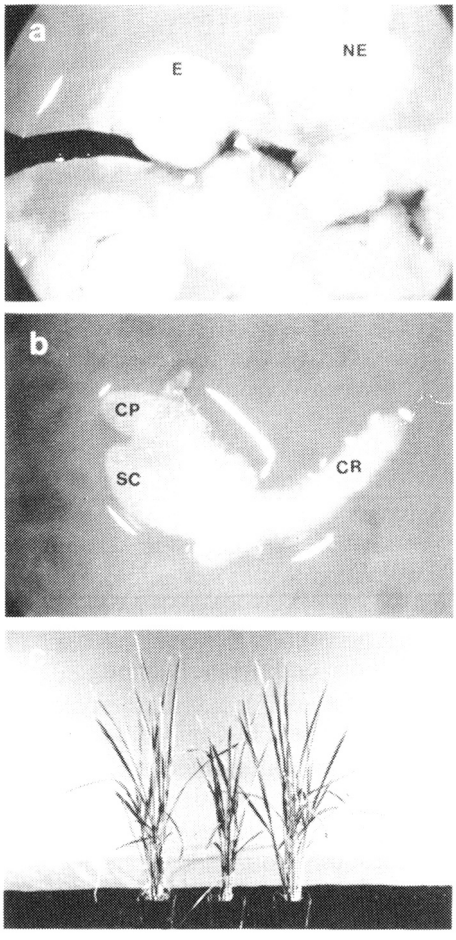
Two weeks after the second subculture, five samples of callus from each treatment were microscopically examined to identify E and NE calli (see figure, a). The E calli were smooth and yellowish and were composed of small compact cells with dense cytoplasm. The NE calli were pale and loosely packed and were composed of larger, crescent-shaped cells.

To condition the medium (5 ml of MS medium supplemented with 20 μM 2, 4-D), 5 g E callus were subcultured to 10 15-mm petri dishes (conditioned medium). Ten petri dishes with medium but without E callus were the control (unconditioned medium). All dishes were sealed and kept in darkness for 10 d.

E calli were removed from the conditioned medium and 5 2-3 mm NE callus pieces were transferred onto all 20 petri dishes. NE calli that produced E calli were counted after 2 wk.

No NE calli cultured in unconditioned medium produced E calli; 16% of the NE calli grown in conditioned medium produced some organized cells. Those cells were subcultured onto medium containing 2.5 μM 2, 4-D and incubated under dim light (30 μE/m^2 per s). The nodules that were produced developed into normal-appearing embryos 2 wk after they were subcultured onto growth regulator-free differentiation media. All somatic embryos looked normal (see figure, b), germinated in 5-7 d, and produced plants (see figure, c). □



Rice somatic embryogenesis: a) E callus vs NE callus formed in cultures; b) a normal somatic embryo with distinct coleoptile (CP), coleorhiza (CR), and scutellum (SC), ×80; c) plants grown from somatic embryos, ×0.17.

Yield potential

A path-coefficient analysis of rice panicle characters

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The relationship between high density (HD) grains (those with specific gravity of 1.20 or higher) and other panicle characters could be an effective selection criterion,

We studied 50 panicles from 9 parents, 50 panicles from 6 F_1s, and 250 panicles from F_2s. HD grain index (HDI) was calculated by dividing the number of HD grains by the total number of spikelets per panicle on primary and secondary branches. Path-coefficient analysis was used to assess the direct and indirect influence of different panicle characters on HDI on primary branches (HDIPB).

The number of primary branches and number of spikelets on primary branches had a strong positive association with HDIPB in all generations (see table). Those characters are probably controlled by an additive gene action. The number of secondary

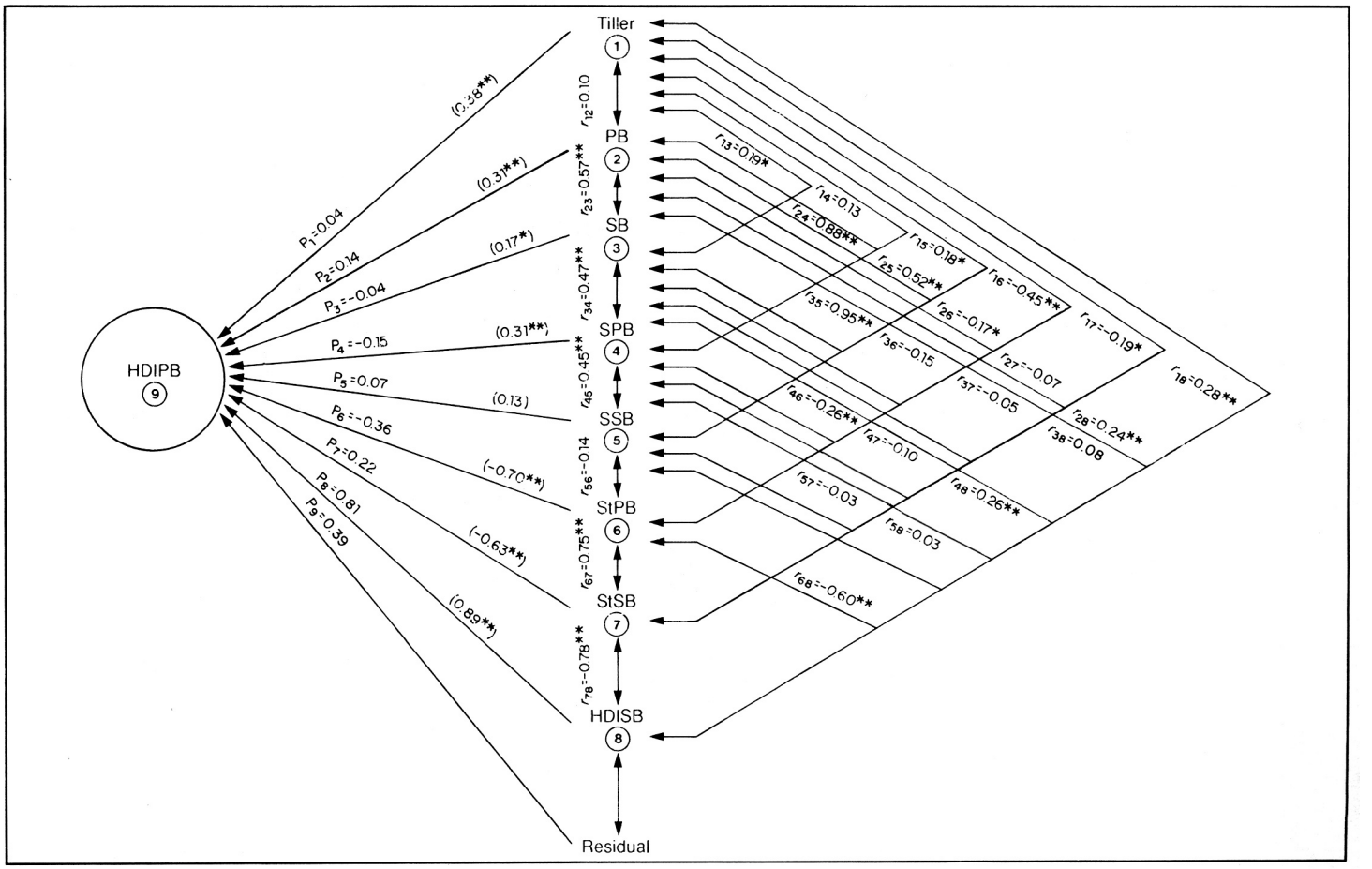
Direct (underlined) and indirect effects of associated traits on high density grain index on primary branches (HDIFB).[a] IRRI, 1988.

Trait	Generation	Tiller	PB	SB	SPB	SSB	StPB	StSB	HDISB	*r*
Tiller	P	–0.19	–0.02	–	–0.01	–	0.01	–0.02	0.64	0.40*
	F_1	0.26	0.02	–	0.03	0.01	–	–	0.34	0.65**
	F_2	0.04	0.01	–0.01	–0.01	0.01	0.01	–0.04	0.23	0.39**
Primary branch (PB)	P	–0.03	–0.14	0.04	0.28	–	–0.01	–0.11	0.38	0.44**
	F_1	0.07	0.08	–	0.07	–	0.01	–	0.26	0.49**
	F_2	–	0.14	–0.02	–0.10	0.03	0.06	–0.02	0.20	0.31**
Secondary branch (SB)	P	–	–0.09	0.06	0.24	0.01	0.02	–0.22	0.33	0.34*
	F_1	0.01	–	–	0.01	0.13	–0.07	–	–0.15	–0.07
	F_2	0.01	0.08	–0.04	–0.05	0.06	0.05	–0.01	0.06	0.17*
Spikelet on PB (SPB)	P	–	–0.11	0.04	0.34	–	–0.03	–0.11	0.39	0.54**
	F_1	0.07	0.06	–	0.11	–	0.02	–	0.31	0.56**
	F_2	–	0.13	–0.02	–0.15	0.03	0.09	–0.02	0.21	0.31**
Spikelet on SB (SSB)	P	0.01	–0.09	0.05	0.24	0.01	0.02	–0.22	0.40	0.43*
	F_1	0.01	–	–	–	0.18	–0.08	–	–0.19	–0.17
	F_2	0.01	0.07	–0.04	–0.05	0.07	0.05	–0.01	0.03	0.13
Sterility on PB (StPB)	P	–0.02	0.01	0.01	–0.09	–	0.11	–0.33	–0.08	–0.39*
	F_1	–	–	–	–0.01	0.06	–0.23	0.01	–0.32	–0.49**
	F_2	–0.01	–0.02	0.01	0.03	–0.01	–0.36	0.16	–0.48	–0.70**
Sterility on SB (StSB)	P	–0.01	–0.03	0.03	0.08	–	0.09	–0.44	0.15	–0.13
	F_1	–0.01	–0.01	–	–0.01	0.05	–0.20	0.01	–0.37	–0.56**
	F_2	–0.01	–0.01	–	0.01	–	–0.28	0.22	–0.56	–0.63**
HDI on SB (HDISB)	P	–0.13	–0.06	0.02	0.14	–	–0.01	–0.07	0.91	0.81**
	F_1	0.14	0.03	–	0.05	–0.06	0.12	–	0.61	0.90**
	F_2	0.01	0.03	–	–0.03	–	0.22	–0.15	0.81	0.89**

[a] – indicates value almost equal to zero. Residual effects: parent (P), 0.41; F_1, 0.31; F_2, 0.39.

branches and of spikelets on secondary branches was correlated positively with HDIPB only in parents; it was not consistent in the F_1 and F_2. HDI on secondary branches (HDISB) was correlated positively with and had direct effects on HDIPB in both segregating (see figure) and nonsegregating generations. In most cases, negative correlations and direct and indirect effects were found between HDISB and sterility.

Higher HDI depends on more primary branches and more spikelets on primary branches, and not on number of spikelets on secondary branches. A plant type for increased yield should have more primary branches and spikelets on primary branches, with few secondary branches and spikelets on secondary branches. □



Path diagram and coefficients of factors influencing HDIPB in F_2.

Heterosis and heterobeltiosis for high density grain index (HDI) and other rice panicle characters

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We assessed heterosis and heterobeltiosis for 9 quantitative characters in 6 crosses, using 6 high density (HD)-grain parents (at least 30% of grains with more than 1.20 specific gravity) and 2 low density (LD)-grain parents. HDI was calculated as number of HD grains divided by total number of spikelets/panicle on primary (PB) and secondary (SB) branches.

Estimates of overall degree and direction of heterosis ($Fmac_1$–Pmac) were significantly positive for number of tillers (1.74*), PB (1.27*), SB (3.28*), spikelets on PB (8.65*), spikelets on SB (8.41*), and sterility on SB (5.37*), indicating dominance of higher values. Heterosis was negative only for number of spikelets on PB (–3.01*). Low or nonsignificant heterosis for other characters may be due to little genetic interactions or differences among parents.

The individual F_1 family differed from overall estimates for different characters showing positive, negative, or no heterosis. The F_1 means deviated conspicuously from parental and midparental values, indicating involvement of nonadditive gene action in the expression of most characters.

Substantial heterosis in the desirable direction was observed in PB number, spikelets on PB, and HDI on PB and SB. Three crosses among HD-grain