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Effect Of Rice Tungro Disease (Rtd) On Biochemical Changes Of Promising Rice Genotypes

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Abstract

Biochemical changes were found to be induced in rice leaves due to infection by rice tungro disease. The carbohydrate fraction viz., reducing sugars, non-reducing sugars, total sugars and starch content were significantly differed in RTD inoculated and uninoculated plants irrespective of the rice cultivars. The inoculated plants of susceptible rice cultivars showed highest increase in carbohydrate fractions with the advancement of the plant age as compared to moderately resistant and resistant rice cultivars. Among the nine rice cultivars tested, the increase in carbohydrate fractions was found high in susceptible rice cultivar T(N)1 74.5 %, 69.6 %, 71.7 % and 55.5 % at 40 days after inoculation. Total phenol content was decreased in susceptible rice cultivar T(N)1 (22.9%, 45.3% and 60.5%), CO 39 (21.1%, 41.0% and 59.3%) and MTU 1010 (19.2%, 37.5% and 53.7%) at 20, 30 and 40 DAI, respectively. Biochemical parameters viz., reducing sugars, non-reducing sugars, total sugars and starch content were found high in susceptible rice cultivars (T(N)1, CO 39 and MTU 1010) as compared to moderately resistant (IR 64, RPBIO 226 and MTU 7029) and resistant rice cultivars (Vikramarya, Utrirajapan and Nidhi). The phenol content of susceptible rice cultivars (T(N)1, CO 39 and MTU 1010) was observed to be decreased over moderately resistant and resistant rice cultivars.

Key word: Rice, Rice Tungro virus, biochemical changes, leaf hoppers, phenol

Introduction

Rice is the main staple food crop for more than half of the world's population. An average daily consumption of rice provides 20-80% of dietary energy and 12-17% of dietary protein for Asians. More than 90% of world's rice is grown and consumed in Asia of which about 55% is accounted by China, India and Taiwan alone. *Oryza sativa* L. belonging to the family Gramineae is considered as one of the most important cereal crops as it holds the key for household food and nutritional security. However, in major rice-growing southeastern countries, many rice viruses have been posing a major threat to sustainable rice production. Of these, rice tungro virus disease is wide spread and occurred in epidemic form in several states of India and gained considerable importance during the last 50 years. Tungro disease is caused by co-infection of two different viruses, Rice tungro bacilliform virus (RTBV, genus Tungro virus, family Caulimoviridae) a pararetrovirus with a double stranded DNA genome, and Rice tungro spherical virus (RTSV, genus Waikavirus, family Secoviridae), a plant picorna virus with a single – stranded (+)-sense RNA genome. Both these viruses are transmitted in a semipersistant manner by green leafhopper vector *Nephotettix virescens* (Distant) and some other leafhopper species Hibino *et al*., 1983 and Hibino *et al.*, 1978). The most conspicuous symptoms of rice plants infected with both RTSV and RTBV are stunting and yellow to orange discoloration of the leaves Rivera and Ou (1967). Symptoms of tungro disease in rice plants may vary according to the age of the plant, rice variety and virus strains. The most important symptoms of rice plants infected with tungro complex exhibited stunting, twisting of leaves and yellow to orange discoloration of the leaves. Yellowing of the tips of young leaves is the first symptom to appear with interveinal chlorosis or chlorotic mottling.

Inspite of phenomenal increase in area and production of rice its productivity is limited by various biotic constraints. Among the biotic constraints, rice tungro disease (RTD) is one of the most devastating problems affecting rice crop in South-east Asia with an estimated annual losses to an extent of US $ 1.5 x 10^9 (Herdt, 1988). In addition to the extensive planting of high yielding cultivars and intensive use of fertilizers and the introduction of new technologies to increase the rice production in the late 1960's culminated in the emergence of rice tungro disease (RTD). The occurrence of this disease is sporadic in nature and it can appear at any time from seedling stage to reproductive phase (Muralidharan *et al.,* 2003; Krishnaveni *et al.,* 2011).

Biochemical changes in starch and sugar contents due to tungro infection in rice has been investigated well (Sridhar *et al.,* 1976; Mohanty and Sridhar, 1986; Yesuraja and Mariappan, 1993). The concentration of reducing sugars gradually increased with the age of the leaf blades attached to plants in both healthy and tungro infected rice plants. Similar observations on the decrease in reducing sugar content and increase in non-reducing sugar content in tungro-infected rice leaves with an increase in the plant age were made by Yadav and Mishra (1987).

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The amounts of total phenols generally increased with the age of the plants. The healthy plants of susceptible rice cultivar T(N)1 possessed higher amounts of total phenols than the tolerant rice cultivar (IR 20). Disease development lowered the total phenolic concentration in the leaves of T(N)1 than the healthy plants whereas the inoculated leaves of rice cultivar IR 20 showed slightly higher levels of phenols than the healthy plants. Sridhar *et al.* (1976).

Materials and Methods

Nine rice varieties comprising of three susceptible rice varieties T(N)1, MTU1010 and CO39, three moderately resistant rice varieties IR 64, MTU 7029 and RPBIO 226 and three resistant rice varieties Vikramarya, Nidhi and Utrirajapan were selected.

Nine rice genotypes T(N)1, MTU1010 and CO39 (susceptible), IR 64, MTU 7029 and RPBIO 226 (moderately resistant), Vikramarya, Nidhi and Utrirajapan (resistant) were inoculated with RTD at 20 Days after sowing (DAS) by viruliferous *Nephotettix virescens* (Distant) @ 3 adult/tiller by encaging individual plants with a polymethyl methacrylate tubes for 24 h. The insect were allowed to acquire the virus by feeding for 24 h. on diseased plant. One plant from each of the three replications of both inoculated and uninoculated plots was randomly selected 10 days after inoculation for studies on biochemical changes. Biochemical changes were recorded at 30, 40, 50 and 60 days after sowing along with uninoculated seedlings for all nine genotypes. The observation on biochemical changes viz., carbohydrates, starch and phenol were recorded in inoculated and uninoculated control.

Collection of leaf samples

For biochemical studies due to RTD infection leaf samples were collected from inoculated and uninoculated rice cultivars at 30, 40, 50 and 60 days after sowing. These samples were brought to the laboratory in polythene bags covered with brown paper and washed first in tap water followed by two changes of distilled water. These leaf samples were dried in two folds of filter paper and used for biochemical analyses. In untreated control, sampling was done similarly at different dates of sowing and collected the leaf material from uninoculated plants of different rice cultivars.

Reducing sugars present in the leaf samples were estimated by Nelson-Somogyi's DNS method. Non reducing sugars present in plant extracts were first hydrolyzed with either sulphuric acid to reducing sugars. Then, the total reducing sugars was estimated by adapting Nelson-Somogyi's DNS method. The starch content in healthy and infected leaves of different nine rice genotypes were analyzed by Anthrone method (Sadasivam and Manickam, 2008). Phenol content in infected and healthy samples of different rice genotypes were estimated colorimetrically by following Arnows method (Malik and Singh, 1980).

Result and discussion

The effect of rice tungro disease on biochemical changes of promising nine rice cultivars viz., T(N)1, MTU1010 and CO 39 (susceptible), IR 64, MTU 7029 and RPBIO 226 (moderately resistant) and Vikramarya, Utrirajapan and Nidhi (resistant) were tested. Twenty days old rice seedlings of nine rice cultivars were inoculated at 20 DAS and reducing sugar, non-reducing sugar, total carbohydrate and phenol were estimated at 10, 20, 30 and 40 days after inoculation (DAI) with an interval of 10 days. The biochemical changes due to RTD infection in rice cultivars were quantitatively estimated and expressed in mg/g of fresh weight and per cent increase or decrease in different rice cultivars were estimated.

Reducing sugars

The effect of rice tungro disease on reducing sugars of nine rice cultivars viz., T(N)1, CO 39 and MTU 1010 (susceptible), IR 64, RPBIO 226 and MTU 7029 (moderately resistant) and Vikramarya, Utrirajapan and Nidhi (resistant) rice cultivars were tested. The results revealed that the reducing sugars was significantly differed in RTD inoculated and uninoculated plants irrespective of the rice cultivars and date of inoculation. In general in the uninoculated control plants of all the nine rice cultivars, the contents of reducing sugars was increased with the advancement of the crop age irrespective of the rice cultivars and days after inoculation. The inoculated plants of susceptible rice cultivars showed highest increase in reducing sugar content with the advancement of the plant age as compared to moderately resistant and resistant rice cultivars. Among the nine rice cultivars tested, the increase in reducing sugar content was high in susceptible rice cultivars T(N) 1 (23.9 %, 41.3 %, 62.8 % and 74.5 %) followed by CO 39 (21.4 %, 39.4 %, 57.4 % and 70.2 %) and MTU 1010 (18.6 %, 36.5 %, 53.4 % and 66.6 %) as compared to moderately resistant rice cultivars IR 64 (8.03 %, 23.6 %, 32.9 % and 38.9 %), RPBIO 226 (6.93 %, 19.2 %, 28.5 % and 35.7 %) and MTU 7029 (5.86 %, 18.1 %, 27.2 % and 31.3 %) and resistant rice cultivars, Vikramarya (3.14 %, 3.37 %, 3.72 % and 4.56 %), Utrirajapan (4.27 %, 4.41 %, 4.82 % and 5.54 %) and Nidhi (4.98 %, 5.25 %, 5.58 % and 6.82 %) at different days after inoculation. The increase in reducing sugar content was highest in T(N)1 (74.5 %) and least in resistant rice cultivar Vikramarya (4.56 %), at 40 days after inoculation, as compared to the other rice cultivars tested.

In the remaining rice cultivars the increase in reducing sugar content ranged from 5.54 to 70.2% at 40 days after inoculation (Table 1).

Similar type of changes in reducing sugar contents due to tungro disease in rice plant were reported earlier by Chowdhury and Mukhopadhyay (1974b), Sridhar *et al*. (1976), Mohanty and Sridhar (1986), Yadav and Mishra (1987) and Yesuraja and Mariappan (1993). The changes in reducing sugar might be attributed to decreased photosynthesis and increased respiration occurred in virus infected tissues which altered the concentration of carbohydrates.

Non reducing sugar

The effect of rice tungro disease on non-reducing sugar content of nine rice cultivars viz., T(N)1, CO 39 and MTU 1010 (susceptible), IR 64, RPBIO 226 and MTU 7029 (moderately resistant) and Vikramarya, Utrirajapan and Nidhi (resistant) rice cultivars were tested. The results indicated that non reducing sugar content was significantly differed in RTD inoculated and uninoculated plants irrespective of the rice cultivars and days after inoculation (Table).

Significant differences in non-reducing sugar content were observed in different rice cultivars and at different days after inoculation (10, 20, 30 and 40). In general, in the uninoculated control plants of all the nine rice cultivars, the contents of non-reducing sugar were increased with the advancement of the crop age. The inoculated plants of susceptible rice cultivars showed highest increased levels of non-reducing sugar content with the advancement of the

plant age as compared to moderately resistant and resistant rice cultivars. Among the nine rice cultivars tested, the reduction in non-reducing sugar content was high in susceptible rice cultivars T(N) 1 (22.0 %, 44.8 %, 56.6 % and 69.6 %) followed by CO 39 (20.0 %, 40.0 %, 52.2 % and 61.2 %) and MTU 1010 (18.8 %, 36.7 %, 49.7 % and 56.9 %) as compared to moderately resistant rice cultivars IR 64 (7.61 %, 14.1 %, 25.7 % and 31.2 %), RPBIO 226 (6.44 %, 13.7 %, 24.7 % and 28.3 %) and MTU 7029 (5.33 %, 12.2 %, 21.9 % and 29.4 %) and resistant rice cultivars Vikramarya (1.15 %, 2.47 %, 3.23 % and 3.99 %), Utrirajapan (1.60 %, 3.01 %, 3.93 % and 4.52 %) and Nidhi (1.71 %, 3.14 %, 4.82 % and 5.64 %) at 10, 20, 30 and 40 DAI, respectively. The increased levels of non-reducing sugar were highest in susceptible rice cv. T(N)1 (69.6 %) and least in resistant rice cv. Vikramarya (3.99 %), at 40 days after inoculation, as compared to the other rice cultivars tested.

The present finding is in agreement with Mohanty and Sridhar (1986) who reported that the concentration of non-reducing sugars gradually increased with the age of the leaf blades attached to the plants in both healthy and tungro infected rice plants. On contrast, Yadav and Mishra (1987) observed a decreased reducing sugar content and increased non reducing sugar contents in tungro infected rice leaves with increase in the plant age.

Total sugars

The results pertaining to the total sugars revealed that susceptible, moderately resistant and resistant rice cultivars differed significantly in the amount of total sugar present in the leaves. In general, the amount of total sugars was found to be increased significantly in the un inoculated plants irrespective of the cultivars and days after inoculation (DAI). Inoculated plants of susceptible rice cultivars showed more increase in total sugar as compared with moderately resistant and resistant rice cultivars with the advancement of the plant age (Table 4.9 and Figure 4.8). The highest increase in total sugar due to inoculation with RTD was observed in rice cultivar T (N)1 (71.7 %) at 40 days after inoculation. The increase in total sugar was more pronounced at 40 DAI as compared to 30, 20 and 10 DAI. Among the nine rice cultivars, increase in total sugar was less in resistant rice cultivar, Vikramarya (4.23 %) followed by Utrirajapan (4.91 %) and Nidhi (6.12 %) as compared to moderately resistant rice cultivars IR 64 (34.2 %), RPBIO 226 (31.4 %) and MTU 7029 (30.2 %) at 40 DAI.

The increase in total sugar content was less in moderately resistant rice cultivars IR 64 (7.80 %, 18.4 %, 28.7 % and 34.2 %), RPBIO 226 (6.61 %, 15.9 %, 26.2 % and 31.4 %) and MTU 7029 (5.52 %, 14.6 %, 24.1 % and 30.2 %). Susceptible rice cultivar MTU 1010 with RTD infection showed increased total sugar content (18.8 %, 36.6 %, 51.3 % and 60.9 %), CO 39 (20.2 %, 39.8 %, 54.5 % and 65.4 %), T(N)1 inoculated plants showed increased total sugars (22.8 %, 43.3 %, 59.3 % and 71.7 %), respectively at 10, 20, 30 and 40 DAI. The differences in per cent increase in total sugar content at different days after inoculation was found high in susceptible rice cultivars T(N)1, CO 39 and MTU 1010 and moderately high in moderately resistant rice cultivars IR 64, RPBIO 226 and MTU 7029 and less in resistant rice cultivars Vikramarya, Utrirajapan and Nidhi. The total sugar content was significantly increased in inoculated plants with RTD. In the uninoculated plants of all the nine rice cultivars, the content of total sugars were increased with the increase in age of the host plant.

The present finding are in agreement with Chowdhury and Mukhopadhyay (1974b), Sridhar *et al*. (1976), Mohanty and Sridhar (1986), Yadav and Mishra (1987) and Yesuraja and Mariappan (1993) who reported changes in reducing sugar might be attributed to decreased photosynthesis and increased respiration occurred in virus infected tissues which altered the concentration of carbohydrates.

Starch contents

The effect of rice tungro disease on starch content of nine rice cultivars was tested. The results revealed that starch content was significantly differed in RTD inoculated and uninoculated plants irrespective of the rice cultivars and date of inoculation (Table 4.10 and Figure 4.9). In general in the uninoculated plants of all the nine rice cultivars, the contents of starch content was increased with the advancement of the crop age. The inoculated plants of all the susceptible rice cultivars showed highest increase in starch content with the advancement of the plant age as compared to moderately resistant and resistant rice cultivars. Among the nine rice cultivars tested, the increase in starch content was high in susceptible rice cultivars T(N) 1 (15.9 %, 21.6 %, 41.7 % and 55.5 %) followed by CO 39 (15.9 %, 20.5 %, 38.8 % and 47.4 %) and MTU 1010 (13.3 %, 19.2 %, 34.6 % and 43.8 %) as compared to moderately resistant rice cultivars IR 64 (6.14 %, 10.3 %, 19.6 % and 29.4 %), RPBIO 226 (5.60 %, 9.83 %, 17.1 % and 27.6 %) and MTU 7029 (5.62 %, 8.51 %, 16.0 % and 24.5 %) and resistant rice cultivars Vikramarya (1.61 %, 2.86 %, 3.86 % and 4.71 %), Utrirajapan (2.40 %, 3.16 %, 4.66 % and 5.51 %) and Nidhi (2.81 %, 4.76 %, 5.69 % and 7.57 %) at 10, 20, 30 and 40 DAI, respectively. The increase in starch content was highest in susceptible rice cultivar, T(N)1 (55.5 %) and least in resistant rice cultivar Vikramarya (4.71 %), at 40 days after inoculation , respectively as compared to all the rice cultivars tested.

In the remaining rice cultivars the increase in starch content ranged from 5.41 to 47.38 % at 40 days after inoculation (Table).

The present study indicated that the accumulation of starch in virus affected plants suggested that infected regions act as metabolic sink restricting the translocation of carbohydrates and resulted in their accumulation. Increased accumulation of soluble (sugars) and insoluble (starch) carbohydrates in virus infected leaves indicated that translocation of the former as well as of the hydrolytic products of the latter form the diseased leaf is much less than from the healthy leaf. Starch accumulation is a characteristic of a number of virus diseases (Matthews, 1991). Similarly, a striking accumulation of starch was noticed especially in rice cultivar T(N)1. The extent of increase in starch content in diseased leaves has been found to be related to the relative severity of the disease symptoms. Accumulation of starch has been observed in tungro-infected susceptible leaves (IRRl. 1967a; Chowdhury and Mukhopadhyay, 1974b; Sridhar *et al.,* 1976).

Phenol contents

The effect of rice tungro disease on phenol content of nine rice cultivars viz., T(N)1, CO 39 and MTU 1010 (susceptible), IR 64, RPBIO 226 and MTU 7029 (moderately resistant) and Vikramarya, Utrirajapan and Nidhi (resistant) rice cultivars were tested.

The quantities of the phenol contents in healthy plants generally increased with the age of the plants of all the nine cultivars tested. The healthy plants of moderately resistant and resistant cultivars possessed higher amount of total phenols than the susceptible cultivars.

In susceptible cultivars T(N)1, CO 39 and MTU 1010, there was significant increase in the total phenols content i.e., 15.9 %, 13.3 % and 12.0 %, respectively at 10 DAI due to RTD. But in subsequent stages at 20, 30 and 40 DAI, the total phenols were found to be decreased drastically. The maximum decline was noticed in susceptible rice cultivar T(N) 1 (60.5 %) samples analysed at 40 DAI. (Table).

Total phenol content was decreased in susceptible rice cultivar T(N)1 (22.9 %, 45.2 % and 60.5 %), CO 39 (21.1 %, 41.0 % and 59.3 %) and MTU 1010 (19.2 %, 37.5 % and 53.7 %) at 20, 30 and 40 DAI, respectively. But in moderately resistant and resistant cultivars total phenol were increased at different days after inoculation.

The increase in total phenol content were less in moderately resistant cultivar IR 64 (12.7 %, 8.76 % and 1.97 %), RPBIO 226 (12.8 %, 5.95 % and 1.68 %) and MTU 7029 (8.33 %, 3.35 % and 1.17 %) as compared to resistant cultivars at 10, 20 and 30 DAI. Total phenol content was decreased in moderately resistant cultivars IR 64 (2.24 %), RPBIO 226 (2.06 %) and MTU 7029 (1.64 %) at 40 DAI.

The total phenol content was increased in resistant rice cultivars Vikramarya (7.16 %, 8.10 %, 10.3 % and 14.6 %), Utrirajapan (6.26 %, 5.90 %, 9.53 % and 12.1 %) and Nidhi (4.86 %, 5.1 %, 8.79 % and 11.2 %) at 10, 20, 30 and 40 DAI, respectively and the maximum increased was observed in resistant rice cultivar Vikramarya at 40 DAI 14.6 %.

The present study indicated that there was a spurt in the phenolic content in T(N)1 after inoculation with RTD infection. However total phenol content was brought down drastically during the later stages of crop growth. In general, the total phenols were always higher at all the stages of crop growth in the inoculated plants of moderately resistant and resistant rice cultivar.

Increased as well as decreased levels of phenols and their derivatives in rice plants infected with tungro have been reported by several workers (Sridhar *et al.*. 1976, Subba Rao, 1978; Yadav and Mishra, 1987). Although, healthy plants of susceptible rice cultivar T(N)1 possessed lower amounts of phenolic compounds than the tolerant and resistant cultivars. These results are inconformity with Sridhar *et al* (1976) who reported that tungro disease development lowered the total phenolic concentration in the leaves of susceptible rice cultivar than the healthy plants. On the other hand, the inoculated leaves of tolerant cultivar showed slightly higher levels of phenols than the healthy plants.

The overall per cent increase in biochemical characteristics viz., reducing sugar, non-reducing sugar, total sugars and starch content in susceptible rice cultivars (T(N)1, CO 39 and MTU 1010) were found to be very high as compared to moderately resistant (IR 64, RPBIO 226 and MTU 7029) and resistant rice cultivars (Vikramarya, Utrirajapan and Nidhi). The phenol content of susceptible rice cultivars (T(N)1, CO 39 and MTU 1010) was observed to be decreased whereas increased in moderately resistant and resistant rice cultivars.

Table 1. Effect of rice tungro disease (RTD) in reducing sugar (mg g^{-1}) of fresh leaf tissues of nine rice cultivars

S.No.	Rice Cultivars	Treatment	Reducing sugar (mg g^{-1}) Days after Inoculation (DAI)				
			10	20	30	40	Mean
1.	T(N) 1 (S)	Uninoculated control	11.5	12.1	13.7	14.7	12.9
		RTV infection	13.8	17.1	21.3	25.6	19.5
		Per cent increase/decrease	(+ 23.9)	(+ 41.3)	(+ 62.8)	(+ 74.5)	(+ 50.7)
2.	CO 39 (S)	Uninoculated control	10.4	11.7	13.3	14.1	12.4
		RTV infection	12.7	16.2	21.0	24.0	18.5
		Per cent increase/decrease	(+ 21.4)	(+ 39.4)	(+ 57.4)	(+ 70.2)	(+ 49.3)
3.	MTU1010 (S)	Uninoculated control	10.4	11.6	13.1	14.0	12.3
		RTV infection	12.4	15.9	20.1	23.4	17.9
		Per cent increase/decrease	(+ 18.6)	(+ 36.5)	(+ 53.4)	(+ 66.6)	(+ 45.7)
4.	IR 64 (MR)	Uninoculated control	8.21	9.16	10.6	11.6	9.93
		RTV infection	8.87	11.3	14.3	16.1	12.7
		Per cent increase/decrease	(+ 8.03)	(+ 23.6)	(+ 32.9)	(+ 38.9)	(+ 27.4)
5	RPBIO 226 (MR)	Uninoculated control	8.08	9.05	10.6	11.3	9.75
		RTV infection	8.64	10.8	13.6	15.3	12.1
		Per cent increase/decrease	(+ 6.93)	(+ 19.2)	(+ 28.5)	(+ 35.7)	(+ 23.9)
6.	MTU 7029 (MR)	Uninoculated control	8.02	8.9	10.4	11.7	9.64
		RTV infection	8.49	10.6	13.3	14.7	11.7
		Per cent increase/decrease	(+ 5.86)	(+ 18.1)	(+ 27.2)	(+ 31.3)	(+ 21.9)
7.	Vikramarya (R)	Uninoculated control	6.35	6.51	7.97	8.76	7.40
		RTV infection	6.55	6.71	8.27	9.16	7.67
		Per cent increase/decrease	(+ 3.14)	(+ 3.37)	(+3.72)	(+ 4.56)	(+ 3.64)
8.	Utrirajapan (R)	Uninoculated control	6.08	6.34	7.88	8.47	7.19
		RTV infection	6.34	6.60	8.26	8.94	7.54

		Per cent increase/decrease	(+ 4.27)	(+ 4.41)	(+4.82)	(+ 5.54)	(+ 4.86)
9.	Nidhi (R)	Uninoculated control	6.02	6.29	7.70	8.35	7.09
		RTV infection	6.32	6.62	8.13	8.92	7.50
		Per cent increase/decrease	(+ 4.98)	(+ 5.25)	(+5.58)	(+ 6.82)	(+ 5.78)
SEm ±			0.09	0.04	0.07	0.06	
CD (0.05) (UI)			0.16	0.12	0.22	0.17	
SEm ±			0.07	0.05	0.08	0.08	
CD (0.05) (I)			0.20	0.17	0.24	0.23	

Figures in parentheses indicate per cent increase (+)/decrease (-) over uninoculated control

Table 2. Effect of rice tungro disease (RTD) in non-reducing sugar (mg g^{-1}) of fresh leaf tissues of nine rice cultivars.

S. No.	Rice Cultivars	Treatment	Carbohydrates non reducing sugar (mg g^{-1})				
			Days after Inoculation (DAI)				
			10	20	30	40	Mean
1.	T(N) 1 (S)	Uninoculated control	15.1	16.5	18.1	20.2	17.5
		RTV infection	18.5	23.9	28.4	34.3	26.3
		Per cent increase/decrease	(+ 22.0)	(+ 44.8)	(+ 56.6)	(+ 69.6)	(+ 50.1)
2.	CO 39 (S)	Uninoculated control	15.1	16.4	17.2	19.9	17.1
		RTV infection	18.6	22.9	26.2	32.2	24.9
		Per cent increase/decrease	(+ 20.0)	(+ 40.0)	(+ 52.2)	(+ 61.2)	(+ 45.0)
3.	MTU1010 (S)	Uninoculated control	15.0	16.1	16.8	19.6	16.9
		RTV infection	17.9	22.0	25.1	30.8	23.9
		Per cent increase/decrease	(+ 18.8)	(+ 36.7)	(+49.7)	(+ 56.9)	(+ 41.8)
4.	IR 64 (MR)	Uninoculated control	12.9	13.5	15.2	17.9	14.9
		RTV infection	13.9	15.5	19.1	21.6	17.5
		Per cent increase/decrease	(+ 7.61)	(+ 14.1)	(+25.7)	(+ 31.2)	(+ 17.8)
5	RPBIO 226 (MR)	Uninoculated control	12.7	13.3	15.1	15.8	14.2
		RTV infection	13.5	15.1	18.8	20.3	16.6
		Per cent increase/decrease	(+ 6.44)	(+ 13.7)	(+24.7)	(+ 28.3)	(+ 19.0)
6.	MTU 7029 (MR)	Uninoculated control	12.7	13.2	15.0	15.9	14.1
		RTV infection	13.0	14.8	18.3	20.7	16.7
		Per cent increase/decrease	(+ 5.33)	(+ 12.2)	(+21.9)	(+ 29.4)	(+ 18.1)
7.	Vikramarya (R)	Uninoculated control	11.3	12.1	14.3	14.5	13.1
		RTV infection	11.4	12.4	14.6	15.1	13.4
		Per cent increase/decrease	(+ 1.15)	(+ 2.47)	(+3.23)	(+ 3.99)	(+ 2.83)
8.	Utrirajapan (R)	Uninoculated control	11.2	12.0	14.0	14.1	12.8
		RTV infection	11.4	12.3	14.5	14.8	13.3
		Per cent increase/decrease	(+ 1.60)	(+ 3.01)	(+3.93)	(+ 4.52)	(+ 3.35)
9.	Nidhi (R)	Uninoculated control	11.1	11.7	13.7	14.0	12.6
		RTV infection	11.3	12.1	14.3	14.8	13.5
		Per cent increase/decrease	(+ 1.71)	(+ 3.14)	(+4.82)	(+ 5.64)	(+ 4.03)
SEm ±			0.06	0.05	0.05	0.06	
CD (0.05) (UI)			0.19	0.14	0.14	0.17	
SEm ±			0.04	0.06	0.06	0.11	
CD (0.05) (I)			0.12	0.17	0.19	0.32	

Figures in parentheses indicate per cent increase (+)/decrease (-) over uninoculated control

			Total sugars (mg g^{-1})

			Days after Inoculation (DAI)				
			10	**20**	**30**	**40**	**Mean**
1.	T(N) 1 (S)	Uninoculated control	26.3	28.6	31.8	34.9	30.4
		RTV infection	32.3	41.0	50.7	59.9	46.0
		Per cent increase/decrease	(+ 22.8)	(+ 43.3)	(+ 59.3)	(+ 71.7)	(+ 51.1)
2.	CO 39 (S)	Uninoculated control	25.7	28.0	30.5	34.0	29.6
		RTV infection	30.9	39.2	47.2	56.6	43.3
		Per cent increase/decrease	(+ 20.2)	(+ 39.8)	(+ 54.5)	(+ 65.4)	(+ 46.6)
3.	MTU1010 (S)	Uninoculated control	25.5	27.7	29.9	33.6	29.2
		RTV infection	30.2	37.9	45.2	54.1	41.7
		Per cent increase/decrease	(+ 18.8)	(+ 36.6)	(+ 51.3)	(+ 60.9)	(+ 43.5)
4.	IR 64 (MR)	Uninoculated control	21.1	22.7	26.1	29.5	24.8
		RTV infection	22.7	26.8	33.4	39.6	30.6
		Per cent increase/decrease	(+ 7.80)	(+ 18.4)	(+ 28.7)	(+ 34.2)	(+ 23.5)
5	RPBIO 226 (MR)	Uninoculated control	20.9	22.4	25.7	27.1	23.8
		RTV infection	22.9	25.9	32.4	35.3	28.9
		Per cent increase/decrease	(+ 6.61)	(+ 15.9)	(+ 26.2)	(+ 31.4)	(+ 21.7)
6.	MTU 7029 (MR)	Uninoculated control	20.4	22.1	25.5	27.1	23.8
		RTV infection	21.5	25.3	31.6	35.3	28.4
		Per cent increase/decrease	(+ 5.52)	(+ 14.6)	(+ 24.1)	(+ 30.2)	(+ 19.6)
7.	Vikramarya (R)	Uninoculated control	17.6	18.6	22.2	23.3	20.5
		RTV infection	18.0	19.1	23.0	24.3	21.1
		Per cent increase/decrease	(+ 1.87)	(+ 2.71)	(+ 3.41)	(+ 4.23)	(+ 3.12)
8.	Utrirajapan (R)	Uninoculated control	17.3	18.3	21.9	22.6	20.0
		RTV infection	17.7	18.9	22.8	23.7	20.8
		Per cent increase/decrease	(+ 2.54)	(+ 3.53)	(+ 4.31)	(+ 4.91)	(+ 3.91)
9.	Nidhi (R)	Uninoculated control	17.1	18.0	21.4	22.4	19.7
		RTV infection	17.6	18.8	20.5	23.7	20.1
		Per cent increase/decrease	(+ 2.86)	(+ 4.10)	(+ 5.11)	(+ 6.12)	(+ 2.12)
SEm ±			0.08	0.07	0.07	0.07	
CD (0.05) (UI)			0.02	0.19	0.26	0.22	
SEm ±			0.07	0.08	0.16	0.12	
CD (0.05) (I)			0.21	0.24	0.34	0.36	

Table 3. Effect of rice tungro disease (RTD) in total sugar (mg g^{-1}) of fresh leaf tissues of nine rice cultivars.

Figures in parentheses indicate per cent increase (+)/decrease (-) over uninoculated control

Table 4. Effect of rice tungro disease (RTD) in starch content (mg g^{-1}) of fresh leaf tissues of nine rice cultivars.

S.No.	Rice Cultivars	Treatment	Starch contents (mg g^{-1})				
			Days after Inoculation (DAI)				
			10	20	30	40	Mean
1.	T(N) 1 (S)	Uninoculated control	5.23	5.92	6.16	7.19	6.13
		RTV infection	6.06	7.20	8.73	11.18	8.29
		Per cent increase/decrease	(+ 15.9)	(+ 21.6)	(+ 41.7)	(+ 55.5)	(+ 35.2)
2.	CO 39 (S)	Uninoculated control	5.09	5.80	6.14	7.07	6.03
		RTV infection	5.90	6.99	8.52	10.42	7.96
		Per cent increase/decrease	(+ 15.9)	(+ 20.5)	(+ 38.8)	(+ 47.4)	(+ 32.0)
3.	MTU1010 (S)	Uninoculated control	5.02	5.74	6.02	6.94	5.93
		RTV infection	5.69	6.84	8.10	9.98	7.65
		Per cent increase/decrease	(+ 13.3)	(+ 19.2)	(+ 34.6)	(+ 43.8)	(+ 29.0)
4.	IR 64 (MR)	Uninoculated control	4.88	5.45	5.91	6.19	5.61
		RTV infection	5.18	6.01	7.07	8.01	6.57
		Per cent increase/decrease	(+ 6.14)	(+ 10.3)	(+ 19.6)	(+ 29.4)	(+ 17.1)
5	RPBIO 226 (MR)	Uninoculated control	4.65	5.39	5.78	6.12	5.49
		RTV infection	4.91	5.92	6.77	7.81	6.37
		Per cent increase/decrease	(+ 5.60)	(+ 9.83)	(+ 17.1)	(+ 27.6)	(+ 16.0)
6.	MTU 7029 (MR)	Uninoculated control	4.27	5.29	5.64	6.08	5.32
		RTV infection	4.51	5.74	6.54	7.57	6.09
		Per cent increase/decrease	(+ 5.62)	(+ 8.51)	(+ 16.0)	(+ 24.5)	(+ 14.5)
7.	Vikramarya (R)	Uninoculated control	4.35	4.88	5.17	5.52	4.98
		RTV infection	4.42	5.02	5.37	5.78	5.15
		Per cent increase/decrease	(+ 1.61)	(+ 2.86)	(+ 3.86)	(+ 4.71)	(+ 3.41)
8.	Utrirajapan (R)	Uninoculated control	4.16	4.74	5.15	5.36	4.88
		RTV infection	4.26	4.89	5.39	5.65	5.04
		Per cent increase/decrease	(+ 2.40)	(+ 3.16)	(+ 4.66)	(+ 5.41)	(+ 3.27)
9.	Nidhi (R)	Uninoculated control	4.02	4.62	5.09	5.28	4.75
		RTV infection	4.14	4.84	5.38	5.68	5.01
		Per cent increase/decrease	(+ 2.81)	(+ 4.76)	(+ 5.69)	(+ 7.57)	(+ 5.47)
SEm ±			0.03	0.04	0.03	0.03	
CD (0.05) (UI)			0.10	0.12	0.09	0.10	
SEm ±			0.03	0.03	0.32	0.16	
CD (0.05) (I)			0.11	0.11	0.09	0.05	

Figures in parentheses indicate per cent increase (+)/decrease (-) over uninoculated control

Table 5. Effect of rice tungro disease (RTD) in phenol content (mg g^{-1}) of fresh leaf tissues of nine rice cultivars.

S.No.	Rice Cultivars	Treatment	Phenol contents (mg g^{-1})				
			Days after Inoculation				
			10	20	30	40	Mean
1.	T(N) 1 (S)	Uninoculated control	5.23	14.2	16.4	18.2	13.5
		RTV infection	6.06	11.0	8.95	7.19	8.29
		Per cent increase/decrease	(+ 15.9)	(- 22.9)	(- 45.2)	(- 60.5)	(- 38.6)
2.	CO 39 (S)	Uninoculated control	5.17	13.2	15.4	17.8	12.9
		RTV infection	5.86	10.4	9.07	7.25	8.14
		Per cent increase/decrease	(+ 13.3)	(- 21.1)	(- 41.0)	(- 59.3)	(- 36.8)
3.	MTU1010 (S)	Uninoculated control	5.09	13.0	15.1	16.9	12.5
		RTV infection	5.70	10.5	9.45	7.85	8.38
		Per cent increase/decrease	(+ 12.0)	(- 19.2)	(- 37.5)	(- 53.7)	(- 33.2)
4.	IR 64 (MR)	Uninoculated control	15.2	16.1	18.4	19.0	17.2
		RTV infection	17.1	17.6	18.8	18.5	18.0
		Per cent increase/decrease	(+ 12.7)	(+ 8.76)	(+ 1.97)	(- 2.44)	(+ 4.65)
5	RPBIO 226 (MR)	Uninoculated control	14.0	15.6	17.8	18.4	16.5
		RTV infection	15.8	16.6	18.1	18.0	17.1
		Per cent increase/decrease	(+ 12.8)	(+ 5.95)	(+ 1.68)	(- 2.06)	(+ 4.00)
6.	MTU 7029 (MR)	Uninoculated control	13.9	15.2	17.2	18.1	16.1
		RTV infection	15.1	15.7	17.4	17.8	16.5
		Per cent increase/decrease	(+ 8.33)	(+ 3.35)	(+ 1.17)	(- 1.64)	(+ 2.48)
7.	Vikramarya (R)	Uninoculated control	16.6	18.2	19.7	20.4	18.7
		RTV infection	17.8	19.7	21.7	23.4	20.6
		Per cent increase/decrease	(+ 7.16)	(+ 8.10)	(+ 10.3)	(+ 14.6)	(+ 10.3)
8.	Utrirajapan (R)	Uninoculated control	16.5	18.1	19.3	20.1	18.5
		RTV infection	17.5	19.2	21.1	22.6	20.1
		Per cent increase/decrease	(+ 6.26)	(+ 5.90)	(+ 9.53)	(+ 12.1)	(+ 8.59)
9.	Nidhi (R)	Uninoculated control	16.0	17.7	18.9	19.1	17.9
		RTV infection	16.8	18.6	20.5	21.3	19.3
		Per cent increase/decrease	(+ 4.86)	(+ 5.10)	(+ 8.79)	(+ 11.2)	(+ 7.69)
SEm ±			0.17	0.08	0.11	0.11	
CD (0.05) (UI)			0.35	0.24	0.32	0.34	
SEm ±			0.05	0.06	0.05	0.15	
CD (0.05) (I)			0.14	0.18	0.14	0.44	

Figures in parentheses indicate per cent increase (+)/ decrease (-) over uninoculated control

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