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Photosynthetic Rate, Dry Matter Accumulation and Yield Inter-relationships in Genotypes of Rice

R DEVENDRA, M UDAYA KUMAR and K S KRISHNA SASTRY
Department of Crop Physiology, University of Agricultural Sciences GKVK, Bangalore 560 065

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The relationship between photosynthetic efficiency, dry matter accumulation and yield in five genotypes of paddy derived from a single cross between Jaya X Halubbalu was studied. Photosynthetic efficiency of younger leaves, on the main tiller was higher than in the older leaves. A significant positive correlation between RuDPcase activity and photosynthetic efficiency was observed in these genotypes. Also a similar positive correlation between dry matter production and photosynthetic efficiency during vegetative period but not during post-anthesis period was observed. Genotypes with high photosynthetic efficiency and also the genotypes with high LAD produced higher dry matter. A reduction in LAD or in photosynthetic efficiency during the post-anthesis period and thus a reduction in source capacity which occurred specially in late types resulted in a lesser ratio between productive and total tillers and also higher per cent sterility. Differences in yield amongst the genotypes were not significant, since in the late types MR. 333 and MR. 335, the post anthesis dry matter production was low due to lesser source capacity. But in the early types though the total dry matter was less the post-anthesis source capacity was high. The importance of post-anthesis leaf area or photosynthetic efficiency in productivity in genotypes of rice is highlighted.

Key Words : Photosynthetic rate, RuDPcase, Leaf area duration, Crop productivity

Introduction

Biological yield is dependent on high rates of CO_2 fixation (Yoshida 1972). Genotypes of several crop species have been shown to differ in their capacity to fix CO_2, including that of rice (Tsunoda 1972, Murty et al. 1976, Ohno 1976; Janardhan & Murty 1978a). Besides photosynthetic rate another physiological determinant of biological yield is the leaf area duration or area of photosynthetic apparatus (Watson 1952). Population photosynthesis is shown to be particularly dependent on leaf area, at low LAI levels (Janardhan & Murty 1978b). However, relationship between economic yield and photosynthetic rate is yet to be established.

The activity of the carboxylating enzyme which determines the rate of photosynthesis depends upon the ontogeny, the position of the leaf and internal demand for the assimilates (Wareing et al. 1968, Frey & Moss 1976). Differences in photosynthetic efficiency of leaves at different stages of growth within a species, are also well established (Janardhan & Murty 1978b).

In the present study, changes in the rate of carboxylating enzymes, photosynthetic efficiency at different stages of the growth, their relationship with dry matter production and yield in five genotypes of rice were investigated. Further, an attempt was made to establish the relationship between the source capacity at different stages of growth and dry matter accumulation, tiller production and development and yield.

Materials and Methods

Five genotypes (MR. 272, MR. 320, MR. 99, MR. 333 and MR. 335) derived from a single cross between Jaya X Halubbalu (S. 317) were selected for this study with an object to minimise variations in many characters. The genotypes were raised under field conditions during summer season (January) following the Package of Practices-for High Yields (Anonymous 1978).

At fifteen-day intervals, starting from 30 days after transplanting up to harvest, plant samples were collected for estimation of tiller number, leaf area and dry matter accumulation. RuDPcase activity and photosynthetic efficiency of the leaf were estimated in each sample.

Photosynthetic efficiency of the genotypes were determined using radiometric method as described by Vaznisensky et al. (1965), RuDPcase activity in the second and third leaves were estimated according to the method of Wareing et al. (1968).

At harvest, data on yield and its attributes were collected.

Results

During early stages of growth the differences in the photosynthetic rate amongst the leaves were not statistically significant (table 1). However, at later stages of growth, younger leaves showed higher $^{14}CO_2$ fixation. MR. 333 showed higher rate of $^{14}CO_2$ fixation than other genotypes, at all stages of growth. In MR.335 the differences in photosynthetic rate between old and young leaves were less marked.

Photosynthetic efficiency, leaf area and dry matter accumulation

Photosynthetic efficiency of the second and third leaves were assessed at different growth stages and the genotypes differed significantly in photosynthetic efficiency (table 2). With regards to dry matter, MR.333 produced high dry matter followed by MR.335 (figure 1). The relationship between mean photosynthetic efficiency and dry matter was assessed. The mean photosynthetic efficiency showed a positive correlation with dry matter production during vegetative period but not during the post-anthesis period (figure 2). Per day dry matter production was also high in these two genotypes. However, biological yield per unit LAD was high in MR. 333 and MR. 272 and least in MR. 335 (table 3). This indicated that in addition to carbon fixation, other biochemical processes were important in the total dry matter production and varieties differed in this aspect, MR. 335 being less efficient.

Another parameter intimately related to dry matter accumulation is the leaf area, which did not not differ significantly during the early stages of growth but differed considerably during the post-anthesis period. A significant positive correlation between leaf area and dry matter production at different stages of

Figure 1 Periodic leaf area and dry matter production for genotypes (a—MR.272, b—MR.320, c—MR. 99, d—MR.333 and e—MR.335) of paddy. (↑) indicates 50% flowering,(↓)indicates time of harvest

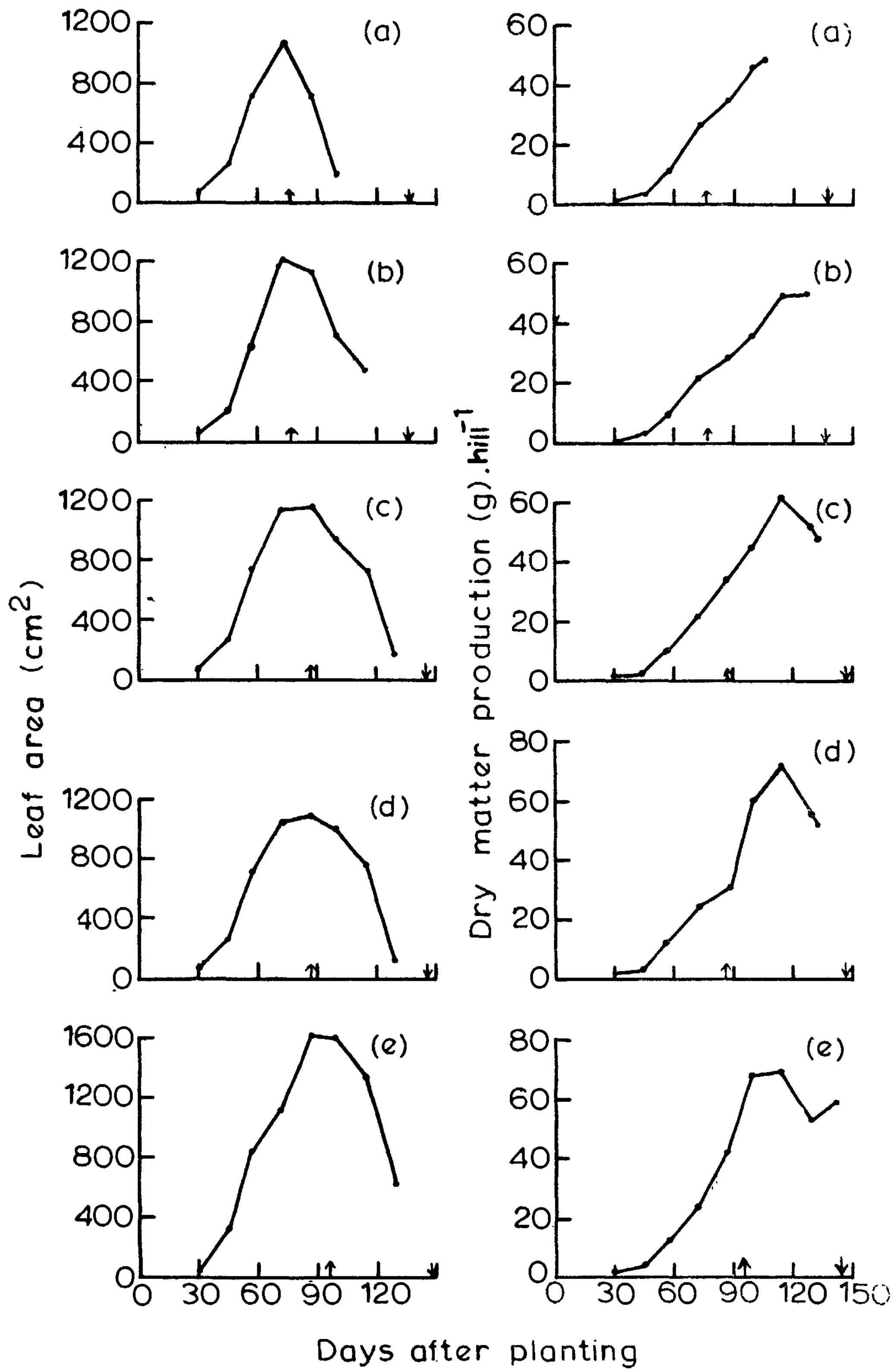
Leaf area (cm^2)
Dry matter production (g).hill^{-1}
Days after planting
(a)
(b)
(c)
(d)
(e)
0
400
800
1200
1600
20
40
60
80
30
60
90
120
150

Figure 1

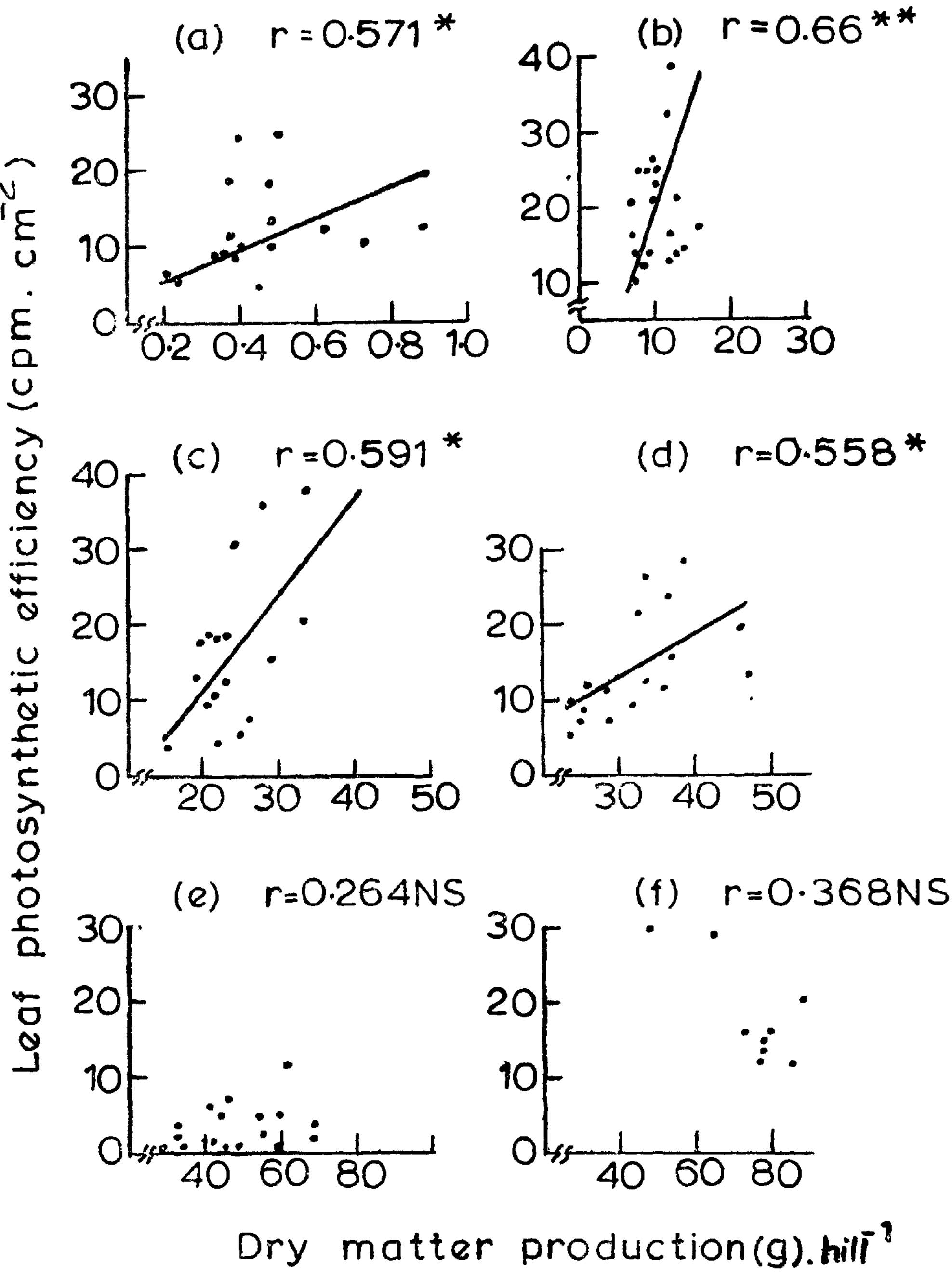

Figure 2 Relationship between leaf photosynthetic efficiency and dry matter production in paddy genotypes at different stages of growth (a—30, b—58, c—71, d—86, e—99 and f—113) days after planting

Table 1 *$^{14}CO_2$ fixation (cpm/g of leaf) in different leaves on the main tiller at different growth stages in 5 genotypes of paddy*

Leaf position	MR.272	MR.320	MR.99	MR.333	MR.335	F test		CD at 5%	CD at 1%
			40th day after planting						
Basal leaf	3,565	4,875	5,314	12,443	11,349				
2nd leaf	3,390	4,299	5,490	8,588	12,470	A	**	4693	6446
3rd feaf	5,727	5,007	5,756	11,063	7,812	B	NS	—	—
						C	NS	—	—
			54th day after planting						
Basal leaf	1,472	1,951	2,184	3,018	4,805				
2nd leaf	1,509	4,128	2,711	3,810	4,904	A	*	3026	4242
3rd leaf	2,750	2,592	3,108	3,495	6.907	B	NS	—	—
4th leaf	2,644	2,598	2,267	5,638	2,019	C	NS	—	—
5th leaf	2,039	1,069	3,207	4,499	2,180				
			72nd day after planting						
Basal leaf	4,175	4,454	5,429	4,850	4,462				
2nd leaf	3,508	2,815	8,867	3,190	3,723	A	**	5163	7238
3rd leaf	6,020	5,584	9,171	6,116	2,689	B	**	2333	3103
4th leaf	10,527	5,349	12,356	9,559	1,995	C	*	5218	6940
5th leaf	12,827	7,876	10,937	14,356	4,943				
6th leaf	—	—	12,034	16,682	2,924				
			97th day after planting						
Basal leaf	1,663	1,113	5,064	1,004	1,308				
2nd leaf	1,326	1,271	1,902	1,288	2,037	A	NS	—	—
3rd leaf	1,076	2,070	1,197	1,966	1,771	B	NS	—	—
4th leaf	1,088	1,286	2,538	3,107	3,051	C	**	1493	1995
5th leaf	—	—	—	—	2,642				

A—Varieties, B—Leaf position, C—Interaction between varieties X leaf position

Table 2 *Photosynthetic efficiency (DPM/cm² of leaf) at different growth stages in 5 genotypes of paddy*

Variety	Number of days from planting					
	32	47	61	75	89	116
MR.272	509.5	1414.5	747.0	922.0	681.0	—
MR.320	488.5	2420.0	1051.5	272.5	615.0	1476.0
MR.99	425.0	2420.0	1266.0	641.0	587.0	804.0
MR.333	909.0	1626.5	1678.0	786.0	1071.5	359.5
MR.335	539.0	2392.5	720.5	897.5	338.0	—
'F' test :	NS	**	*	**	NS	**
CD at 5%		614.5	503.0	212.0		251.5
CD at 1%		861.5	—	297.5		380.5

*Significant at 5% level
**Significant at 1% level

Table 3 *Per day/per LAD dry matter production in 5 genotypes of paddy*

Variety	Dry matter produced	
	Per day	Per LAD
MR 272	0.288	0.181
MR.320	0.297	0 152
MR 99	0 356	0.156
MR.333	0.404	0.185
MR 335	0.374	0.130
'F' test :	*	*
CD at 5%	0 077	0.040

Table 4 *Correlation coefficients between mean leaf area and dry matter accumulation in the shoot and entire plant at intervals after transplanting in 5 genotypes of paddy*

Intervals after transplanting	'r' values	
	Shoot only	Entire plant
35 days	0.998**	0.995**
47 ,,	0.896**	0 855**
51 ,,	0.691**	0.774**
60 ,,	0.358	0.446*
74 ,,	0.312	0.682**
91 ,,	0.478*	0.580*
102 ,,	0.444	0.617**
115 ,,	0.425	0.280

*Significant at 5% level
**Significant at 1% level

growth was observed in all varieties (table 4). However during the vegetative phase differences in leaf area between genotypes were not significant while the differences in photosynthetic efficiency were significant Thus during the vegetative phase the differences in dry matter production could be attributed to differences in photosynthetic efficiency amongst the genotypes. However during post-anthesis stages of growth, dry matter production was dependent upon the leaf area, since at this stage there was no correlation between photosynthetic efficiency and dry matter production.

Photosynthetic efficiency and RuDPcase Activity

RuDPcase activity per unit leaf area, during the entire growth period was significantly correlated with photosynthetic efficiency, in all the genotypes (figure 3). Similarly there was a significant positive correlation between photosynthetic efficiency and specific activity of RuDPcase.

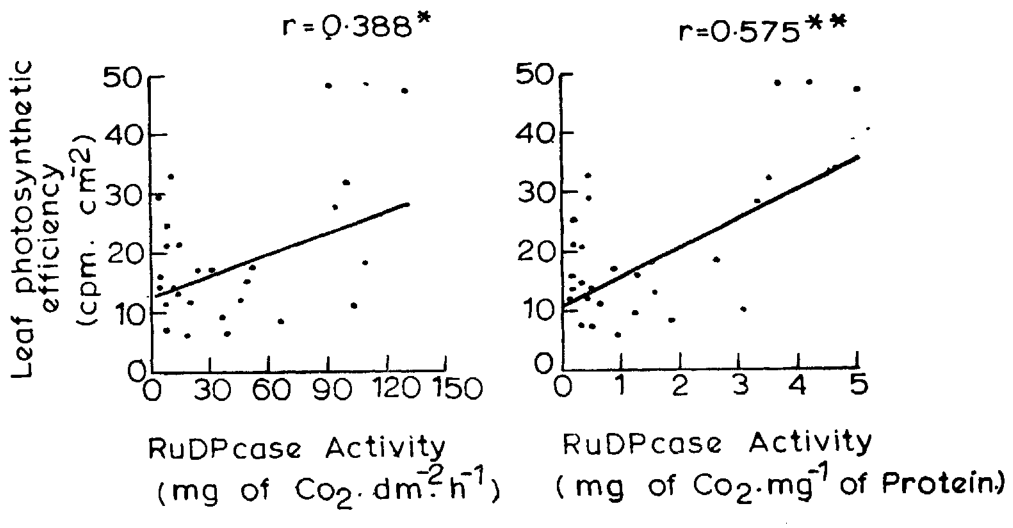

Figure 3 Relationship between RuDPcase activity and leaf photosynthetic efficiency in paddy genotypes

Tiller production and yield parameters

There were significant genotypic difference in the number of panicle/m^2, number of spikelets/panicle and per cent spikelet sterility (table 5) at harvest Differences in tiller number per plant, amongst the genotypes at peak tillering were not significant, but at harvest, there were significant differences in total and also in productive tiller number (table 6). Genotypes differed in this regard. The tiller number at harvest was less in MR. 99, MR. 333 and MR. 335 and the ratio of productive tillers to maximum tiller was highest in MR. 272.

Genotype MR. 333 and MR. 335, which accumulated high dry matter also produced larger number of spikelets/panicle but their grain yields were not significantly different from those of MR. 272 and MR. 320. MR. 335 though significantly superior to other genotypes in dry matter accumulation and also in spikelets/panicle, the grain yield was not high because of high spikelet sterility. The lower economic yield in genotypes MR. 333 and MR. 335, inspite of their ability for higher dry matter accumulation was due to a reduction in the leaf area (source) during later stages of growth. In early types (MR. 272 and MR. 320) post-anthesis leaf area and photosynthetic rate were higher.

Table 5 *Yield and yield parameters*

Varieties	Number of spikelets/ panicle	Percentage of sterility	1000 grain weight	Number of panicles/m^2	Grain yield kg/m^2	Straw yield kg/m^2	Biological yield kg/m^2
MR.272	80.5	13.3	19.1	708	1.005	1.172	2.177
MR.320	89.3	25.4	17.2	755	1.224	0.823	2.047
MR.99	109.2	28.9	17.6	558	1.186	1.198	2.384
MR.333	115.6	33.6	19.4	393	1.093	1.019	2.112
MR.335	118.1	43.5	16.6	635	1.259	1.800	3.059
'F' test:	**	**	NS	**	NS	**	**
CD at 5%	15.3	5.6		88.5		0.350	0.519
CD at 1%	21.4	7.9		124.1		0.491	0.728

Table 6 *Tiller counts/hill of 5 genotypes of paddy*

Varieties	Maximum tillers produced	At harvest			% of productive tiller	
		P	NP	Total	Total	Max. tiller
MR.272	22.75	17.0	1.0	18.0	95.00	74.73
MR.320	21.75	15.5	0.5	16.0	97.00	71.27
MR.99	20.75	12.75	0.25	13.0	98.25	62.00
MR.333	19.00	10.25	0.25	10.5	97 75	54.52
MR.335	22.50	15.25	0.5	15.75	96.75	71.05
'F' test	NS	**	NS	**	NS	**
CD at 5%		3.103		3.65		10.05
CD at 1%		4.350		5.08		14.09

Discussion

Photosynthetic efficiency and photosynthetic area are the two important parameters which countribute for dry matter accumulation. Relationship between dry matter accumulation and photosynthetic efficiency was observed in several species (Treherne 1972 and Yoshida 1972). Varietal differences in photosynthetic efficiency and leaf area has been shown in rice (Janardhan & Murty 1977, Ohno 1976).

In this study a positive correlation between photosynthetic efficiency and dry matter accumulation was observed during vegetative period and the differences were significant. Genotype MR. 333 showed higher photosynthetic efficiency and dry matter accumulation during vegetative stage. The genotype MR.335 though had lower CO_2 fixation rate also showed higher dry matter accumulation, which was mainly due to higher LAD. Total biological yield at harvest was also high in MR. 335, which showed high LAD values during post-anthesis period than in MR. 333 and MR. 99.

Of the genotypes included in this study MR. 272 and MR.320 were early, MR.99, MR. 333 and MR. 335 were late. In the early types at the time of anthesis (75th day) the photosynthetic efficiency of the top leaves was high whereas in late type at anthesis (90th day) photosynthetic efficiency was low (table 1). In early types a high rate of photosynthesis at the time of anthesis and during post-anthesis period, was observed compared to late types. Murata (1961) showed that at anthesis and during grain filling period the photosynthetic rate is generally higher in short duration varieties. The consequent higher source capacity accounted for the higher productive tiller number in these genotypes. This resulted in high panicle numbers/unit area at harvest. In the early duration types lesser tiller mortality and lesser sterility could be attributed to high photosynthetic efficiency particularly during post-anthesis stage (table 5). While in late types though a major reduction in tiller number occured in the lag phase (between 71–86 days after transplanting) subsequently also the number continued to decrease up to the harvest and this decrease was associated with a concurrent decrease in leaf area and photosynthetic efficiency. In rice, it is well established that 90 per cent of the assimilates for panicle development and for grain filling come from current photosynthesis (Matsushima 1976, Venkateswarlu et al. 1977). High source capacity. during later stages of growth is essential for higher productivity. Therefore genotypes in which higher source capacity (photosynthesis efficiency and LAD) during post-anthesis period is high, are expected to be more productive, particularly so in late types.

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