Table 2. Traits affecting yield heterosis. Andhra Pradesh, India. 1995 WS.

Particular			Plant height	Tiller number	Panicle number	Panicle length	Panicle weight	Filled spikelets	Sterile spikelets	100-grain weight
	H>R	:Hybrid	107	9.88	9.00[a]	26.38	3.89	139	36	2.76
		:Restorer	105	9.00	7.75	25.28	3.47	113	19	2.63
	H<R	:Hybrid	99	9.75	8.28	26.02[a]	3.50	134[a]	31[a]	2.51
		:Restorer	104	9.83	8.33	24.52	3.34	114	20	2.32
IR58025A-based hybrids	H>R	:Hybrid	111	9.40	9.00	27.13	3.88	144	39	2.88
		:Restorer	108	8.80	7.60	25.75	3.44	111	18	2.68
		:IR58025B	98	10.00	9.00	26.02	3.48	132	32	1.94
	H<R	:Hybrid	101	8.88	7.63	26.74[a]	3.79	142[a]	31	2.61[a]
		:Restorer	105	10.13	8.50	24.11	3.42	118	21	2.27
		:IR58025B	98	10.00	9.00	26.02	3.48	132	32	1.94
IR62829B-based hybrids	H>R	:Hybrid	99	10.67	9.00	25.11	3.90	129	29	2.55
		:Restorer	99	9.33	8.00	24.15	3.53	115	22	2.55
		:IR62829B	83	11.00	10.00	24.38	3.16	99	18	1.94
	H<R	:Hybrid	96	11.50	10.50[a]	24.57	2.91	118	31	2.31
		:Restorer	103	9.25	8.00	25.34	3.19	106	17	2.41
		:IR62829B	83	11.00	10.00	24.38	3.16	99	18	1.94

[a] Significant at the 5% level.

yield superiority of those restorers comes mainly from grain weight. Higher yield of hybrids or restorers was related positively to tiller number and panicle number. The grain yield of hybrids in the H<R group (except IR62829A- based hybrids) was affected by tiller number / panicle number; for all other traits, hybrids were superior.

We found reproductive phase initiation always early in hybrids. Hybrids yield better than parents when their days to 50% flowering is similar or later than their respective restorers. The study indicates that hybrids with better performance can be identified right in the testcross nursery by comparing their tiller number, plant height, and days to 50%, flowering with their respective restorers. ■

Breeding methods

Callus induction and plant regeneration from anther culture of six high-yielding indica/basmati crosses

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Anther culture of F_1 hybrids facilitates recovery of rare gene combinations in a small population of doubled haploids (DH). Two main problems limit exploitation of anther culture from indica rices: low frequencies of callusing from cultured anthers and green plant regeneration from calli.

We attempted anther culture from six crosses of high-yielding indica and basmati varieties (Table 1). Young panicles were collected from field-grown plants at the commencement of flowering from primary tillers, when the distance between flag leaf base and the auricle of the penultimate leaf was 4-7 cm. After cold pretreatment (4 °C) for 7-10 d, anthers with microspores at the early uninucleate stage were cultured on media based on N6 media composition:

2.5 mg 2,4-D L^{-1} + 0.5 mg kinetin L^{-1} + 3% sucrose.
2.5 mg 2,4-D L^{-1} + 0.5 mg lunetin L^{-1} + 5% sucrose.
2.5 mg 2,4-D L^{-1} + 0.5 mg kinetin L^{-1} + 3% maltose.
2.5 mg 2,4-D L^{-1} + 0.5 mg kinetin L^{-1} + 5% maltose.

Table 1. Callus induction from anthers of six rice crosses cultured on modified N6 medium. Ludhiana, India.

Cross/parentage	Anthers cultured (no.)	Anthers forming calli (no.)	Callus induction (%)
Basmati 385/PR109	3,607	147	4.1
Pusa Basmati 1/PAU1198	4,899	522	10.7
Pusa Basmati 1/PR109	6,504	125	1.9
Basmati 370/IR64//Basmati 385	11,965	1,227	10.3
Basmati 385/IR64//Basmati 385	6,346	351	5.6
Basmati 385/PR4141//Basmati 385	8,822	564	6.4

Table 2. Plant regeneration from anther-derived calli in four rice crosses. Ludhiana, India.

Cross/parentage	Calli transferred to regeneratton medium (no.)	Calli showing shoot differentiation (no.)	Calli regenerating green plants (%)	Green plants transferred to soil (no.)
Basmati 385/PR109	110	52 (47.3)	50.00	25
Pusa Basmati 1/PAU1198	103	44 (42.7)	47.36	14
Pusa Basmati 1/PR109	75	22 (27.3)	25.00	3
Basmati 370/IR64//Basmati 385	220	156 (70.1)	31.03	41

[a] Figures in parentheses are percentage values.

Cultured anthers from all crosses exhibited callusing with varying frequency (1.9-10.7%). Highest callusing (10.7%) was observed in the cross Pusa Basmati 1 /PAU1198 on medium supplemented with 2.5 mg, 2,4-D L^{-1} + 0.5 mg lunetin L^{-1} + 3% maltose. N6 medium was found superior to Murashige and Skoog's, Blayde's, SK-8, and R-2 media for anther culture (Chu 1982, Lenka and Reddy 1994). Ammonium level was a critical factor: indica varieties gave better results with ammonium concentration of 3.0 mM (Chen et a1 1982). One to several globular structures resembling pollen embryoids were observed in the responding anthers. Anther-derived calli regenerated either into green or albino shoots, suggesting that physiology of donor plants, stage of anther development, pre- and postcultural conditions of anthers may be responsible for regeneration of green plants. Frequencies of calli-producing green plants varied in different crosses (Table 2). Chaleff and Stolarz (1981) and Hu (1985) also reported varied frequencies of callusing and green plant regeneration in rice. Callus induction, shoot regeneration, and number of green vs albino plants appear to be under independent genetic control. Anther-derived, field-grown plants exhibited morphological trait variations. Concerted efforts are needed to increase the number of responding pollen and pollen embryos through anther/microspore culture. Use of nurse culture, maltose, and proline may increase anther culture efficiency.

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Long days slow down panicle development of late rice strains

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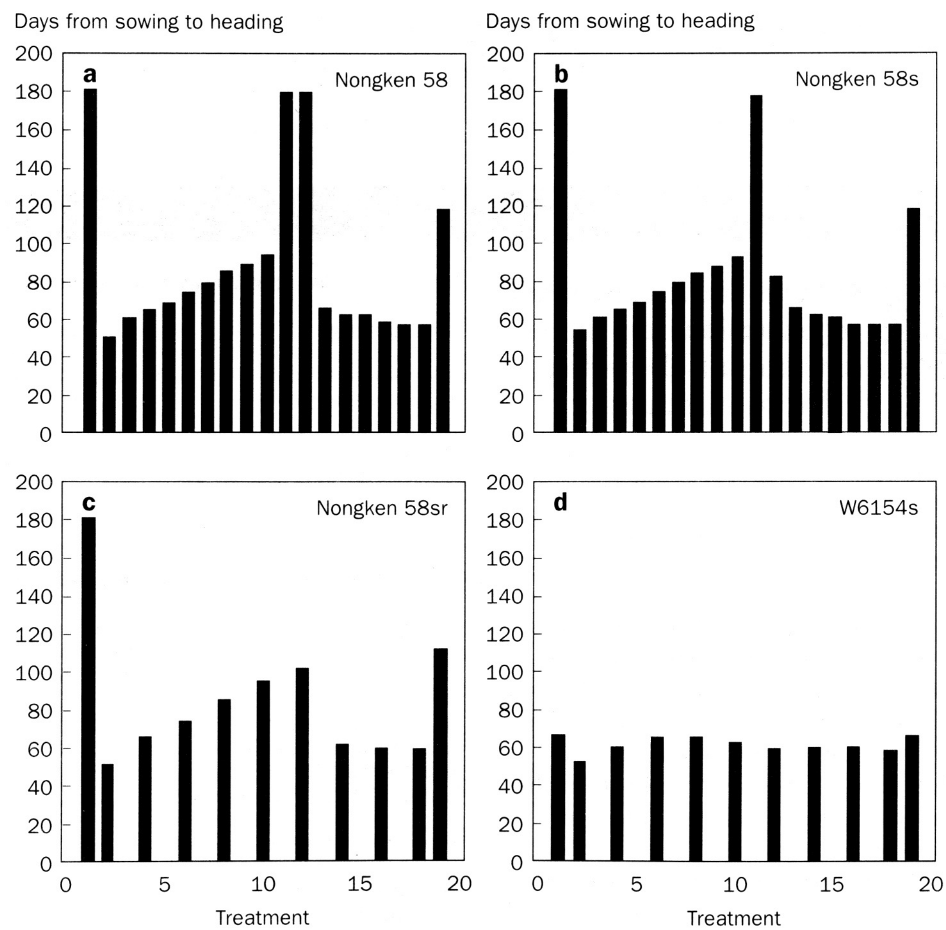
This experiment probed the mechanism of photoperiod sensitivity in male sterile lines. Materials included wild type Nongken 58, conditional male sterile line Nongken 58s, Nongken 58sr (a mutant of Nongken 58s that is male fertile under long-day conditions), and a transferred conditional male sterile line W6154s, an indica line which was obtained by a series of complicated crosses originally with Nongken 58s and Zhengshan 97. Seedlings were transplanted 25 d after sowing, and three photoperiodic regimes were imposed: ND, the natural daylength from May to October (13-15h); LD, 16 h day/ 8 h night; and SD, 10 h day/14 h night. Photoperiodic treatments were applied from transplanting (see figure). The parameters used to define the type of photoperiodic responses were days from sowing to heading of main tillers, leaf numbers, main panicle development stage, ratio of spikelet number to



Days from sowing to heading at different photoperiodic treatments. Heading dates in each treatment were the average of three plants. Series number of the treatments follows: 1) LD; 2) SD; 3) 5 d LD + SD until heading; 4) 10 d LD + SD until heading; 5) 15 d LD + SD until heading; 6) 20 d LD + SD until heading; 7) 25 d LD + SD until heading; 8) 30 d LD + SD until heading; 9) 35 d LD + SD until heading; 10) 40 d LD + SD until heading; 11) 5 d + LD until heading; 12) 10 d SD + LD until heading; 13) 15 d SD + LD until heading; 14) 20 d SD + LD until heading; 15) 25 d SD + LD until heading; 16) 30 d SD + LD until heading; 17) 35 d SD + LD until heading; 18) 40 d SD + LD until heading; 19) ND. Only treatments 1, 2, 4, 6, 8, 10, 12, 14, 16, 18, and 19 were shown in C and D.