coefficient in the hybrids. It should be possible to increase GSR and BY simultaneously in hybrids, but not in parents.

The multiple regression equation for GY heterosis was $GY = 4.609 + 0.100\,DH + 1.039\,CN + 0.068\,FSN + 0.429\,GW + 0.312\,BY + 27.286\,GSR$. This model was effective in predicting GY heterosis, accounting for 88% of the total variation (Table 2). Except for DH, the effect of the regression was highly significant. Biological yield was the most important contributing character in the formation of GY heterosis.

Heterosis of GY depends on heteroses of BY, FSN, CN, PH, PL, FSP, GW, and GSR. It would be helpful in hybrid rice breeding to take into account the heterotic relationships among some metrical characters. □

Table 1. Correlation coefficients for heterosis of F_1 and parents among 11 characters.[a]

Trait		DH	CN	PL	PH	TSN	FSN	FSP	GW	BY	GSR	GY
DH	P	1	–.20	–.06	.14	.37**	.42**	.22	–.35**	.14	–.19	.13
	F_1	1										
CN	P	–0.2	1	.08	.08	–.30*	–.24*	–.04	.09	.59**	–.10	.50**
	F_1	–.38**	1									
PL	P	.78**	–.10	1	.65**	.22	.40**	.11	.23*	.33**	.19	.39**
	F_1	.43**	–.27*	1								
PH	P	.81**	.02	.92**	1	.47**	.49**	–.07	.10	.43**	.08	.41**
	F_1	.57**	–.20	.74**	1							
TSN	P	.49*	–.37	.48*	.52*	1	.72**	–.30**	–.27*	.34**	–.25*	.23
	F_1	.55**	–.61**	.34**	.41**	1						
FSN	P	.76**	–.38	.76**	.69**	.68**	1	.39**	–.03	.49**	.29*	.57**
	F_1	.57**	–.60**	.58**	.44**	.84**	1					
FSP	P	.44*	–.14	.39	.23	–.20	.57*	1	.17	.12	.75**	.38**
	F_1	.30**	–.28*	.59**	.26*	.15	.65**	1				
GW	P	.18	–.34	.25	.31	–.16	.12	.26	1	.21	.27*	.31**
	F_1	.14	–.11	.32**	.27*	–.21	.01	.30**	1			
BY	P	.85**	.18	.81**	.84**	.32	.68**	.48*	.37	1	–.04	.86**
	F_1	.47**	.14	.53**	.53**	.32**	.52**	.49**	.43**	1		
GSR	P	–.61**	–.23	–.53*	–.58**	–.35	–.36	–.08	–.02	–.56*	1	.29*
	F_1	–.44**	.11	.08	–.26**	–.25**	.11	.53**	.15	.02	1	
GY	P	.81**	.19	.77**	.80**	.28	.71**	.56*	.36	.98**	–.48	1
	F_1	.40**	.14	.54**	.44**	.23*	.54**	.65**	.46**	.91**	.29	1

[a] Correlation coefficients for parents (P) and F_1 below the diagonal, those for heterosis above the diagonal. *,** = significant at 5 and 1% levels, respectively.

Table 2. Statistical test for the model of grain yield heterosis.[a]

SV	DF	SS	@	MS	F	R^2
DH	1	5.503	6	5.503	2.66	
CN	1	21.734	3	21.734	10.49**	
FSN	1	18.942	4	18.942	9.14**	
GW	1	16.097	5	16.097	7.77**	
BY	1	47.109	1	47.109	22.73**	
GSR	1	37.017	2	37.017	17.86**	
Multiple regression	6	976.366		162.728	78.51**	0.8787
Error	65	134.722		2.073		
Total	71	1111.090				

[a] @ = magnitude order of SS, ** = significant at the 1% level.

Restorers and maintainers for two cytoplasmic male sterile lines

J. S. Bijral, T. R. Sharma, B. B. Gupta, K. Singh, and C. L. Raina, SKUAST, Regional Agricultural Research Station (RARS), R.S. Pura 181102, India

In a hybrid rice breeding program based on a cytoplasmic male sterility and fertility restoration system, identification of effective maintainers and restorers is of great importance. We crossed 10 short-, medium-, and long-duration rice cultivars with cytoplasmic male sterile lines Zhen Shan 97 A and V20 A in 1988 wet season at Ranbir Singh Pura, Jammu, and Kashmir. The F_1 hybrids were evaluated for spikelet fertility during the 1989 wet season.

Varieties showing more than 80% spikelet fertility were classified as restorers; those with 30-79%, 1-29%, and less than 1% spikelet fertility were rated as partial restorers, partial maintainers, and effective maintainers, respectively.

All test cultivars except Dular, IET10770, and N22 were identified as restorers (see table). N22 partially restored the fertility of both cytosterile lines. IET10770 and Dular were classified as effective maintainers. □

Restorers and maintainers for 2 cytoplasmic male sterile lines identified at RARS, R.S. Pura, India, 1989 wet season.[a]

Variety	Spikelet fertility	
	Zhen Shan 97 A	V20 A
IR35454-18-1-2-2	R	R
IR25912-30-2-3-2	R	R
IR29692-99-2	R	R
IR9761-19-1-R	R	R
B4227 E-KN-10	R	R
IET10321	R	R
IET10770	M	M
IET1410	R	R
Dular	M	M
N22	PR	PR

[a] R = restorer (80% spikelet fertility), PR =partial restorer (30-79% spikelet fertility, PM = partial maintainer (l-29% spikelet fertility), M = maintainer (less than 1% spikelet fertility).

Heterosis in physiological attributes of rice hybrids

K. S. Murty, S. K. Dey, and P. J. Jachuck, Central Rice Research Institute, Cuttack 753006, India

Heterosis in yield characters of F_1 rice hybrids from cytoplasmic genetic male sterile (CMS) lines has been well recognized. Information on the heterosis of physiological characters, however, is meager.

We studied standard heterosis over check Jaya of seven F_1 hybrids (six from CMS line IR54752 A and one from Madhu A) during 1989 wet season (Jul-Oct). The hybrids and Jaya were transplanted (25 d after seeding) at 20- × 15-cm spacing, one seedling/hill, in a randomized block design with three replications. Fertilizer (80 kg N/ha) was applied in 3 equal splits: at transplanting, 20 d after transplanting, and at panicle initiation.

The season was cloudy, with less than 4.5 h of bright light/d. Periodic samples were taken for leaf area index (LAI), total dry matter (TDM), and crop growth rate (CGR). Photosynthetic rates (Pn) of the second leaf before flowering and the flag leaf at flowering were measured with LI-6000 Portable Photosynthesis System; maintenance respiration (MR) was measured by Gilson differential respirometer. Crop photosynthesis is assumed to be Pn × LAI.

Yield and yield attributes were recorded at harvest. Given a high frequency of sterile plants in the hybrids, 20 normal fertile plants were taken for yield assessment. Standard heterosis was calculated over check Jaya.

Considerable standard heterosis was apparent in Pn, LAI, and Pn × LAI at 30 d after planting and in post-flowering CGR, TDM, and yield (see table). Heterosis of MR was negative. Panicle number and grain number/m^2 exhibited high heterosis. The hybrid with Madhu A showed good heterosis in Pn, MR, and Pn/MR at flowering (F).

Among the hybrids with IR54752 A, Swarna and IR54 hybrids combined strong heterosis in LAI, TDM, and yield, but heterosis in Pn at flowering and CGR at reproductive growth was poor. Heterosis for photosynthesis in these hybrids might be improved by combining them with photosynthetically effective restorers. □

Standard heterosis for physiological characters and yield of rice hybrids, Cuttack, India, 1989 wet season.

Character [a]	Standard check Jaya	Standard heterosis (%) of hybrids over						
		IR54752 A						Jaya
		IR54 (UAS)	IR54 (CRRI)	IR27-31.5	Prabhat	Swarna	Pratiba	Madhu A/ IR15324
Pn at 30 d (mg CO_2/ dm^2 per h)	28.1	22	8	20	12	8	9	17
Flowering	34.6	4	5	–11	–11	–14	4	23
MR at flowering	2.6	–9	4	–14	–7	–14	–14	12
Pn/MR at flowering	8.9	0	3	0	–17	–7	4	18
Pn × LAI (F) gCO_2/m^2	11.3	35	22	11	–2	3	–13	19
LAI at 30 d	0.92	39	31	4	19	42	6	3
Flowering	3.28	42	16	25	9	20	–9	4
SLW at flowering (mg/dm^2)	520	8	11	12	–2	4	18	–14
Flag leaf area (cm^2)	29.3	22	19	17	11	26	14	4
FL SLW (mg/dm^2)	541	2	7	5	8	3	9	–9
TDM at 30 d (g/m^2)	88	30	39	–2	4	22	9	–2
Flowering	870	23	11	40	–16	40	14	–26
Harvest	1051	60	62	66	26	54	28	13
CGR at 0-30 d (g/m^2 per d)	2.93	30	39	–2	4	24	9	–2
50 d tooflowering	14.7	15	3	15	48	6	–10	8
Flowering-harvest	6.0	243	311	190	226	123	96	203
Yield (g/m^2)	384	68	73	77	2	71	17	7
Yield (g/m^2 per d)	2.9	59	62	59	0	55	7	14
Panicles/m^2	177	53	52	52	33	33	28	23
Grains/panicle (no.)	87.7	3	4	9	–21	45	–16	–7
Grains/m^2 ($\times 10^2$)	155	56	45	65	4	94	7	–25
1000-grain wt (g)	26.3	4	–7	6	0	–11	–7	–22
HI (%)	36	6	8	8	–17	11	–8	4

[a]Pn = photosynthetic rate, MR = maintenance respiration rate, LAI = leaf area index, TDM = total dry matter, CGR = crop growth rate, SLW = specific leaf wt, FL SLW = flag leaf specific leaf wt

Meiotic behavior of some WA cytosterile lines

R. K. Mandal and S. Saran, Botany Department, Patna University, Patna 800005; and V. N. Sahai, A.R.I. Mithapur farm, Patna I, India

The meiotic behavior of CMS lines IR46827 A, IR46828 A, IR46829 A, and IR46830 A was studied to ascertain chromosomal abnormality associated with pollen abortion or sterility.

Meiosis of microsporogenesis showed 12 regular, well-developed bivalents at diakinesis and metaphase I with a normal 12: 12 separation of chromosomes at anaphase I; 3 secondary associations of 2 bivalents each in a large number of preparations; a variable number and behavior of nucleoli; and a gradual disintegration of chromatin setting in at anaphase I, resulting in its complete disappearance by late telophase I (see table).

Complete sterility of microspores in all CMS lines showed that they belonged to the CPA (complete pollen abortion) type. In this type, meiosis initially progresses normally, but the microspores tend to abort. Total absence of chromatin matter at telophase I is a new report of a cytological basis for pollen abortion in CMS lines. Imbalance of synthesis and degradation of auxins could be the reason for pollen abortion and complete sterility. □

Meiotic behavior of chromosomes in 4 CMS lines.

CMS line	Pollen mother cell scored (no.)	Diakinesis	Metaphase I	Anaphase I	Remarks
IR46827 A	50	12 II	12 II	12:12	
IR46828 A	50	12 II	12 II	12:12	Chromatin becomes feeble in anaphase I and disintegrates completely in telophase I.
IR46829 A	50	12 II	12 II	12:12	
IR46830 A	50	12 II	12 II	12:12	