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Determination of Heterotic Groups and Heterosis Analysis of Yield Performance in *indica* Rice

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Abstract: To compare the heterosis levels among various groups of parental lines used extensively in China, identify foundational heterotic groups in parental pools and understand the relationship between genetic distance and heterosis performance, 16 parental lines with extensive genetic variation were selected from various sub-groups, and 39 hybrid combinations were generated and evaluated in Fujian and Hainan Provinces of China. The main results were as follows: (1) The 16 parental lines can be grouped into 7 sub-groups consisting of 1 maintainer sub-group and 6 restorer sub-groups; (2) Mean grain yield of the restorer lines was higher than that of the maintainer lines, and mean yield of parental lines was higher than that of the hybrid combinations; (3) The two best heterotic patterns were II-32A × G5 and II-32A × G6, moreover, the order of restorer sub-groups according to grain yield, from the highest to lowest, was G7, G6, G5, G4, G3 and G2; High specific combining ability values were observed for combinations of II-32A × G5, II-32A × G6 and Tianfeng A × G7; (4) Hybrid combinations derived from II-32A crossed with 13 restorer lines had higher yield trait values (mid-parent heterosis, better-parent heterosis, standard heterosis over check and specific combining ability) than any other combinations; (5) Genetic distance was positively correlated with panicle number, grain length and length-to-width ratio (P < 0.05) and negatively correlated with grain width, grain yield, seed-setting rate, as well as mid-parent heterosis, standard heterosis over check, and specific combining ability for grain yield (P < 0.01). These heterotic groups and patterns and their argonomic traits will provide useful information for future hybrid rice breeding programs.

Key words: rice heterosis; heterosis group; general combine ability; specific combine ability; genetic distance

Rice is one of the most important cereal food crops in China. The success of three-line hybrid rice and hybrid rice breeding programs in China throughout the 1970s have made important contributions to food security, both in China and the rest of the world. Heterosis is the theoretical foundation of hybrid rice and has been widely applied in other crops as well, including maize, sorghum, cotton, tomato and rapeseed (Gai et al, 2016). However, breeding practices to date have shown that superior parents do not always produce superior heterosis combinations, moreover, parents of elite heterotic combinations are always developed from different heterotic groups (Zeng et al, 2007). Studies of heterotic groups and patterns have

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allowed breeders to achieve specific traits through cross-hybridization and have improved crossing efficiency between diverse parents. Therefore, determining heterotic groups and patterns is an important part of hybrid rice breeding (Reif et al, 2003; Menz et al, 2004; Fischer et al, 2010; Lu and Xu, 2010).

China has been leading the world in hybrid rice breeding research for many years. Moreover, the success of hybrid rice breeding has solved food supply problems in China and made important contributions to food security throughout the world. Whereas research on the application of hybrid rice breeding has developed considerably over the past 50 years in China, studies on heterosis theory and heterotic groups lag behind, reflected in the lack of systematic analyses of heterotic groups. In particular, little is known about primary parental lines of major hybrid rice crops. A number of studies have shown that the sterile (maintainer) lines and restorer lines widely used today are based on two major heterotic groups derived from China's three-line *indica* hybrid rice breeding programs (Wang and Lu, 2006; Wang et al, 2006a, b). Furthermore, germplasm techniques and the development of two-line hybrid rice have resulted in many new groups (Wang and Lu, 2007; Lu and Xu, 2010). Heterotic groups of 12 maintainer lines and 6 restorer lines representing 168 International Rice Research Institute (IRRI) tropical rice parents were examined by Xie et al (2014). The results showed that preferred heterotic groups are female G5 or G3 and male G3 or G2. Another study carried out by the same group integrated a tropical germplasm to identify possible heterotic groups of tropical rice parents from IRRI (Wang et al, 2015). As a result, efficiency of hybrid rice breeding at IRRI was increased.

We previously studied the population structure of primary parent lines and intermediate lines in China, along with several rice lines from other countries (Wang et al, 2016). Over the past few decades, many parental lines have been used extensively in China's hybrid rice breeding programs, including Minghui 63, Gui 99, Shuhui 527, Minghui 86, Duoxi 1, II-32A and Tianfeng A. Furthermore, many new germplasms or intermediate lines have been widely used in hybrid rice breeding in recent years to achieve superior rice quality, blast resistance and lengthen storage time. In this study, heterosis levels among groups of parental lines were investigated for three reasons: to further understand the primary hybrid rice parental lines of China, to identify the foundational heterotic groups in parental pools and provide a reference for hybrid rice breeding, and to understand the relationship between genetic distance (GD) and heterosis performance.

MATERIALS AND METHODS

Plant materials

A set of 16 hybrid rice parental lines (Table 1), consisting of 3 maintainer (B) lines and 13 restorer (R)

Table 1. Pedigree, group, yield, and general combining ability (GCA) for yield trait of 16 parental lines.

Accession	Pedigree	Group	Yield per plant (g)	GCA (g)
IR79532-21-2-2-1	IR79532-21-2-2-1	G2	31.07 a	-20.60
Shuhui 527	1318 / 88-R3360	G4	30.81 ab	5.33
IR68058-64-1-2	IR68058-64-1-2	G2	30.01 abc	-21.63
Minghui 70	IR54 / Minghui 63	G3	29.14 abc	4.29
Minhui 3139	Minghui 70 / Yanhui 559	G5	29.08 abc	20.32
IR71701-28-1-4	IR71701-28-1-4	G2	28.73 abc	-47.06
Minghui 86	P18 / Minghui 75	G4	28.01 abc	16.42
Fuhui 7018	(Minghui 86 / Tainong 67 // Duoxi 1 /// Chuan R) / (Yunyin / Minghui 86)	G5	27.23 abc	19.26
Minghui 63	IR30 / Gui 630	G4	25.59 abc	-8.42
Gui 99	Longye 5-3 / IR661 / IR2061	G7	25.54 abc	19.39
CNR2	Luhui 6 / Zhonghui 9560	G5	25.24 abc	-5.38
II-32B	Zhenshan 97 / IR665	G1	24.81 abc	10.86
Shuhui 881	R6323 / *japonica*	G4	23.21 bc	5.19
R453	93-11 / B5-10	G6	22.92 c	12.88
Tianfeng B	Mi 31 // Bo B / Zhe 9248	G1	22.71 c	-4.41
Taifeng B	Bo B / G9248	G1	22.51 c	-6.45
Mean			26.66	
R			27.43 a	
B			23.64 b	
CK	Yiyou 673		31.02	

Different lowercase letters following the yield per plant indicate significant difference at the 0.05 level.