

Biochemical changes in low-irradiance tolerant and susceptible rice cultivars

P.K. CHOWDHURY, M. THANGARAJ and M. JAYAPRAGASAM

Centre for Plant Molecular Biology, Tamil Nadu Agricultural University, Coimbatore-641 003, India

Abstract

In the topmost leaves of low-irradiance (LI) tolerant CO 43 and LI susceptible IR 20 rice cultivars, the contents of chlorophyll (chl) *a* and *b* and carotenoids and the Hill reaction activity increased under LI. The increase was greater in cv. CO 43 than that in cv. IR 20, and in Chl *b* than in Chl *a*. The contents of soluble proteins and reducing sugars and nitrate reductase activity of the leaves decreased while the content of non-reducing sugars increased due to shading. The decrease in reducing sugars was greater in cv. CO 43 than in cv. IR 20. On the other hand, the decrease in soluble proteins and nitrate reductase was much less in cv. CO 43 as compared with cv. IR 20.

Introduction

The productivity of crop plants is affected during the monsoon period when cloudy weather prevails for long period of every day. In peninsular India, this is a problem during October to December when the North-East monsoon brings rain. This monsoon coupled with the winter season brings down the yield of rice very much. Though high yielding rice cultivars are available, their susceptibility to low irradiance (LI) makes them inefficient yielders. Attempts were made in this study to understand LI tolerance in rice by comparing the biochemical changes taking place in a LI tolerant cultivar and a LI susceptible cultivar under the LI stress.

Materials and methods

The rice cultivars IR 20 (LI susceptible) and CO 43 (LI tolerant) were raised in pots during June to October, 1991. Irradiance was reduced to about 50 % of sunlight by

Received 5 May 1993, accepted 26 August 1993.

Acknowledgement: The authors express their gratitude and thank Dr. M. Nagarajan, Professor and Head of the Department of Crop Physiology for his keen interest and constant encouragement during the work. The senior author received a fellowship from the Department of Biotechnology of the Government of India during the course of study.

white gada cloth:

1. from transplanting to panicle initiation (T_1),
2. from transplanting to flowering (T_2),
3. from panicle initiation to flowering (T_3),
4. from transplanting to harvest (T_4),
5. from panicle initiation to harvest (T_5),
6. from flowering to harvest (T_6).

All other agronomic practices were common to all the treatments and the treatments were replicated five times.

The topmost fully opened leaf was taken immediately after the stress period for analysis. The leaves from the unshaded plants collected at panicle initiation, flowering and harvest stages served as controls. The pigments were estimated spectrophotometrically in 80 % acetone by the method of Arnon (1949). Hill reaction activity was assayed by measuring the reduction of 2,5-dichlorophenol indophenol at 600 nm in a Beckman UV-VIS spectrophotometer model DU 64 before and after irradiation. Sugars were determined by the Somogyi (1952) method using alkaline copper and arsenomolybdate reagents in the ethanol extract of the leaf before and after acid hydrolysis. The soluble protein content was estimated in the ethanol extract according to Lowry *et al.* (1951). Catalase activity was measured as reported by Abel (1974), the activity of nitrate reductase (NRA) by the method of Nicholas *et al.* (1976), and phosphatases according to Plummer (1978). The analyses from each replication were done in triplicate.

Results and discussion

Shading increased the Chl *a* and Chl *b* contents of both the rice cultivars (Table 1). The longer the shading treatment, the higher was the increase in pigment content. The

Table 1. Effect of low irradiance on pigment contents of rice cultivars IR 20 and CO 43 [g kg⁻¹(f.m.)].

	Chl (<i>a</i> + <i>b</i>)		Chl <i>a</i>		Chl <i>b</i>		Chl <i>a/b</i> Ratio		Carotenoids	
	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43
T_1	2.83	3.61	2.00	2.70	0.73	0.91	2.76	2.97	0.91	1.15
Control	2.06	2.48	1.54	1.87	0.52	0.60	2.99	3.11	0.68	0.83
T_2	4.41	4.29	3.09	2.99	1.33	1.30	2.33	2.30	1.11	1.11
T_3	3.91	3.68	2.81	2.67	1.10	1.01	2.55	2.63	0.94	0.95
Control	3.35	2.91	2.46	2.11	0.89	0.80	2.74	2.65	0.85	0.81
T_4	3.16	3.43	2.31	2.57	0.85	0.86	2.74	2.98	0.91	1.14
T_5	3.03	3.16	2.17	2.32	0.86	0.84	2.53	2.76	0.84	1.03
T_6	2.93	3.30	2.07	2.45	0.86	0.85	2.42	2.88	0.79	0.90
Control	2.54	2.11	1.88	1.58	0.65	0.52	2.87	3.03	0.68	0.70
CD between treatments	0.09		0.08		0.06		0.14		0.04	
CD between cultivars	0.24		0.20		0.16		0.37		0.11	

Chl *a/b* ratio was also decreased and the decrease was proportional to the period of shading. A similar trend was obtained with carotenoids content. The differences between the treatments and the cultivars were statistically significant. The increase in pigment contents was much higher in cv. CO 43 than that observed in cv. IR 20. The total Chl content was increased by a maximum of 62.8 % over control at harvest in cv. CO 43 as compared to 24.5 % in cv. IR 20 for the same treatment.

The rice plant adapts itself to LI by increasing the pigment contents so that it absorbs maximum radiant energy (Murthy *et al.* 1976, Venkateswarlu *et al.* 1977, Nayak and Murty 1980, Jiao 1992). The increase in Chl *b* was higher than that in Chl *a* thereby lowering the Chl *a/b* ratio. Though the rise in Chl *b* was higher in cv. CO 43, the reduction in Chl *a/b* ratio was higher in cv. IR 20. According to Reger and Krauss (1970), there was a shift in photosynthetic pigment contents from Chl *a* to Chl *b* due to LI.

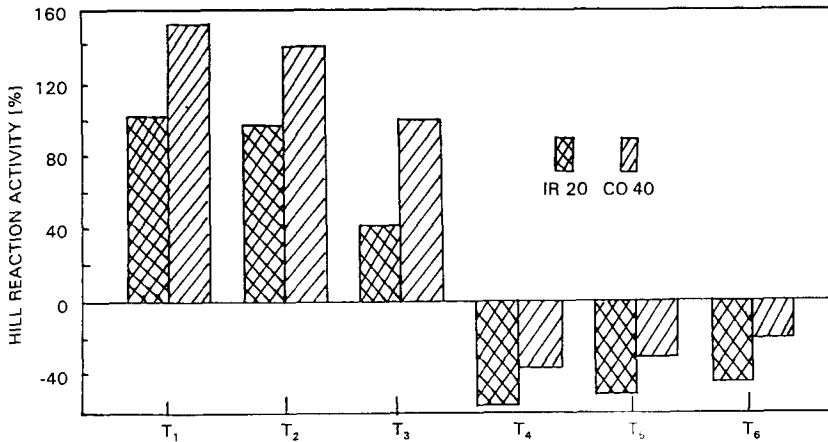


Fig. 1. Effect of low irradiance on Hill reaction activity of rice cultivars [% increase or decrease over control].

Due to LI, the Hill reaction activity was enhanced at panicle initiation and at flowering, and decreased at harvest (Fig. 1). The changes were also proportional to the length of shading period, and they were larger in cv. CO 43 than in cv. IR 20 in the initial two stages and *vice versa*. The decrease in Hill activity at harvest might be due to a generally low rate of photosynthesis (Nayak *et al.* 1978) and reduced photosynthetic efficiency of the crop canopy (Venkateswarlu 1977). The soluble protein content was decreased in all the treatments and the decrease was lower in cv. CO 43 than in cv. IR 20 (Fig. 2). The soluble protein content represents the ribulose 1,5-bisphosphate carboxylase activity (RuBPC). The decrease in Hill reaction activity and in soluble protein content ultimately affects the biomass production and the grain yield.

The contents of total sugars and non-reducing sugars in the leaf increased due to shading at panicle initiation and at flowering (Table 2) while the contents of the reducing sugars decreased at all the stages of growth. Reducing sugars are the metabolically active sugars and reduction of their contents in leaf indicates a

decrease in metabolic activity of the leaf under shading. Murty and Murty (1982) reported that the translocation of sugars from the leaf to grain and other parts of the plant is impaired leading to accumulation of sugars in the leaf. This is probably the reason for the increase in the non-reducing sugar content of the leaf under LI.

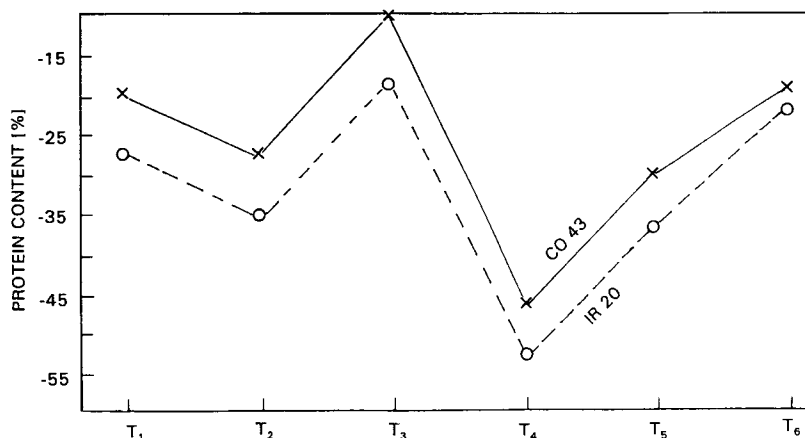


Fig. 2. Effect of low irradiance on soluble protein content in the leaf of rice cultivars [% decrease over control].

Table 2. Effect of low irradiance on sugar contents [$\text{g kg}^{-1}(\text{f.m.})$] in leaves of rice cultivars.

	Total sugars		Reducing sugars		Nonreducing sugars	
	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43
T ₁	10.79	9.63	3.13	2.24	7.66	7.39
Control	9.86	8.62	3.43	2.52	6.43	6.10
T ₂	11.02	10.21	3.82	1.60	7.21	8.61
T ₃	10.51	9.46	4.57	1.86	5.94	7.59
Control	9.97	8.82	4.77	3.36	5.19	5.46
T ₄	9.17	8.57	5.42	4.14	3.75	4.42
T ₅	8.78	8.81	5.81	4.63	2.97	4.18
T ₆	10.12	9.01	5.23	3.78	4.89	5.23
Control	10.74	10.67	5.05	3.42	5.68	7.25
CD between treatments	0.31		0.09		0.08	
CD between cultivars	0.81		0.25		0.21	

NRA was lowered in all shade treatments and the decrease was less in cv. CO 43 than in cv. IR 20 (Table 3). The maximum decrease in NRA was 16.9 % in cv. CO 43 when shading was given for the longest period, *i.e.*, from transplanting to harvest. The decrease in cv. IR 20 was 50 % for the same treatment. Similar results were obtained by Murty *et al.* (1975). The acid phosphatase activity increased while the alkaline phosphatase decreased in all the treatments. Murty *et al.* (1975) observed

a lower activity of phosphatase enzymes under LI. The catalase activity increased during first two stages of the crop and then decreased at harvest. This enzyme is associated with Chl metabolism and contains iron as prosthetic group (Agarwal *et al.* 1965). The increased pigment content with higher Chl *b* might correlate with the higher catalase activity to remove peroxide formed from water during the second photoreaction.

Table 3. Effect of low irradiance on nitrate reductase, acid phosphatase and alkaline phosphatase activities in rice leaves.

	Nitrate reductase [mg(nitrite reduced) s ⁻¹ kg ⁻¹ (f.m.)]		Catalase [rate constant per g(f.m.)]		Acid phosphatase [M(p-nitrophenol released) s ⁻¹ kg ⁻¹ (protein)]		Alkaline phosphatase [M(p-nitrophenol released) s ⁻¹ kg ⁻¹ (protein)]	
	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43	IR 20	CO 43
T ₁	0.44	4.87	1.84	2.45	2.62	1.47	0.208	0.076
Control	0.66	5.07	1.29	2.01	1.48	1.03	0.268	0.088
T ₂	0.77	7.80	1.59	2.24	2.78	2.15	0.190	0.082
T ₃	1.06	7.96	1.70	2.41	2.48	1.98	0.210	0.087
Control	1.21	8.40	1.36	2.04	1.63	1.45	0.282	0.102
T ₄	1.04	7.87	0.40	0.63	3.15	2.95	0.090	0.058
T ₅	1.37	8.13	0.45	0.68	3.30	3.48	0.100	0.060
T ₆	1.65	8.73	0.49	0.69	3.53	3.73	0.057	0.047
Control	2.09	9.47	0.60	0.72	2.00	2.23	0.923	0.072
CD between treatments		0.28		0.06		0.14		0.159
CD between cultivars		0.73		0.15		0.37		0.042

References

- Abel, H.: Catalase. - In: Bergmeyer, H.V. (ed.): *Methods in Enzymatic Analysis*. Vol. 2. Pp. 673. Academic Press, New York 1974.
- Agarwal, S.C., Sharma, S.P., Farooq, S.: Effect of iron supply on growth, chlorophyll, tissue iron and activity of certain enzymes in maize and radish. - *Plant Physiol.* **40**: 493-499, 1965.
- Arnon, D.I.: Copper enzymes in isolated chloroplast. Polyphenoloxidase in *Beta vulgaris*. - *Plant Physiol.* **24**: 1-15, 1949.
- Jiao, D.: Mass screening for rice germplasm tolerant to photoinhibition. - *Photosynthetica* **26**: 399-404, 1992.
- Lowry, O.H., Rosebrough, N.J., Farr, A.L., Randall, R.J.: Protein measurement with Folin-phenol reagent. - *J. biol. Chem.* **193**: 268-275, 1951.
- Murty, P.S.S., Murty, K.S.: Spikelet sterility in relation to nitrogen and carbohydrate contents in rice. - *Indian J. Plant Physiol.* **25**: 40-58, 1982.
- Murty, K.S., Nayak, S.K., Sahu, G.: Effect of low light stress on rice crop. - In: *Proceedings of the Symposium on Crop Responses to Environmental Stresses*. Pp. 74-84. VPKAS Publ., Almora 1975.

- Murty, K.S., Nayak, S.K., Sahu, G., Ramakrishnayya, G., Janardhan, K.V., Rai, R.S.V.: Efficiency of ^{14}C photosynthesis and translocation in local and high yielding rice varieties. - *Plant biochem. J.* **3**: 63-71, 1976.
- Nayak, S.K., Janardhan, K.V., Murty, K.S.: Photosynthetic efficiency of rice as influenced by light intensity and quality. - *Indian J. Plant Physiol.* **21**: 48-52, 1978.
- Nayak, S.K., Murty, K.S.: Effect of varying light intensities on yield and growth parameters in rice. - *Indian J. Plant Physiol.* **23**: 309-316, 1980.
- Nicholas, J.C., Harper, J.E., Hageman, R.H.: Nitrate reductase activity in soybean (*Glycine max* L.). Effect of light and temperature. - *Plant Physiol.* **58**: 731-735, 1976.
- Plummer, D.T.: *An Introduction to Practical Biochemistry.* - McGraw-Hill, London 1978.
- Reger, B.J., Krauss, R.W.: The photosynthetic responses to a shift in the chlorophyll *a* to chlorophyll *b* ratio of *Chlorella*. - *Plant Physiol.* **46**: 568-575, 1970.
- Somogyi, M.: Notes on sugar determination. - *J. biol. Chem.* **200**: 145-154, 1952.
- Venkateswarlu, B.: Influence of low light intensity on growth and productivity of rice (*Oryza sativa* L.). - *Plant Soil* **47**: 713-719, 1977.

Communicated by Z. ŠESTÁK