



112, 2006, IR42, and IR5931), which gave the highest STI values (seedling height = 79%, root length = 81%, and seedling dry matter = 71%), was the most salt-tolerant group.

Use of this method will improve efficiency and save on expenses in breeding programs for seedling tolerance because the most salt-tolerant cultivars can be determined and used. ■

Integrated germplasm improvement—irrigated

Variability, heritability, correlation, path analysis, and genetic divergence studies in M₂ generation of gamma-irradiated upland rice

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We studied the genotypic and phenotypic coefficients of variation, heritability, genetic advance (GA), coefficients of correlation, path analysis, and genetic divergence in 75 M₂ families raised from

eight upland varieties treated with 10-, 20-, 30-, 40-, and 50-kR gamma rays.

Analysis of variance showed significant differences among genotypes for all characters (Table 1). Considerable range of variation was expressed for percent sterility (43.36), tillers plant⁻¹ (14.91), grain yield plant⁻¹ (14.67), and spikelets panicle⁻¹ (13.51), indicating better scope for selection for genetic improvement. Percent sterility had maximum genotypic coefficient of variation (32.23), followed by grain yield plant⁻¹ (29.75), plant height (26.07), spikelets panicle⁻¹ (19.94), tillers plant⁻¹ (13.85), and days to flowering (12.26) and maturity (9.33).

Estimates of heritability ranged from 91.20% for plant height to 35.60% for sterility. Although plant height (91.20), and days to flowering (88.00) and maturity (87.00) had high heritability, these characters had low genotypic coefficients of variation (GCV) values. This might be due to the variation of environmental components involved in these traits. Expected GA ranged from 6.92% (panicle length) to 54.91% (grain yield plant⁻¹). Grain yield plant⁻¹, plant height, percent sterility, and spikelets panicle⁻¹ showed high GA with high GCV values. These characters should therefore be considered in efforts to obtain high genetic gains.

Grain yield plant⁻¹ was positively correlated with tillers plant⁻¹, but was negatively and significantly correlated with days to 50% flowering (−0.409) and maturity (−0.421), plant height (−0.717), panicle length (−0.302), and percent sterility (−0.771). Negative correlation of characters (tillers plant⁻¹, panicle length, and spikelets panicle⁻¹) might be due to the highest correlation ($r^2 = -0.771$) with sterility.

Percent sterility was positively and significantly correlated with plant height (0.579) and panicle length (0.575). Panicle length was found significantly and positively correlated with days to 50% flowering (0.382) and maturity (0.370) and plant height (0.68). Both plant height and tillers plant⁻¹ were significantly and positively correlated with days to flowering (0.416 and 0.376) and maturity (0.425 and 0.361). Days to 50% flowering had a highly significant and positive (0.999) correlation with days to maturity.

Correlation and path analysis studies revealed that filled grains panicle⁻¹, plant height, and panicle length are important yield-contributing characters that must be considered when adopting selection criteria in an upland rice breeding program.

Genetic divergence studies using D2 analysis showed that the 75 M₂ families had formed 14 genetically diverse groups (Table 2). Selection pressure applied on the M₂ families is likely to provide targeted yield and desired combinations of yield-contributing traits in future generations. ■

Table 1. Analysis of variance and genetic parameters of variation in genotypic and phenotypic coefficients of correlation and path analysis for 8 quantitative characters in M₂ generation of upland rice.

Source	df	Days to 50% flowering	Days to maturity	Plant height (cm)	Tillers plant ⁻¹ (no.)	Panicle length (cm)	Spikelets panicle ⁻¹ (no.)	Sterility (%)	Grain yield plant ⁻¹ (g)
<i>Analysis of variance</i>									
Replication	1	26.06	36.00	2.94	0.17	0.78	188.25	2.74	9.08
Treatment	44	313.42*** ^a	303.17**	1382.29**	10.87**	3.55**	1501.70**	10.72* ^b	45.05**
Error	44	20.03	21.00	63.41	3.99	1.39	280.49	5.09	4.88
CD (5%)	—	8.77	8.98	15.60	3.91	2.31	32.82	4.42	4.33
<i>Genetic parameters of variation^c</i>									
Mean		98.76	127.31	98.48	13.39	20.51	123.93	5.20	15.06
CV (%)		4.53	3.59	8.08	14.91	5.74	13.51	43.36	14.67
Range (min)		71.00	100.00	69.40	9.00	16.80	78.60	1.49	5.15
(max)		121.00	156.00	161.10	19.40	26.10	259.60	14.58	30.00
Variance (P)		166.73	162.09	122.85	7.44	2.47	891.10	7.91	24.96
(G)		146.69	141.09	659.44	3.44	1.08	610.60	2.81	20.08
Coefficient (GCV)		13.08	10.00	27.30	20.37	7.66	24.08	54.08	33.17
Variance (PCV)		12.26	9.33	26.07	13.85	5.07	19.94	32.23	29.75
Heritability (BS) (%)		88.00	87.00	91.20	46.30	43.90	68.50	35.60	80.40
Genetic advance		23.40	22.81	50.51	2.60	1.42	42.12	2.06	8.27
Expected genetic advance		23.69	17.92	51.28	19.42	6.92	33.99	39.62	54.91
<i>Coefficients of correlation and path analysis^d</i>									
Days to 50% flowering	rp		0.998	0.411	0.419	0.196	0.297*	0.126	-0.379**
Days to maturity	rg		0.999**	0.466**	0.376**	0.382**	0.288**	0.078	-0.409**
	pcg	1.584	-1.878	-0.187	0.001	0.012	-0.017	0.035	—
	pcp	<u>(52.458)</u>	<u>(-50.593)</u>	<u>(-0.575)</u>	<u>(-0.931)</u>	<u>(-0.807)</u>	<u>(-0.121)</u>	<u>(0.161)</u>	—
Days to maturity	rp		0.420**	0.140	0.186	0.295*	0.134	-0.393**	
	rg			0.425**	0.361**	0.370**	0.281	0.088	-0.421**
	pcg	-1.741	1.581	-0.191	0.001	0.011	-0.017	-0.037	—
	pcp	<u>(-50.634)</u>	<u>(52.416)</u>	<u>(-0.588)</u>	<u>(-0.894)</u>	<u>(-0.782)</u>	<u>(-0.118)</u>	<u>(0.178)</u>	—
Plant height (cm)	rp			-0.288	-0.480**	0.261**	0.365**	-0.265**	
	rg			-0.284	0.658**	0.265	0.579**	-0.717**	
	pcg	-0.455	0.651	-0.730	-0.002	0.029	-0.015	-0.102	—
	pcp	<u>(-1.383)</u>	<u>(21.815)</u>	<u>(-21.523)</u>	<u>(0.704)</u>	<u>(-1.392)</u>	<u>(-0.112)</u>	<u>(1.173)</u>	—
Tillers plant ⁻¹ (no.)	rp			0.013	-0.136	-0.101	0.118	0.118	
	rg			-0.128	-0.142	0.222	0.147		
	pcg	0.009	0.237	<u>(-0.243)</u>	<u>(0.104)</u>	0.001	0.008	-0.003	—
	pcp	<u>(-2.479)</u>	<u>(19.705)</u>	<u>(-18.260)</u>	<u>(0.393)</u>	<u>(0.271)</u>	<u>(0.060)</u>	<u>(0.457)</u>	—
Panicle length (cm)	rp			0.212	0.084	-0.207			
	rg			0.136	0.575**	-0.302**			
	pcg	0.061	0.310	-0.324	-0.219	0.000	-0.012	-0.241	—
	pcp	<u>(-2.114)</u>	<u>(20.028)</u>	<u>(-18.731)</u>	<u>(-0.910)</u>	<u>(0.317)</u>	<u>(-0.057)</u>	<u>(1.165)</u>	—
Spikelets panicle ⁻¹ (no.)	rp			0.025	0.084	-0.201			
	rg			-0.150	-0.130				
	pcg	-0.058	0.471	-0.513	-0.119	-0.001	0.013	0.007	—
	pcp	<u>(-0.420)</u>	<u>(15.105)</u>	<u>(-14.208)</u>	<u>(-0.367)</u>	<u>(0.317)</u>	<u>(-0.288)</u>	<u>(0.303)</u>	—
Sterility (%)	rp								-0.473**
	rg								-0.771**
	pcg	-0.280	0.200	-0.233	0.166	-0.000	0.005	0.001	—
	pcp	<u>(-2.027)</u>	<u>(4.156)</u>	<u>(-4.444)</u>	<u>(-0.800)</u>	<u>(-0.559)</u>	<u>(-0.215)</u>	<u>(0.063)</u>	—
Grain yield/plant (g)	rg								
	pcg								
	pcp								

^a*** = significant at the 1% level. ^b* = significant at the 5% level. ^cGCV = genotypic coefficient of variation; PCV = phenotypic coefficient of variation; BS = broad sense. ^dFigures in parentheses indicate genotypic and underlined figures indicate direct effects; residual effect = 1,354 rg, rp, pcg and pcp = genotypic correlation, phenotypic correlation, genotypic path and phenotypic path coefficient, respectively.

Table 2. Distribution of 45 M₂ families of 8 upland rice varieties treated with different irradiation doses and cluster means for different characters studied.

Cluster no.	Treatments (no.)	Treatment		Days to		Plant height (cm)	Tillers plant ⁻¹ (no.)	Panicle length (cm)	Spikelets panicle ⁻¹ (no.)	Sterility (%)	Yield plant ⁻¹ (g)	(IX)	(X)	(XI)	(XII)	(XIII)	(XIV)
		Variety	Gamma ray doses (kR)	50% flowering (I)	Maturity (II)												
I	14	Jaya	10	98.3	123.35	76.34	14.12	20.16	106.65	5.77	17.05						
		JS180	50	(12.20)													
		R24	30, 50														
		Kundalika	20, 30, 40, 50														
		ACK5	10, 20, 30, 40, 50, control														
II	6	Ghansal	30	89.73	118.67	88.74	11.40	20.04	133.15	5.26	17.62						
				(13.63)	(19.26)												
		R24	20														
		HS17	30, 40, control														
		Kundalika	Control														
III	5	Jaya	20, 30, 40, control	103.46	131.75	84.56	15.03	20.18	134.77	1.75	21.72						
				(27.52)	(47.28)	(14.07)											
		Kundalika	10														
IV	5	Ghansal	10, control	109.74	147.81	140.86	13.25	21.66	155.48	7.34	7.65						
		JS180	10, 20, 30, 40	(101.97)	(130.12)	(121.15)	(-15.65)										
V	3	HS17	10, 20	86.42	115.00	128.83	11.53	22.27	118.47	6.30	15.68						
				(117.75)	(53.62)	(131.35)	(155.88)	(19.29)									
VI	2	Basmati	10														
		Basmati	30, 40	92.00	121.50	115.50	13.15	21.60	106.50	6.91	11.36						
				(66.03)	(62.28)	(99.58)	(54.42)	(68.06)	(23.88)								
VII	3	Ghansal	40, 50	79.33	108.50	89.47	11.65	19.33	107.20	7.87	10.60						
				(80.20)	(46.67)	(123.03)	(148.80)	(46.88)	(53.76)	(15.46)							
		Basmati	50														
VIII	1	Ghansal	20	108.00	136.38	139.70	16.00	20.98	173.95	4.24	9.17						
				(101.71)	(101.10)	(108.53)	(27.45)	(93.86)	(47.62)	(110.96)	(0.00)						
IX	1	JS180	Control	123.50	152.50	153.90	11.75	22.50	38.08	28.65	8.76	-					
				(132.60)	(207.45)	(193.08)	(40.96)	(222.77)	(74.69)	(207.52)	(93.05)	(0.00)					
X	1	R24	10	102.67	130.34	84.50	11.47	21.34	210.96	3.68	14.41	-	-				
				(18.75)	(46.73)	(40.45)	(136.58)	(120.47)	(124.50)	(112.18)	(103.89)	(257.53)	(0.00)				
XI	1	R24	20	99.50	129.00	89.00	13.00	22.10	116.10	2.76	12.46	-	-	-			
				(56.86)	(41.47)	(44.45)	(82.27)	(107.19)	(44.69)	(64.66)	(38.84)	(14.88)	(69.50)	(0.00)			
XII	1	R24	Control	95.00	123.50	78.00	20.30	18.40	71.30	17.73	15.39	-	-	-	-		
				(29.18)	(48.26)	(48.53)	(109.14)	(118.15)	(74.11)	(74.41)	(88.25)	(180.88)	(65.05)	(50.33)	(0.00)		
XIII	1	Basmati	20	95.75	124.00	132.60	30.90	22.69	101.85	6.27	15.06	-	-	-	-	-	
				(154.12)	(134.13)	(206.10)	(57.07)	(142.60)	(13.18)	(128.98)	(64.44)	(44.24)	(238.28)	(118.45)	(152.75)	(0.00)	
XIV	1	Basmati	Control	121.00	150.50	115.60	10.60	17.30	98.80	3.85	7.51	-	-	-	-	-	-
				(88.45)	(134.12)	(112.03)	(48.35)	(183.24)	(79.90)	(140.27)	(75.72)	(86.45)	(164.27)	(61.92)	(117.37)	(111.74)	(0.00)