Tungro epidemics and yield losses in paddy fields in India

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Tungro virus epidemics occur frequently in some parts of the country as indicated by production-oriented surveys in rice fields. The aim was to quantify the levels of disease incidence, analyse the historical data on epidemic occurrence and estimate the grain-yield losses. Tungro disease, which appeared in north India during 1967, moved to peninsular India in 1977. Tungro outbreaks were discontinuous within a district, state and country over the years. The outbreaks of this disease were restricted to irrigated and rainfed shallow lowlands. The loss from tungro epidemics steadily increased during 1979–80. Three major epidemics in farmers' fields during 1984, 1988 and 1990, caused severe quantitative and monetary losses. Each of the other two epidemics during 1987 and 1998 led to a similar loss of about a million tonnes (mt) in rice production, but showed a steady increase in loss in terms of real value. An epidemic outbreak of tungro during 2001 in three districts of West Bengal caused an unmilled rice production loss of 0.5 mt valued at Rs 2911 millions at current prices. This study demonstrates that tungro epidemics could cause a maximum production loss of 53% in a district, 23% in a state and 2% in the country.

TUNGRO virus disease occurs if a susceptible variety, virus inoculum and the vector, green leafhopper (*Nephotettix virescens*) that carries the virus are available in a rice field. Raychaudhuri *et al.*[1] reported that *N. virescens* transmitted a new disorder designated as leaf-yellowing. The disease attracted the public attention for the first time following an epidemic outbreak in the eastern parts of Uttar Pradesh and Bihar[2]. Plants infected with rice tungro virus showed marked stunting, yellow to yellow-orange leaf discolouration and reduced ear-bearing tillers[3]. Two viral particles, namely spherical (RTSV – an RNA virus) and bacilliform (RTBV – a DNA pararetrovirus) are known to be associated with rice tungro virus disease[4,5]. The panicles in diseased plants are often small, sterile and incompletely exerted. Grains in such panicles are covered with dark blotches, and show reduced weight[6]. Also it is reported to reduce the number of panicles and spikelets, and decrease grain-filling, grain-weight yield and starch content in the grains[7–9].

Production-oriented survey (POS) organized by the Directorate of Rice Research (DRR) from 1974, uses the multi-disciplinary team approach to document constraints to rice production in various states of the country[10]. These surveys are made during the crop season every year by groups of scientists, extension functionaries and farmers in more than 100 rice-growing districts in the country. Extensive studies have been made[8] to estimate the yield loss caused by natural rice tungro disease outbreaks in farmers' fields. Data on hundreds of hill-sampling units were collected in a large number of farm fields (> 10 ha) in several districts, where different varieties were grown. Rajarajeswari[8] derived a best-fit regression model to predict the yield of well-filled grains using per cent tungro incidence in hill-sampling units as: $y = 23.49–0.19x$, where y is the well-filled grain-yield/hill and x the proportion of tungro (% tillers infected in a hill) incidence. Figures quoted, often on losses due to rice tungro virus disease, are largely based on speculation[11]. The aim of this study was to make a scientific assessment on yield loss using actual data gathered on the proportion of tungro virus in different categories of disease incidence in rice fields, regression model-derived yield estimates, and 27 year-long POS data on the intensity of tungro occurrence in different states and districts.

In POS, depending on the eye estimates on intensity of occurrence, the proportion of tungro virus disease in rice fields in a district has been systematically categorized as severe (>50%), moderate (25–50%), low (11–25%), or trace (<10%)[10]. For each of the categories, fields were identified and extent of disease incidence was recorded along two diagonals of the fields in 100 hill-sample units. Such tungro incidence estimates were made at ten different locations during 1998–2001. The overall mean tungro disease intensity was calculated for each category of tungro disease incidence in farmers' fields. The linear regression model of Rajarajeswari[8] and the estimates on the proportion of tungro in farmers' fields were used to derive the well-filled grain yield in farmers' fields classi-

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fied under each category of tungro incidence. From these derivations on well-filled grain yield/hill, the loss on attainable yield was further estimated for each of the categories (Table 1). Records on the occurrence of tungro virus disease in various districts during the POS[10] were gathered. Historical data on all-India rice production over the years were tabulated along with data on production in each district for the year, when tungro disease incidence was also categorized. Using the loss estimates derived for each of the categories of tungro incidence in the districts (Table 1), the losses in grain yields on potential rice production within a state and the whole country were calculated for individual data records during 1975–2001. Further, the monetary losses from tungro epidemics were also derived using procurement price announced by the Government of India for the respective years.

Trends in tungro outbreaks in farmers' fields clearly established that tungro was confined to parts of Bihar, east Uttar Pradesh and West Bengal during 1967–76. Tungro disease apparently moved towards peninsular India during 1977 and caused extensive damage in Krishna and Guntur districts, Andhra Pradesh. Occurrence of tungro in Shimoga district, Karnataka in 1979 was also reported. Later, severe tungro virus disease outbreaks threatened rice production in Andhra Pradesh and Tamil Nadu during 1984 (refs 12 and 13). In 1985, tungro appeared in Kerala and caused damage to rice crops in Pathanamthitta and Alleppey districts.

The data from POS clearly established the discontinuous occurrence of tungro in the country[10,14]. The surveys were limited to a few states till 1974, and later included all major rice-growing states in the country. In kharif 1969, leaf-yellowing symptoms suspected to represent tungro were reported from Assam (Jorhat), Bihar (Patna and Arrah), Uttar Pradesh (Varanasi), and West Bengal (Burdwan). Tungro virus disease was not observed as a constraint in any rice field in India during 1970–75, 1978, 1981–82, 1989, 1996 and 1997. Within a rice-growing state also, tungro incidence was discontinuous over the years. POS records for 27 years showed tungro incidence in farmers' rice fields during ten-years in Andhra Pradesh, six-years in Tamil Nadu, three-years each in Bihar, Pondicherry and West Bengal, two-years in Assam and Uttar Pradesh, and one year each in Karnataka, Kerala, Orissa and Punjab. So far, tungro disease damaged crops only in 11 rice-growing states. Tungro virus disease has not been detected as a constraint in Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Madhya Pradesh, Maharashtra and Rajasthan.

During 1975–2001, tungro disease occurrence caused considerable damage to rice production only in 48 districts. All these tungro-affected districts were under-irrigated and rainfed lowland ecosystems. Severe tungro damage was reported only from Andhra Pradesh, Bihar, Punjab and Tamil Nadu. Merely in 11 districts tungro incidence was recorded for more than a year, while in the remaining 37 districts the damage was recorded for only one year. Tungro incidence was recorded in farmers' fields for four years in Nellore (1984, 1988, 1990 and 1992); three-years each in East Godavari (1986, 1990 and 1995), Pondicherry (1991, 1999 and 2000), and South Arcot and Thanjavur (1984, 1987 and 1988); and two years each in Burdwan (1999 and 2001), Chengal pattu (1998 and 2000), Chittoor (1984 and 1992), Krishna (1977 and 1985), North Arcot (1987 and 1988) and West Godavari (1990 and 1995) districts. In 27 years of survey, disease incidence was in traces in five districts, low in 21 districts, moderate in 19 districts and severe in 19 districts. The disease damage was normally limited to only one season and exceptionally to two continuous seasons in any district.

Attempts were made to estimate yield losses at different levels of tungro incidence within a district. Data of two-diagonal samples in different farmers' fields affected by tungro at trace, low, moderate and severe levels were tabulated to derive the overall mean values for disease incidence (% tillers affected/hill) under each of the categories of the outbreak. Using the derived overall mean proportions of disease in the linear regression model of Rajarajeswari[8], the loss in yield from tungro under each category of disease incidence was calculated (Table 1). The per cent yield loss increased with increasing levels from trace to severe incidence of tungro in the farmers' fields. The minimum yield loss (6%) was recorded when tungro incidence was classified as trace. Even under severe levels of tungro incidence, only about one-half (up to 53%) of the yield was lost.

Table 1. Grain yield derived using regression model (ref. 8) and tungro incidence (%) in different categories of disease intensity in farmers' fields

Disease intensity	*a* (intercept)	*b* (slope)	*x* (proportion of tungro*)	Predicted yield (g well-filled grains/hill)	Loss in yield (g well-filled grains/hill)	Yield loss (%)
Trace	23.49	0.19	7 ± 1.3	22.16	1.33	5.66
Low	23.49	0.19	19 ± 5.7	19.88	3.61	15.37
Moderate	23.49	0.19	38 ± 13.9	16.27	7.22	30.74
Severe	23.49	0.19	65 ± 17.2	11.14	12.35	52.58

*Overall mean and SE for disease incidence (% tillers affected/hill) under each of the categories (n = 1000) of outbreak in farmers' fields.

Quantitative losses from tungro epidemics were estimated within a state for each year when the tungro epidemic occurred (Table 2). The loss in production in a tungro-affected state ranged from a maximum of 1.54 million tonnes (mt) (23%) in Tamil Nadu during 1984 to a minimum of 0.02 mt (0.06%) in Karnataka during 1979.

Table 2. Estimated yield loss from rice tungro virus disease within states in India during 1975–2001

State/year	Production (mt)	Loss (mt)	Loss (%)
Andhra Pradesh			
1977	7.35	0.13	1.7
1979	7.40	0.11	1.4
1984	13.20	0.18	1.4
1985	10.35	0.19	1.9
1986	11.55	0.14	1.2
1988	10.65	0.07	0.7
1990	15.15	1.30	8.5
1991	16.05	0.12	0.7
1992	13.95	0.33	2.4
1995	13.80	0.47	3.4
Assam			
1991	4.95	0.08	1.6
1994	5.10	0.02	0.4
Bihar			
1980	5.40	0.28	5.3
1983	4.65	0.13	2.9
1995	9.30	0.05	0.5
Karnataka			
1979	3.30	0.02	0.1
Kerala			
1985	1.95	0.08	4.2
Orissa			
1992	10.05	0.07	0.7
Pondicherry			
1991	0.09	0.00	2.4
1999	0.09	0.00	4.8
2000	0.09	0.00	2.4
Punjab			
1998	11.85	0.71	6.0
Tamil Nadu			
1984	6.75	1.54	22.8
1985	8.10	0.15	1.9
1987	12.45	0.81	6.5
1988	8.40	1.56	18.6
1991	8.70	0.20	2.3
2000	10.85	0.12	1.1
Uttar Pradesh			
1976	6.45	0.03	0.5
2000	19.35	0.12	0.6
West Bengal			
1993	17.10	0.09	0.5
1999	19.95	0.12	0.6
2001	18.60	0.50	2.7

*Loss estimates using actual data gathered on the proportion of tungro virus in different categories of disease incidence in farmers' fields, regression model-derived yield estimates[8], 27 years POS data[10] on the intensity of tungro in different states and districts, and state rice production data[16] for the respective years.

Data on harvest losses are expressed in terms of either monetary value or quantity *per se* of the harvested crop. Expression in terms of quantity has the advantage of providing an exact value, which is independent of market interaction and which still permits a clear assessment even after an extended period, without entailing painstaking reconstruction of the currency situation. However, it has the disadvantage of neglecting reductions of quality. Such reductions can be taken into account when crop losses are expressed in terms of money. Again, the disadvantage arises from the price situation and the monetary equivalent value becoming involved as extremely variable factors[15]. Estimation on crop loss should preclude fluctuations in yield and market price during different years. In this study, taking into account the procurement price of paddy in the respective year, we derived both quantitative (in mt) and monetary (in Rs million) loss assessments. To eliminate year-wise fluctuations, loss on actual production in a particular year when tungro disease caused damage was calculated. Further, by taking the rupee value of 1975 as 100 paise, the price index was also calculated to neutralize the changed rupee value, and thus deflated loss estimates were compared (Table 3).

Per hectare rice yields have been showing a continuous increase[16]. Between 1976 and 2001, there was more than a twofold increase in the all-India rice production. The loss in rice production from tungro disease damage steadily increased from 1976 to reach peak levels during mid-1980s. The loss estimated from tungro indicated occurrence of epidemic outbreaks. Three major tungro virus epidemics devastated rice crops in farmers' fields in 1984, 1988 and 1990, causing more or less similar production (1.30 to 1.72 mt of paddy) and monetary (Rs 2356 to 2655 millions) losses. Yet, when calculated using the deflating rupee value, the real value of losses in 1990 was nearly twice that of the loss estimated for the 1984 epidemic. This evidence also suggests that the production increase from 88 mt in 1984 to 111 mt in 1990 had no influence on the crop loss due to tungro virus disease outbreaks. Two other tungro epidemics in 1987 and 1998 caused more or less similar production losses (0.71–0.81 mt) Calculation of losses in terms of percentage of total production, however, showed a drastic reduction (0.94 to 0.54%). The reason for similar quantitative losses in the two epidemics is the increased all-India rice production from 1987 to 1998. In contrast, the loss in 1998 was more than sevenfold the loss in 1987 in terms of real value. Five other tungro virus disease epidemics during 1985, 1991, 1992, 1995 and 2001 caused nearly similar production losses (0.43 to 0.52 mt). Although the all-India production during these epidemic years varied, the loss in terms of percentage of total production was more or less similar (0.36 to 0.45%). But the loss in terms of monetary value steadily increased with an increasing

Table 3. Estimated yield loss from rice tungro virus disease in farmers' fields in India during 1976–2001

Year	All-India paddy production (mt)	Loss in production*			Value per price index 1975+
		Million tonnes	Percentage (%)	Million rupees**	Million rupees
1975	73.11	0.00	0.00	0	0
1976	62.88	0.03	0.05	27	29
1977	79.01	0.13	0.16	103	119
1978	80.66	0.00	0.00	0	0
1979	63.50	0.12	0.20	118	146
1980	80.45	0.28	0.35	298	413
1981	79.88	0.00	0.00	0	0
1982	70.68	0.00	0.00	0	0
1983	90.15	0.13	0.15	176	334
1984	87.51	1.72	1.93	2356	4990
1985	95.75	0.43	0.44	607	1365
1986	90.84	0.14	0.15	198	476
1987	85.29	0.81	0.94	1212	3117
1988	105.74	1.64	1.52	2620	7255
1989	110.36	0.00	0.00	0	0
1990	111.44	1.30	1.15	2655	8689
1991	112.02	0.40	0.36	926	3705
1992	109.29	0.40	0.37	1090	4907
1993	120.45	0.09	0.08	284	1278
1994	122.72	0.02	0.02	73	374
1995	115.47	0.52	0.45	1872	11231
1996	122.61	0.00	0.00	0	0
1997	123.80	0.00	0.00	0	0
1998	129.12	0.71	0.54	3107	22371
1999	134.22	0.12	0.09	606	4360
2000	128.25	0.25	0.19	1308	9419
2001	136.13	0.50	0.37	2911	20956

*Loss estimates using actual data gathered on the proportion of tungro virus in different categories of disease incidence in rice fields, regression model-derived yield estimates[8], 27 years POS data[10] on the intensity of tungro occurrence in different states and districts, and state rice production data[16] for the respective years.
**Values derived on the basis of procurement price of paddy announced for respective years by the Government of India.
+Estimated on the rupee value of 1975 as 100 paise.

trend in all-India rice production and minimum support (procurement) price announced by the government. Tungro epidemic in only three districts of West Bengal in 2001 caused an unmilled rice production loss of 0.5 mt that amounted to Rs 2911 millions at current prices.

This study imposed certain limitations to the calculation on yield loss from tungro disease epidemics. The first limitation is that POS does not necessarily proclaim to cover all the areas under rice. Therefore, tungro disease incidence records are less than the actual figures and thus lead to underestimated yield losses. The second limitation is that estimation of proportion of tungro incidence in severe, moderate, low and trace categories made during 1998–2001 may not represent those classified during the earlier years, as genotypes and cultural conditions varied. The third limitation is that production figures for a district in a particular year used to derive yield loss estimate have already suffered the loss and hence, the yield losses estimated may actually be underestimates. The actual yield losses might be of much higher magnitude than the conservative estimates made in this study. Overall, the losses estimated over large areas in the districts and the country as a whole in this study, can be taken to represent the minimum grain yield losses due to tungro virus epidemics in rice fields. This study demonstrates that the tungro epidemics could cause a maximum production loss of 53% in a district, 23% in a state and 2% in this country.

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