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PHYSIOLOGICAL BASIS OF HETEROSIS FOR GRAIN YIELD IN RICE

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ABSTRACT

Eight CMS based rice hybrids of medium and mid-early duration were evaluated along with their parents and three check varieties for various physiological parameters like shoot and root dry matter accumulation at different growth stages of the plant, spikelet fertility, panicle dry weight at harvest, harvest index and grain yield per plant. Standard heterosis and heterobeltiosis for growth and yield parameters were computed and hybrids were grouped into three categories based on heterosis for grain yield per plant. The results indicate that yield heterosis in hybrids comes through heterosis for total dry matter at different growth stages coupled with heterosis for panicle dry weight without much change in harvest index. Despite negative heterosis for spikelet fertility, due to increased number of spikelets, three hybrids showed standard heterosis for grain yield mainly due to increased number of filled grains. In all the CMS based hybrids, sink is the major limitation rather than the source because of high spikelet sterility, which may be related to restoration ability of the male parent.

Key Words : Heterosis, hybrid rice, source-sink relationship, physiological basis

Grain yield is a complex trait influenced by a number of genetically controlled physiological components. Some of the components like rate of accumulation of biomass, and actual yield, as well as the ratio between these two can determine the yielding ability of a genotype. Increasing the biomass and maintaining high harvest index are considered as the main breeding strategies for achieving further breakthrough in rice yield. The increased yield observed in rice hybrids is primarily due to the higher initial crop growth rate coupled with less deterioration in canopy structure and higher partitioning of photosynthates to grain [1]. F_1 hybrids exhibit vigour in initial seedling growth and maintain that growth advantage until heading [1-4]. Higher heterosis in root : total dry weight [5] at mid vegetative stage and in root weight and root activity at the reproductive stage of F_1 rice hybrids [6] were reported. The literature on physiological bases of heterosis for grain yield in CMS based hybrids is scanty and hence the present study was undertaken to look into these aspects so that some of the key morpho-physiological parameters can be used in selection of potential parents for obtaining heterotic hybrids.

MATERIAL AND METHODS

The material consisting of eight hybrids of medium (130-140 days) and mid-early (120-130 days) duration along with their seed parents (A) and maintainers (B) and pollen parents (R) and three checks, viz., Jaya, IR 72 and Tellahamsa was planted in three replications using completely randomised block design at Directorate of Rice Research farm, Rajendranagar, Hyderabad, during *kharif* 1994. Observations on shoot and root weight and dry matter accumulation were recorded at 30, 50, 70, 90 days after sowing and at flowering on five randomly selected plants in each replications. Grain yield per plant, shoot dry weight, panicle dry weight and root dry weight were recorded after harvest. Based on the data, total dry matter accumulation at different growth stages, harvest index and spikelet fertility percentage were calculated. Standard heterosis and heterobeltiosis for various growth and yield parameters were calculated and subjected to test of significance. For the sake of brevity and also to accommodate large number of growth and yield parameters, +, 0, and – signs were used to represent positively significant, insignificant and negatively significant standard heterosis/heterobeltiosis respectively.

RESULTS AND DISCUSSION

Based on standard heterosis and heterobeltiosis for various growth parameters like shoot, root and total dry weight at different growth stages, direction of heterosis exhibited by eight hybrids for each trait has been presented in Table 1. The hybrids viz., IR 58025A/Swarna, PMS 3A/PR103, IR 58025A/IR 32809, IR 62829A/IR 54742 and IR 58025A/IR 35366 showed consistent and significant standard heterosis and heterobeltiosis for most of the growth parameters from the very early growth stages of the plant. Howevever, some of the hybrids viz., PMS 2A/IR 31802 and IR 62829A/IR 53901 showed significant heterobeltiosis and standard heterosis for only few growth parameters. The hybrid IR 58025A/IR52256 showed no standard heterosis and heterobeltiosis for most of the growth parameters. The data suggest that the shoot and root growth pattern varies from hybrid to hybrid. Some hybrids showed consistent and steady heterosis in drymatter accumulation from the very beginning (PMS 3A/PR 103, IR 62829A/IR 54742 and IR 58025A/IR 32809). However, the hybrid IR 58025A/Swarna showed no heterosis for shoot dry weight at 50 and 70 days after sowing but did pick up growth in later stages.

Based on standard heterosis and heterobeltiosis for grain yield per plant, eight hybrids were grouped in to three different categories (Table 2). The three hybrids viz., IR 58025A/Swarna, PMS 3A/PR 103 and IR 58025A/IR 32809 showed positively significant standard heterosis for grain yield per plant, shoot and panicle dry weight

Table 1. Direction of standard heterosis and heterobeltiosis for growth parameters

Hybrid	Shoot dry weight (g/plant) at DAS					Root dry weight (g/plant) at DAS					Total dry weight (g/plant) at DAS					Total
	30	50	70	90	F	30	50	70	90	F	30	50	70	90	F	(+)
IR58025A/ Swarna	+	0	0	+	+	+	0	+	+	+	+	0	+	+	+	11
	+	0	0	+	+	+	0	+	+	+	+	0	+	+	+	11
PMS 3A/ PR103	+	+	+	0	0	+	+	+	+	+	+	+	+	+	0	12
	+	+	+	0	0	+	+	+	+	+	+	+	+	+	+	13
IR58025A/ IR32809	0	0	+	+	+	+	+	0	+	+	+	+	+	+	+	11
	+	0	+	+	0	0	+	0	+	0	+	+	0	0	+	8
PMS 2A/ IR 31802	+	0	+	0	0	0	0	0	0	0	+	0	+	0	0	4
	+	0	0	0	0	+	+	+	0	+	+	+	0	0	+	8
IR62829A/ IR54742	+	+	+	+	+	0	+	0	+	0	+	+	+	+	+	12
	+	+	+	0	+	+	+	0	+	0	+	+	+	+	+	12
IR58025A/ IR35366	+	+	+	+	0	0	+	0	+	0	+	+	+	+	0	10
	+	0	+	+	+	0	+	0	+	0	+	+	+	+	0	10
IR58025A/ IR52256	0	0	0	0	0	0	+	0	+	0	0	+	0	+	0	4
	0	0	0	0	0	0	0	0	0	0	0	+	0	0	0	1
IR62829A/ IR53901	0	0	+	+	0	0	+	0	+	0	+	+	+	+	0	8
	0	+	0	0	0	+	+	0	0	0	+	+	0	0	0	5
RH (%)	–9-53	5-23	9-34	–3-32	–5-15	–10-34	–12-45	–6-62	2-58	–7-22	–9-32	–3.30	10- 26	–0.5-26	–7-10	-
	–11-31	5-36	–3-34	0.5-17	–6-21	–9-48	5-40	–12-78	12-66	0.6-42	4-44	10-37	4-26	0-27	2-28	-

DAS = Days after sowing; F = At flowering; + = Positive heterosis; 0 = No heterosis; RH = Range of heterosis.
1st row indicates standard heterosis whereas 2nd row indicates heterobeltiosis.

and total dry weight at harvest in addition to highly significant heterosis for most of the growth parameters. The results clearly indicate that, the initial growth advantage, consistent heterosis for all growth parameters and signigicant heterosis for panicle dry weight resulted in significant standard heterosis for grain yield per plant [1-4].

Table 2. Direction of standard heterosis and heterobeltiosis for different characters

Hybrid		Direction and magnitude of heterosis						Heterosis for 15 growth parameters	
		GYP	TDM	SDH	PDH	HI	SF	Significant	Insignificant
I. Positive Heterosis									
	IR58025A/Swarna	+(+)	+(+)	0(+)	+(+)	0(0)	–(–)	11(11)	4(4)
	PMS 3A/PR 103	+(+)	+(+)	+(+)	+(+)	0(0)	–(–)	12(13)	3(2)
	IR58025A/IR32809	+(+)	+(+)	+(+)	+(+)	0(0)	–(–)	11(8)	4(7)
II NO Heterosis									
	PMS 2A/IR31802	0(+)	+(+)	0(+)	0(+)	0(0)	–(–)	4(8)	11(7)
	IR62829/IR54742	0(+)	+(+)	+(+)	0(+)	0(0)	–(–)	12(12)	3(3)
	IR58025A/IR35366	0(0)	+(+)	0(0)	0(0)	0(0)	–(–)	10(10)	5(5)
III. Negative Heterosis									
	IR58025A/IR52256	–(–)	+(0)	0(0)	0(0)	–(–)	–(–)	4(1)	11(14)
	IR62829A/IR53901	–(0)	0(0)	0(0)	–(0)	–(–)	–(–)	8(5)	7(10)
Range of Heterosis (%)	SH	–28-16	–3-24	–0.4-30	–21-21	–27-2.5	–24-–9		
	HB	–15-27	–0.1-22	–2.3-23	–11-39	–17-5.3	–24-7.5		

+ - Positive heterosis; – = Negative heterosis; 0 = No heterosis; GYP = Grain yield per plant; TDM = Total dry matter; SDH = Shoot dry weight at harvest; PDH = Panicle dry weight at harvest; HI = Harvest index; SF = Spikelet fertility; SH = Standard heterosis; HB = Heterobeltiosis. Figures in the parenthesis indicate heterobeltiosis.

On the other hand some of the hybrids viz., IR 62829A/IR 54742 and IR 58025A/IR 353566 which showed consistent heterosis for most of the growth parameters could not exhibit standard heterosis for grain yield because of insignificant heterosis for panicle dry weight owing to high spikelet sterility. The hybrids, IR 58025A/IR 52256 and IR 62829A/IR 53901 exhibited negative heterosis for grain yield and no heterosis/negative heterosis for panicle dry weight and for many other growth parameters.

These results clearly indicate that initial and consistent growth advantage coupled with better dry matter partitioning and higher spikelight fertility can result in significant heterosis for grain yield. None of the hybrids showed significant heterosis for harvest index and all the hybrids showed negative heterosis for spikelet fertility.

One of the major factors responsible for low harvest index and negative heterosis for spikelet fertility in CMS based hybrids is high percentage of spikelet sterility as compared to B and R lines. Even though lot of sink and source capacity is available, some hybrids could not produce more filled grains because of high spikelet sterility associated with interaction of male sterility inducing cytoplasm and fertility restorer genes. Perhaps the restoration of fertility by the male parent is not complete. In general most of the heterotic hybrids have faster growth rate, as evident by significant standard heterosis and heterobeltiosis for shoot and root dry weights at different growth stages, but all hybrids showing initial heterosis for growth parameters were not heterotic for grain yield per plant.

Yield heterosis in hybrids comes through heterosis for total dry matter at different growth stages coupled with heterosis for panicle dry weight without much change in harvest index. Despite negative heterosis for spikelet fertility, three hybrids showed standard heterosis for grain yield, mainly due to increased number of filled grains. In all the CMS based hybrids, sink is the major limitation rather than the source because of high spikelet sterility. Development of elite parental lines with strong restoration ability will go a long way in further enhancing the magnitude of heterosis in CMS based hybrids.

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