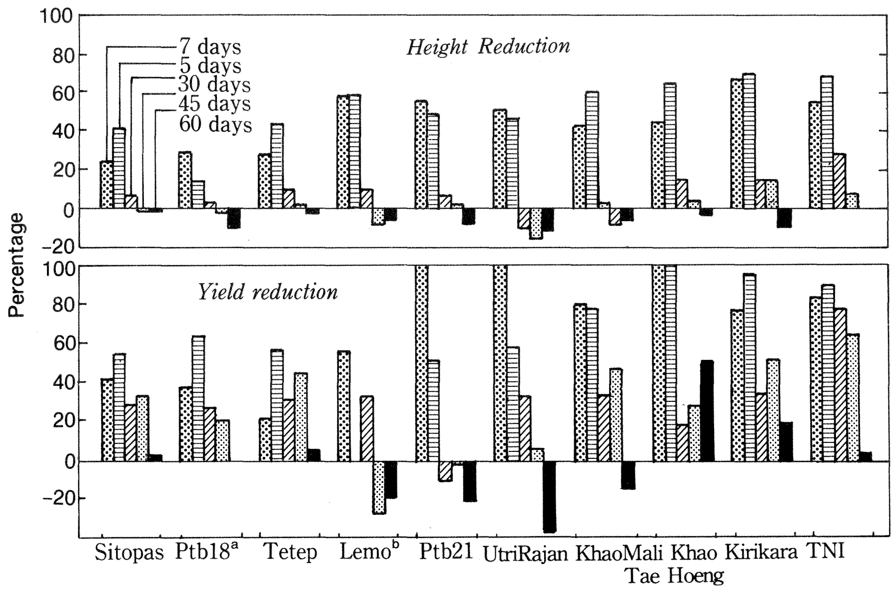

Fig. 3 Reduction in height at 30 days after infection and grain yield reduction in plants of 10 rice cultivars infected with RRSV at 7, 15, 30, 45, or 60 days after soaking (Parejarearn *et al.*, 1987b).

infected at 1 or 5 wk after soaking (Fig. 2). Yield reduction in plants infected with both viruses at 7 wk after soaking was about 80% in TN1, 60% in IR54, 25% in Sigadis and 10% in Balimau Putih.

RTBV concentration in plants infected with both RTBV and RTSV was low in cultivars with tolerance (symptomatic resistance) to tungro, but high in non-tolerant cultivars (Table 2).

2 Ragged stunt

Grain yield reduction in plants infected with rice ragged stunt virus (RRSV) also differed depending on the cultivar and plant age when infected (Parejarearn and Hibino, 1987b). The reduction was lower in cultivars that showed milder symptoms when infected (Fig. 3). Generally, the reduction was high in plants infected at 1-2 wk after soaking and less in plants infected later. Virus concentration in infected plants was lower in cultivars with tolerance to RRSV (Parejarearn and Hibino, 1987a).

Conclusion

An understanding of the mechanisms of yield loss caused by virus diseases can lead to improved methods of resistance screening and disease management. There is still relatively little quantitative information on the field losses due to virus diseases, or on the virus-loss relationships. We hope that this workshop will stimulate collaborative research on this important subject.

References

1) Bajet, N. C., Aguiero, V. M., Daquioag, R. D., Jonson, G. B., Cabunagan, R. C., Mesina, E. M., and Hibino, H. (1986): Occurrence and spread of rice tungro spherical viruses in the Philippines. Plant Dis., 70, 971-973.
2) Chang, P. M., Hashim, H., Omar, O., Abdullah, S., and Mohd. Amin, S., (1985): Penyaki Merah Virus disease of paddy — the problem and strategy for disease control in Malaysia. Integrated Pest Management in Malaysia. Edited by: Lee, B.S., Loke, W.H., and Heong, K.L., pp. 159-182. MAPPS/MARDI.
3) Furuta, T. (1977): Rice waika, a new virus disease found in Kyushu, Japan. Rev. Plant Prot. Res., 10, 70-82.
4) Hasanuddin, A., Daquioag, R. D., and Hibino, H. (1988): New scoring method for resistance to tungro. Int. Rice Res. Newsl. 13. (In press).
5) Hasanuddin, A. (1987): Effect of tungro-associated viruses on symptomatic resistance in rice to symptoms and yield in rice and development of a scoring system. Ph D. Thesis, University of the Philippines, Los Banos. 151 pp.
6) Heong, K. L. and Ho, N. K. (1986): Farmers' perceptions of the rice tungro virus problem in the Muda irrigation scheme, Malaysia. In: Integrated Pest Management: Farmers' Perceptions and Practice. Edited by: Tait, J., Bottrell, D., and Napompeth, B. (In press).
7) Hibino, H., Roechan, M., and Sudarisman, S., (1978): Association of two types of virus particles with penyakit habang (tungro disease) of rice in Indonesia. Phytopathology, 68, 1412-1416.
8) John, V.T. and Ghosh, A. (1980): Estimation of losses due to tungro virus. In: Assessment of losses due to pests and diseases. Edited by: Govindu, H. C., Veeresh, G. K., Walker, P. T., and Jenkyn, J. F., pp. 225-231. Bangalore, University of Agricultural Sciences.
9) Ling, K. C. and Palomar, M. K. (1966): Studies of rice plants infected with the tungro virus at different ages. Philip. Agr., 50, 165-177.
10) Nuque, F. L., Magnaye, A. J. P., Salamatin, C. S., and Teng, P. S. (1988): Rice yield loss caused by tungro using a modified single tiller method. Paper presented at the Annual Convention of the Pest Control Council of the Philippines, Cebu City, May 3-7, 1988.
11) Omura, T., Saito, Y., Usugi, T., and Hibino, H. (1983): Purification and serology of rice tungro spherical and rice tungro bacilliform viruses. Ann. Phytopath. Soc. Jpn., 49, 73-76.
12) Parejarearn, A. and Hibino, H.(1987a): Ragged stunt virus (RSV) concentration in tolerant rice. Int. Rice Res. Newsl., 12 (4), 14.
13) Parejarearn, A. and Hibino, H. (1987b): Symptoms and yield reduction in tolerant varieties infected with ragged stunt virus (RSV). Int. Rice Res. Newsl., 12 (4), 14-15.
14) Reddy, D. B. (1973): High yielding varieties and special plant protection problems with particular

reference to tungro virus of rice. Int. Rice Comm. Newsl., 22z (2), 34-42.
15) Riessig, W. H., Heinrichs, E. A., Litsinger, J. A., Moody, K., Fiedler, L., Mew, T. W., and Barrion, A. T. (1986): Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia. IRRI, Los Banos, Philippines.
16) Serrano, F. B. (1957): Rice "accep na pula" or stunt disease — a serious menace to the Philippine rice industry. Philippine Journal of Science, 86, 203-230.
17) Valencia, S. L. and Mochida, O. (1985): Rice whorl maggot (RWM) effect on yield loss. IRRN, 10(3), 30.
18) Wathanakul, L. and Weerapat, P. (1969): Virus diseases of rice in Thailand, pp. 79-85. In: IRRI. The virus diseases of the rice plant. Proceedings of a symposium at the International Rice Research Institute, April, 1967. The Johns Hopkins Press, Baltimore, Md. 354 pp.

Discussion

Thresh, J.M. (UK): I am not sure that I understand the problem posed by the speaker. To assess loss for any particular variety and season, I would want to know when the plants became infected, the number of plants infected on each sampling occasion and whether the infected plants were isolated or alongside infected neighbours. Is there a problem in experimentation due to the practice of planting more than one seedling per hill?

Answer: The problem I posed concerns the short "management window" of RTV, i.e. 0-40 days after sowing (approximately). During this short period, the spatial pattern of the plants with RTV symptoms is still very clumped. Hence to estimate the RTV-loss potential early in the seasons implies that we have to deal with the highly variable number of clumps (foci) and the severity of the disease in each clump. The severity-loss relationship is in turn a basis for evaluating the economic threshold of the green leafhopper (GLH). The problem is that the relation between the incidence and the severity is not clear enough to set up an index and that the yield reduction is striking.

John, V.T. (IITA): You have highlighted the same issue of deciding whether the incidence and severity should be evaluated by a two digit score, one for the incidence and the other for the severity. Also the assessment in the field is complicated in tungro by management problems. For instance nitrogen deficiency can be mistaken for tungro.

Answer: I agree that other symptoms can be confused with RTV, hence the need for serological methods. The incidence-severity relationships are difficult to define and require much research effort. The SES scale was mainly designed for screening seedlings. The problem of management complicates the issue.

Fajemisin, J.M. (IITA): I would like to give an example in the case of maize. Maize streak is transmitted by a leafhopper, *Cicadulina*. There is a clear difference between the resistant and susceptible varieties as the former show mild symptoms. The resistant plants also display a low incidence of infection, suggesting that in the susceptible varieties the incidence of visits of the vector is higher. How do you interpret the role of the vector in translating the disease effect through the incidence and severity of the disease?

Answer: There are few data on the incidence-severity relationship in cultivars in terms of tolerance or resistance to the leafhopper.

Hibino, Y. (IRRI): Comment: Varieties react differently to tungro infection. There are varieties which show mild symptoms. Generally the yield reduction is correlated to the symptom severity. Regardless of varieties, yield loss can be assessed based on the symptom severity and incidence.

Nagarajan, S. (India): The same problem arises when one looks at other tropical crops. In the case of cereals such as rice and wheat three reactions are scored, prevalence, severity and host-pathogen interaction. The 0-9 scale for scoring genotypes for resistance is not suitable for epidemiological purposes and yield loss studies. The scale should be resolved to resolve the loss. I would like to suggest that an integrated scale with three subscales should be developed as follows: 1. Severity rating on host leaf for host-pathogen interaction. 2. Rating of the whole plant as a unit for evaluating the severity or reduction in height/deformation. 3. The prevalence of the disease should be scored at least to represent 10 m^2.

Answer: I agree with you. I suggest that a percentage scale be used rather than the SES scale in Asia for epidemiological purposes, loss assessment, screening, etc.

Madden, L.V. (USA): What do you mean by a percentage scale? Do you refer to yield reduction, height or other characters? What is the meaning of mild symptoms? Do they express tolerance or resistance? The main problem with virus diseases is to distinguish tolerance from resistance.

Answer: The percentage scale I refer to is a scale to quantify the disease intensity. With RTV, both height reduction and color changes occur. Therefore we need a percentage scale that integrates both of these characteristics. Mild symptoms on RTV-infected plants can mean either tolerance or resistance to the vector.

Teng, P.S. (IRRI): I would like to ask Dr. Nagarajan to indicate how the 0-9 scale and 100% rating scale were used?

Nagarajan, S. (India): The 0–9 scale ratings from 10 cultivars were related to yield and were negatively correlated. When the yield of IR36 and IR5O rated 100%, on the scale for blast was correlated, a similar relationship was observed. This indicates that l. Blast severity is correlated with yield and that the 100% scale was a better fit. 2. As both the varieties were highly susceptible and sampled from a 3 × 3 m plot, host reaction and prevalence were not taken into account. Therefore the model can not be extrapolated for other situations.

Zadoks, J.C. (The Netherlands): Comment: You are dealing with single plant (single hill) assessment of a systemic disease. In such a case quantification of severity seems impossible. You could use a typological scale involving ranking without quantification and then apply non-parametric statistics. In my opinion the idea of quantifying single plants in a systemic disease is ill-chosen.

Ragunathan, V. (India): I would like to report on recent experiences in the southern part of India. Three years ago there was a tungro outbreak and most of the varieties suffered heavily. As a result pesticides were applied to the nurseries and main fields and the disease was brought under control. However, recently in August 1988, the varieties which withstood tungro in the 1985-1986 season suffered heavily in spite of nursery/main field treatment with pesticides.

Hibino, H. (IRRI): Four types of resistance have been identified so far against tungro. All the commercially available varieties showing field resistance are resistant to the vector but not to the viruses. Some varieties are resistant to RTSV infection, tolerant to RTBV and resistant to both RTBV and RTSV infection. Breeding for varieties with these resistances is in progress at IRRI.