Variation in Leaf Photosynthesis among Wild Species in Genus *Oryza* and among the Progeny of Selected Crosses of the Wild species with a Rice Cultivar.

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Abstract

There was a wide range in leaf photosynthetic rates (Pn) of 16 different species of *Oryza* measured in a tropical environment where *O. sativa* and O. *rufipogon* were identified as potential sources of enhanced photosynthetic rate. Two F1 hybrids between *O.sativa ? O. rufipogon* were significantly greater than the *O.sativa* parents and other F1 hybrids. Among the F2 progeny, segregants with even greater rates of photosynthesis were identified, while the F3 derived from superior F2 plants maintained the high-photosynthesis trait, with a highly significant parent-offspring regression coefficient of 0.86. The progenies with high Pn when grown in the tropics were also planted in a temperate area, and good stability of high photosynthetic capacity was found. Genetic resources in the genus Oryza could serve as a source of alleles to increase photosynthetic rate in the cultivated species.

Media summary

Genetic resources in the genus *Oryza* could be one source of increased rates of single leaf photosynthesis in the cultivated species.

Key words

rice, photosynthesis, Oryza ,O. sativa , O. rufipogon

Introduction

The need to improve the rate rice photosynthesis is a more important challenge in order to break the postulated yield potential barrier in rice (Peng, S., 2000). One possible way is to identify high photosynthesis rates among the genetic resources in the genus *Oryza* and use these materials in a wide crossing program. The objectives of this study were to assess the extent of genetic variation for high rates of single leaf photosynthesis (Pn) in wild *Oryza* and to measure the variation in Pn in the progeny from crosses between O.sativa *? O. rufipogon* when grown in a tropic and temperate environment.

Materials and methods

Accessions of 16 different species and eight F1 hybrids of *O.sativa ? O. rufipogon* with relatively high individual plant yield were grown in greenhouse tanks at the International Rice Research Institute (IRRI), Philippines. For the evaluation of F2 progeny, seeds from the F1 plants were planted in an upland experimental field at IRRI. The female parent and F1 were used as controls. Seeds were collected from 16 randomly selected F2 plants and from four high-Pn F2 plants from the hybrid 20557-10. Three high Pn progenies selected from the tropical region (IRRI), their parents and four accessions of *O. rufipogon* were planted in pots in China Agricultural University in order to study the PN under temperate conditions. All plants were grown under well-watered aerobic conditions. Rates of Pn were measured from 10:00am to 3:00pm on clear days during the flowering stage. Leaf Pn of the F1 and F2 progeny grown in China was measured using a CAU photosynthesis measurement system (China Agricultural University). Photosynthetic active radiation (PAR) and leaf temperature was about 1500 to 1700 μmol $m^{-2}s^{-1}$ and 35 to 37 ^{o}C respectively. The Pn of the wild species and of the F3 progeny grown at IRRI was measured with a Li-Cor6400 (Li-Cor corp., USA). Leaf temperature, ambient PAR, and CO_2 concentration was about 30 ^{o}C, 1200 μmol $m^{-2}s^{-1}$, and 350 ppm respectively.

Results

Photosynthetic survey of wild species

There was a wide range in photosynthetic rate (Pn) observed among species (Table 1). *O. rufipogon* accession 105697 achieved a rate of 37.6 μmol $m^{-2}s^{-1}$. *O.australiensis* also reached high levels of Pn.

Photosynthesis of F1 hybrids and parental lines

There were significant differences in Pn among the eight F_1 progeny from *O. sativa* and *O.rufipogon* crosses. Photosynthesis of hybrids 20472-6 and 20557-10 exceeded the apparent mid-parent mean. The average Pn of the *O.rufipogon* accessions were similar to the F_1's except for Tawsan1, which tended to have a lower rate than other entries.

Photosynthetic Characteristics of F_2 populations and parents in the field

Photosynthesis was measured in the F_2 progeny derived from the two F_1 hybrids 20472-6 (n=48) and 20557-10 (n=154). Both populations showed a normal distribution of Pn (Figure 1). On average, the F_2 populations did not differ from the female parent from which they were derived, but exceptional F_2 individuals greatly exceeded the female parent (Table 2). The five plants with the greatest maximum photosynthesis were identified from the hybrid 20557-10. These plants were measured again on different days using the Li-Cor photosynthesis system, and rates greater than 30 μmol m^{-2} s^{-1} were again recorded.

Inheritance of photosynthetic rate in F_3 progeny

The correlation between Pn of the F_2 clones and F_3 plants was 0.86 ($P<0.01$), indicating high realized heritability of this trait (Figure 2). Thirteen of the F_2 clones had a significantly greater Pn than the F_1 clone. Among the F_3 families, one had a significantly greater mean Pn than Azucena. There was still considerable segregation within each F_3 family, indicating that further selection is needed to genetically fix the high-photosynthesis trait.

Stability of high photosynthetic rate when grown in a tropical and temperate area

The progenies also presented higher Pn with 34-35.5 μmol $m^{-2}s^{-1}$, compared with other all cultivated and wild rice when grown in the temperate area (Table3). The Pn of SHP-8 was 61.54,23.53 percentage higher than the female and male parents.

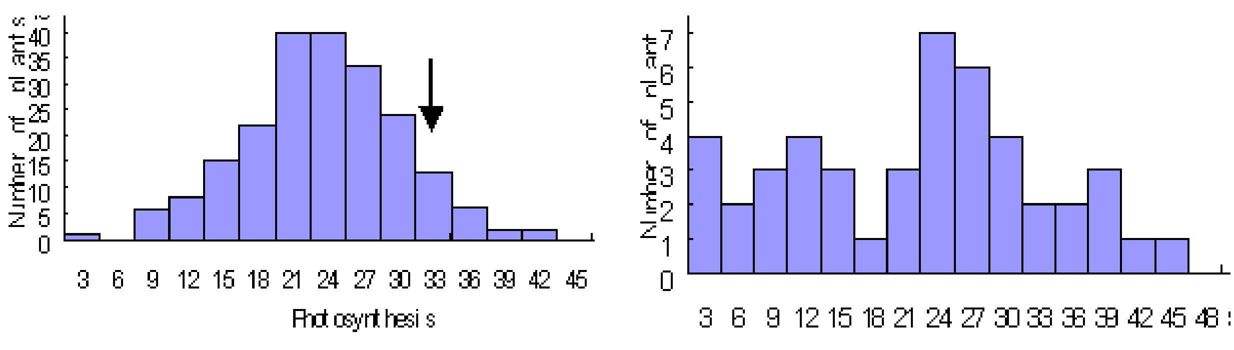

Figure1. Distribution of photosynthetic rate (μmol $m^{-2}s^{-1}$) in populations of field-grown F2 plants derived from two inter-specific hybrids. For hybrids 20557-10(left), n=154; for 20472-6(right), n=48. Arrows indicate photosynthetic rate measured for the *O.sativa* parent in the same experiment.

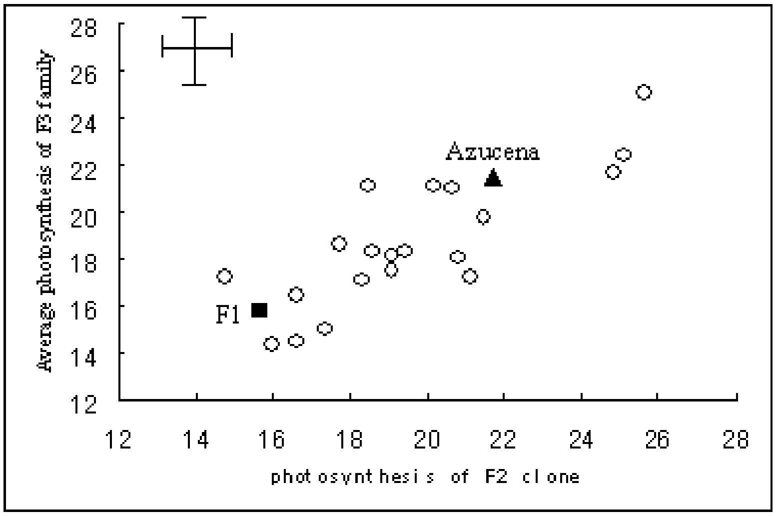

Figure 2. Photosynthetic rates (μmol $m^{-2}s^{-1}$) of twenty F2 clones versus photosynthetic rates of populations of F3 derived from each F2 plant. Error bars reflect the LSD at P<0.05.

Table 1. Characteristics of Oryza accessions evaluated for photosynthetic rate (Pn). Values followed by the same letter do not differ at p<0.05.

Species	IRGC #	Genome	Habitat[a] A/P	S/Sh	Pn (μmol $m^{-2}s^{-1}$)	Species	IRGC#	Genome	Habitat[a] A/P	S/Sh	Pn (μmol $m^{-2}s^{-1}$)
O. alta	105685	CCDD	P	Sh	24.2b	O. longistaminata	101741	AA	P	S	34.4d
O. australiensis	101397	EE	P	S	33.8d	O.?longistaminata	103904	AA	P	S	28.8c
O.?australiensis	103303	EE	P	S	35.6de	O. meridionalis	101148	AA	A/P	S	34.0d
O. australiensis	104090	EE	P	S	36.7e	O. minuta	101099	BBCC	P	S	29.9c
O. australiensis	105272	EE	P	S	34.8d	O. minuta	101081	BBCC	P	S	31.2c
O. barthii	10498	AA	A	S	27.2c	O. minuta	80683	BBCC	P	S	24.5b

	3										
O. barthii	106300	AA	A	S	31.5c	O. officinalis	104707	CC	P	Sh	23.5b
O. eichingeri	100881	CC	A	S	21.1b	O. punctata	101330	BB	A	Sh	22.8b
O. glaberrima	102665	AA	A	S	27.2c	O. rufipogon	104640	AA	P	S	25.6bc
O.?glumaepatula	100971	AA	P	S	14.3a	O. rufipogon	105697	AA	P	S	37.6e
O. grandiglumis	105671	CCDD	P	Sh	25.3bc	O. rufipogon	(Rampur 6)	AA	P	S	34.4d
O. latifolia	100172	CCDD	P	Sh	23.4bc	O. sativa	(Azucena)	AA	A	S	27.6b

[a] Habitat: A/P = annual / perennial, S/Sh= sun / shade.

Table 2. Rates of photosynthesis recorded in the greenhouse for the tillers near flowering in the *O. rufipogon* and F1 hybrids, Photosynthesis was measured using CAU photosynthesis system.

F1	Pn (μmol $m^{-2}s^{-1}$)	*O.sativa*	Pn (μmol $m^{-2}s^{-1}$)	*O. rufipogon*	Pn (μmol $m^{-2}s^{-1}$)
20342-3	28.7			Tawsan 11	38.3
20472-6	45.5	IR63371-38	20.4	Ulanpur 7	36.7
20485-3	27.1	WAB56-50	28.2	Kyant-1	33.8
20495-1	38.4	IRAT216	28.5	Tawsan 1	37.4
20515-12	34.1	Azucena	22.7	Ulanpur 18	35.5
20537-12	24.2			Rampur 11	19.8
20552-10	25.4			Nagesa 18	34.8

20557-10	43.3			Rampur 6	30.0
Average	35.7		23.8		33.6
LSD0.05	9.6		6.9		12.5

[a] LSD to compare entries within a group.

Table3.Rates of photosynthesis recorded at three different development stages in the wild rice and F2, F3 hybrids with high photosynthesis rate, and some cultivated cultivars.

Type	Name	40-day seedling Pn (μmol m^{-2}s^{-1})	70-day plant Pn (μmol m^{-2}s^{-1})	flowering Pn Pn(μmol m^{-2}s^{-1})	Average Pn (μmol m^{-2}s^{-1})	IRRI Pn (μmol m^{-2}s^{-1})
Cultivars	Azucena	34.6?1.2	23.0?1.6	28.7?1.8	28.7b	19.1*
Wild rice	Rampur6	22.2?1.6	16.1?2.3	27.6?1.5	22.0c	26.8*
Hybrids from cultivated and wild rice	SHP1(F_2)	35.6?1.6	34.0?1.3	32.6?1.9	34.0a	42.2*
	SHP1-6(F_3)	36.4?1.5	35.1?1.5	32.6?1.5	34.7a	
	SHP1-8(F_3)	38.2?2.1	34.9?2.1	33.3?2.4	35.5a	

* mean value measured in tropic area in IRRI.

Discussion

Wild *Oryza* species are considered to be a rich source of agronomic traits, including insect and disease resistance and increased biomass, and even yield and its components (Moncada P et al.2001, X..Li et al., 1998) Variation in light-saturated assimilation rate and phosphoenolpyruvate (PEP) carboxylase activity has been reported in a set of *Oryza* species, and the *O.rufipogon* accessions evaluated had photorespiration rates significantly lower than the O.sativa genotypes tested (Yeo et al., 1994). We also found significant variation in photosynthetic rates among different accessions, cultivars, and inter-specific hybrids. The rates of photosynthesis reported here were measured under realistic levels of temperature and radiation for tropical rice, and are substantially greater than those previously reported. Species with very high levels of Pn were *O. australiensis* and *O.rufipogon. O.australiensis* is an EE genome species, and interspecific hybrids show rather limited levels of introgression of the wild genome. This species is adapted to high light environments in seasonally dry areas of Australia. In contrast, *O.rufipogon* is an AA genome species, like rice, and inter-specific hybrids have significant introgression from the wild species. This species is adapted to a wide range of environments, mostly semi-aquatic. Both of these species were capable of maintaining high rates of photosynthesis when grown in well-watered, aerobic soil conditions.

For the inter-specific hybrids showing high photosynthesis in the F_1, photosynthesis in the F_2 showed a normal distribution, indicating that this trait is quantitatively inherited. Photosynthesis of F_2 plants was highly correlated with average photosynthesis of their F_3 progeny, and normal distributions of photosynthetic rate were observed in the F_3 populations. These results are again consistent with a multi-gene trait. And we also found that progenies with high photosynthetic rates in the tropic also had high photosynthetic capacity when in a temperate area.

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