

Genetic study of allogamic traits in *Oryza sativa* L.

(Kajian genetik ciri alogami bagi padi *Oryza sativa* L.)

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Key words: allogamic, dominance, heterosis, inbreeding depression, *Oryza sativa* L.

Abstrak

Ciri alogami empat varieti padi, *Oryza sativa* L. serta progeneri F₁ dan F₂ daripada varieti tersebut telah dikaji. Darjah dan arah heterosis amat berbeza bagi ciri-ciri dan kacukan yang berbeza. Kedua-dua gen bertindak yang aditif dan bukan aditif didapati mengawal ciri-ciri tersebut. Pengaruh pembiakbakaan dalaman amat ketara pada kepanjangan cepe debunga dan saiz debunga. Hubungan kedominanan adalah sangat berbeza. Kedua-dua arah kedominanan sama ada positif atau negatif ditunjukkan bagi semua ciri. Anggaran keterwarisan boleh dikatakan tinggi untuk kepanjangan cepe debunga, berat 100 cepe debunga dan peratus spikelet yang berisi. Kepanjangan cepe debunga berkorelasi positif dengan berat 100 cepe debunga dan saiz debunga. Bukti telah didapati tentang kemungkinan pemilihan pada generasi yang terasing awal bagi ciri-ciri alogami.

Abstract

Four varieties of *Oryza sativa* L. and their F₁ and F₂ progenies were studied with respect to allogamic traits. The degree and direction of heterosis varied greatly for different characters and different crosses. Both additive and non-additive gene actions were evident in controlling the characters. Inbreeding depression was significant for anther length and pollen grain size. The dominance relationships were highly variable. Both positive and negative directions of dominance were indicated for all characters. Heritability estimates were relatively high for anther length, 100-anther weight and percentage of filled spikelets. Anther length was positively correlated with 100-anther weight and pollen grain size. Evidence was obtained for the feasibility of selection in early segregating generation for these traits.

Introduction

Rice (*Oryza sativa* L.) is a naturally self-pollinated species. Some variations for anther length, 100-anther weight, pollen grain size and percentage of filled spikelets existed in Basmati varieties/lines but no or very little genetic information is available on

these allogamic traits in rice crop. Ali et al. (1992) reported that anther length and pollen grain size in rice are monogenically controlled traits. Anther length, pollen grain size and number and percentage of exerted stigma are the interrelated traits that show the outcrossing potential of a genotype (Oka

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and Morishima 1967; Virmani and Athwal 1973). Increased length of anther could improve outcrossing potential not only through its influence on stigma exertion, but also by directly increasing the number of pollen grains available for pollination (Virmani and Athwal 1973).

Yun-bi et al. (1988) observed that the mean stigma exertion ratio (SER) in Indica rice was higher than Japonica type. Upland rices also showed higher SER than lowland rices. They also indicated the importance of single and double-exserted stigma for outcrossing in rice.

The objective of this investigation was to study the interrelationship, dominance effects and inheritance of allogamic traits in *Oryza sativa* L.

Material and methods

Four varieties of rice (*Oryza sativa* L.), viz., Basmati 370, Basmati 385, 4048 and Basmati 198 were used as parents in this study. The six possible direct crosses made were

1. Basmati 370 x Basmati 385,
2. Basmati 370 x 4048,
3. Basmati 370 x Basmati 198,
4. Basmati 385 x 4048,
5. Basmati 385 x Basmati 198 and
6. 4048 x Basmati 198

The parents, F_1 and F_2 populations were grown in three replications using Randomized Complete Block Design at Rice Research Institute, Kala Shah Kaku during 1990–91. The seeds were space planted so that each plant was separated from adjacent ones by 30 cm in each direction. There were 45 plants of each of the parents and F_1 , and 150 plants of F_2 in each replication at maturity. Normal cultural practices were followed throughout the growing season.

Four allogamic traits were studied, viz. anther length, 100-anther weight, pollen grain size and percentage of filled spikelets. Although percentage of filled spikelets was not expected to influence outcrossing, it was

included in the study to find out if it is associated with any of the floral characters.

Data were collected on an individual-plant basis. The length of anther and pollen grain size were measured in millimeters and microns under a binocular microscope. Three observations were made on each plant from each replicate of each of the genotypes. The 100-anther weight per replication was obtained in milligrams. The percentage of filled spikelets was recorded by dividing the number of filled spikelets with the total number of spikelets and multiplied with 100.

Heterosis and inbreeding depression were estimated after Matzinger et al. (1962). Potence ratio method was used to evaluate relative magnitude and direction of dominance (Wigan 1944; Mather 1949). Heritability (broad sense) was calculated using the geometric mean of parental variance as a measure of environmental effect. General and specific combining ability analyses were made using Method 2, Model 1 of Griffing (1956).

Results and discussion

The characteristics of the four parents are given in *Table 1*. The parental varieties showed a wide range of variation for the characters being studied except for pollen grain size.

Heterosis, inbreeding depression and heritability

The degree and direction of heterosis varied greatly for different characters and different cross combinations (*Table 2*). Significant negative heterosis was exhibited for anther length in crosses 1, 2, 3 and 4. Positive but non-significant heterosis was observed in crosses 5 and 6. For 100-anther weight, significant negative heterosis was shown in crosses 3, 4 and 5. Positive and non-significant heterosis was shown in crosses 1 and 6. For pollen grain size, crosses 5 and 6 showed significant positive heterosis. Significant negative heterosis was indicated for this trait in cross 4. For percentage of

Table 1. Allogamic traits of four varieties of *Oryza sativa* L.

Variety	Anther length (mm)	100-anther weight (mg)	Pollen grain size (microns)	Filled spikelets (%)
Basmati 370	2.43b	10.2a	39.14a	88.49a
Basmati 385	2.85a	8.2b	39.78a	88.61a
4048	2.41c	9.4a	40.43a	88.13a
Basmati 198	2.41c	7.8b	40.43a	85.83b
LSD (0.5%)	0.015	0.891	1.919	2.112

Mean values with same letter are not statistically significant.

Table 2. Heterosis estimates of F_1 hybrids over their respective higher parents

Cross	Anther length (mm)	100-anther weight (mg)	Pollen grain size (microns)	Filled spikelets (%)
Bas. 370 x Bas. 385	6.56*	1.86	-0.76	3.85
Bas. 370 x Bas. 4048	-8.12**	-6.86	-4.63	-12.41**
Bas. 370 x Bas. 198	-5.1*	-24.81*	0.05	-5.15*
Bas. 385 x Bas. 4048	-9.65**	-27.45*	-5.98**	-8.79
Bas. 385 x Bas. 198	1.16	-16.32*	3.38**	-17.2
4048 x Bas. 198	0.12	5.94	9.08**	-11.2**

Table 3. Average F_1 and parent values, heterosis, inbreeding depression and heritability estimates for four allogamic traits

Traits	Average F_1	Mean high parent	Heterosis (%)	Inbreeding depression	Heritability
Anther length	2.43	2.54	-4.33	2.53**	76.79
100-anther weight	8.68	9.87	-12.06**	1.64	96.29
Pollen grain size	41.86	41.81	0.12	6.87**	15.22
Filled spikelets	80.99	88.49	-8.48	1.85	86.08

filled spikelets, all the crosses, except cross 1, indicated significant negative heterosis. Crosses 2 and 4 did not show positive heterosis for any trait.

The average, percentage of heterosis, inbreeding depression and heritability estimates for the four traits are given in Table 3. Only the 100-anther weight showed significant negative heterosis, while the heterosis estimates of the remaining characters were non-significant. Significant inbreeding depression, estimated from the average of the F_2 populations, occurred for anther length and pollen grain size. Results on heterosis and inbreeding depression suggest that both additive and non-additive

gene actions were involved. The characters that show the most heterotic response in some F_1 hybrids, viz., pollen grain size and anther length, showed the highest degree of inbreeding depression. However, 100-anther weight exhibited small inbreeding depression. The fact that most of the F_2 populations yielded less than their corresponding midparents and F_1 hybrids as also evident by the significant inbreeding depression coefficient, may indicate the presence of epistatic gene action.

Heritability estimates were relatively high for all the characters except pollen grain size, suggesting that selection may be feasible in early generations and

Table 4. Dominance values estimated by potence ratio method for six crosses

Cross	Anther length (mm)	100-anther weight (mg)	Pollen grain size (micron)	Filled spikelets (%)
1	-0.06	1.15	-0.03	57.83
2	-3.75	0.71	-0.51	-60.00
3	0.71	0.01	1.03	-2.43
4	-0.33	-0.75	-0.59	-31.46
5	2.50	0.04	2.51	-9.96
6	4.00	4.15	6.73	-7.58

Table 5. Correlation coefficients among allogamic traits

Trait		100-anther weight	Pollen grain size	filled spikelets
Anther length	rg	0.23	0.94**	-0.23
	rp	0.18	0.41	-0.21
100-anther weight	rg		-0.75*	-0.41
	rp		-0.2	0.34
Pollen grain size	rg			-0.08
	rp			0.03

rg and rp = genotypic and phenotypic correlation coefficients.

*, ** = significant at 5% and 1% levels respectively

considerable improvement in allogamic traits can be achieved.

Dominance

The relative magnitude and direction of dominance as assessed by potence ratio method are given in *Table 4*. The estimates were highly variable for all characters considered. Complete dominance was exhibited for 100-anther weight in cross 1 and for pollen grain size in cross 3. Overdominance was exhibited for anther length in crosses 5 and 6, for 100-anther weight in cross 6, for pollen grain size in crosses 5 and 6, and for percentage of filled spikelets in cross 1. The remaining crosses exhibited partial dominance or recessiveness for most of the characters. Crosses 5 and 6 may be the potential source of outcrossing due to improved floral traits.

Correlation

Correlation coefficients among the four traits, estimated from the non-segregating populations (parents and F_1) are shown in *Table 5*. Anther length was positively

correlated with 100-anther weight and pollen grain size both as genotypic and phenotypic levels but negatively with percentage of filled spikelets, thus indicating that anther length can be improved by increasing the 100-anther weight and pollen grain size. Virmani and Athwal (1973) also observed positive correlation between anther length and percentage of exerted stigma which indicated that the increased length of anther could improve outcrossing through its influence on stigma exertion as well as by directly increasing the number of pollen grains available for pollination. All other traits were negatively correlated with each other. Only the significant genotypic correlation (0.94**) was observed between anther length and pollen grain size, whereas the correlation was significant but negative (-0.75*) between 100-anther weight and pollen grain size.

Combining ability

The levels of significance of the components for the general and specific combining ability are presented in *Table 6*. All

Table 6. Levels of significance for general (GCA) and specific combining ability components in F₁ and F₂ generations

Trait	F1	F2		
	GCA component	SCA component	GCA component	SCA component
Anther length	**	**	**	ns
100-anther weight	**	**	ns	ns
Pollen grain size	**	**	**	**
Filled spikelets	*	**	**	ns

* $p < 0.05$ ** $p < 0.01$

ns = not significant

characters showed significant mean squares for both general and specific combining ability in the F₁ generation. In the F₂ generation, the general combining ability mean squares for anther length, pollen grain size and percentage of filled spikelets, and specific combining ability mean squares for pollen grain size were significant. The general and specific combining ability estimates for allogamic trait suggest that both additive and non-additive types of gene effects are important for these traits. These findings are also corroborated by the potence ratio for all traits being considered. The combining ability analysis also indicated that specific combining ability was less important in the F₂ than in the F₁. Such a result would be expected when there is a considerable amount of non-additive gene action in the F₁ generation (Niehaus and Pickett 1966).

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