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Yield attributes and yield of rice (*Oryza sativa*) hybrids as influenced by nitrogen sources and its splits application

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ABSTRACT

In a field experiment conducted during the wet season of 1994 and 1995 on a deep black soil (Vertisol), the differential response of recently released rice (*Oryza sativa* L.) hybrids in terms of their yield components and yield to NH_4-N and NH_4 + NO_3-N sources [through urea and calcium ammonium nitrat, (CAN) respectively] and split application of N (as 3 and 4 equal splits) was studied. Four rice hyrbids, 2 of early ('MGR 1' and 'KRH 1') and and the other 2 of mid-duration ('APRH 1' and 'APRH 2') were tested using 2 checks ('Rasi' and 'Jaya'). More stable and easily available NH_4-N was found to be superior to unstable and leachable NO_3-N fraction from CAN which resulted in higher number of tillers and panicles and was mainly responsible for higher grain yields (6.40 and 5.44 tonnes/ha with NH_4-N and 5.73 and 4.59 tonnes/ha with NH_4 + NO_3-N in1994 and 1995 respectively). Application of N in 4 splits, coinciding the last with flowering, improved filled grain percentage, 1,000-grain weight and finally resulted in higher grain yields owing to increased photosynthetic rate and delayed leaf senescence. Among the hybrids, 'MGR 1' in the short-duration group emerged as the most promising by outyielding the check 'Rasi' to the extent of 18–20% more. Grain yield showed significant correlation during 2 years with tiller number ($r = 0.48^*$ and 0.68^{**}), panicle number ($r = 0.47^*$ and 0.66^{**}), filled grain percentage ($r = 0.36$ and 0.53^{**}) and 1,000-grain weight ($r = 0.48^*$ and 0.39). The multiple linear regression analysis revealed significant contribution of 67% by tillers, panicles, spikelets, filled grain percentage and 1,000-grain weight towards grain yield.

Key words: Rice hybrids, N source, Yield

The yield advantae of hybrid rice is about 15–20% higher than that of the best high-yielding commercial varieties. Grain yield is a function of the number of panicles, grains/panicle and grain weight. Hybrid rice has bigger panicles and more spikelets/panicle but, filled spikelet percentage was less probably due to higher nutrient demand during reproductive growth stage and hybrid rice requires different strategies for N management to maximize expression of their yield advantage (Virmani, 1996). Top-dressing a small part of N in the late growth stage is expected to realize the full potential of hybrid rice. Al-though NH_4-N has been accepted as the preferred N source by rice, Yang and Sun (1991) and Ancheng *et al.* (1993) reported greater uptake of NH_3-N in the late growth stages by hybrids. Keeping these in view, the present investigation was conducted to study the differential response of recently released hybrids to 2 nitrogen sources (NH_4-N and $NH_4 + NO_3$-N) and its different split applications in terms of their yield and yield components.

MATERIALS AND METHODS

The field experiment was conducted at Hyderabad during the wet season of 1994 and 1995 on Vertisol (Typic Pellustert) under irrigated condition. The experimental soil was clayey (48% clay), alkaline (pH 8.4), non-saline (EC 0.70 dS/m); calcareous (free $CaCO_3$ 4.95%); CEC 44.1 C mol (p +)/kg soil and organic carbon 0.48%. Soil-available nitrogen was low (230 kg/ha), whereas available phosphorus (64 kg P_2O_5/ha) and potassium (356 kg K_2O/ha) were high. Nitrogen @ 120 kg/ha was given through 2 sources (urea as NH_4-N and calcium ammonium nitrate, (CAN) as $NH_4 + NO_3$-N) in 3 (basal, tillering and panicle initiation (PI) and 4 (basal, tillering, PI and flowering) equal splits. Entire P_2O_5 and K_2O each 60 kg/ha was given basally. Four rice hybrids ('MGR 1','KRH 1, 'ARPH 1' and 'ARPH 2') along with 2 checks ('Rasi' and 'Jaya') were tested in split-split (double split) plot design with 3 replications. The observations on yield attributes like tillers/m², panicles/m², spikelets/panicle and 1,000-grain weight were taken at harvest. Percentage of filled grains (filling percentage) in the panicles of primary tillers was calculated from the total grains/panicle, filled grains and unfilled grains (chaff). Grain yield was also recorded at harvest. Statistical analysis was done for yield and yield attributes using standard procedures recommended by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Tillers/m²

Total tillers/m² were significantly superior in NH_4-N (urea) (Table 1). Jiang *et al.* (1993) also reported that the content of NH_4-N in the soil solution was positively correlated with tillering ability. There was no significant difference in tiller number whether N was applied in 3 or 4 splits. Among the hybrids, 'MGR 1' produced significantly higher tiller than 'Rasi' in the short-duration group, 'APRH 2' produced significantly more tillers than 'Jaya' followed by 'APRH 1'. Significant positive heterosis in tillering capacity of hybrids was also reported by Govinda Raj and Siddiq (1986).

Panicles/m²

Panicles/m² were also significantly higher with NH_4-N (urea) than with NH_4 + NO_3-N (CAN) (Table 1). Late application of N as fourth split did not influence the panicle number and was on a par with 3 splits. Among the hybrids, 'MGR 1 and 'APRH 2' produced significantly higher number of panicles in the short- and mid-duration groups respectively. The interaction between N source and varieties showed that with both urea and CAN, 'MGR 1' and 'APRH 2' produced significantly more panicles than their respective check varieties.

The observed increase in number of tillers and panicles with NH_4-N source clearly indicated that rice preferred NH_4-N in the early stage when root system was not well developed. Further, stable N through urea is more efficient when compared to unstable and leachable 50% NO_3-N from CAN source (Yamasaki and Seino, 1965).

Spikelets/panicle

Unlike tillers and panicles, total spikelets/panicle were not influenced either by N sources or by different N splits (Table 2).

Table 1. Effect of N sources and timing on tillers and panicles

Treatment	Urea						CAN						Mean of varieties	
	N 3splits		N 4splits		Mean		N 3splits		N 4splits		Mean		Y_1	Y_2
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2		
							Tillers/m²							
'MGR 1'	589	467	601	471	595	469	499	417	449	451	474	434	353	451
'KRH 1'	466	401	411	430	438	416	350	405	286	412	318	408	378	412
'Rasi'	379	396	416	455	397	426	400	398	326	436	363	417	380	421
'APRH 1'	402	416	455	431	429	424	336	321	307	316	318	319	374	372
'APRH 2'	433	491	435	475	434	483	365	408	422	409	393	408	414	445
'Jaya'	357	366	385	389	371	377	284	310	315	339	285	324	328	350
Mean	438	423	451	442	444	432	367	377	350	394	359	386	401	408
CD for V at same source					NS	NS					CD (P = 0.05)		39	31
CD for V at same N splits					NS	NS					CV (%)		12	10
Mean of sources			Y_1	Y_2			Mean of N splits			Y_1	Y_2			
		Urea	444	432				N 3splits		402	400			
		CAN	359	386				N 4splits		400	418			
		CD	73	46				CD		NS	NS			
		CV	18	13				CV		13	16			
							Panicles/m²							
'MGR 1'	557	437	554	433	555	435	425	410	374	420	400	415	478	425
'KRH 1'	380	380	359	437	370	408	253	397	258	383	256	390	302	399
'Rasi'	310	373	328	415	319	394	289	377	253	403	271	390	305	392
'APRH 1'	347	376	361	401	354	388	290	310	303	293	296	302	325	345
'APRH 2'	373	426	396	420	385	423	328	403	369	385	348	394	367	408
'Jaya'	293	350	277	359	285	354	210	247	284	303	247	275	261	316
Mean	376	390	379	411	378	401	299	357	307	365	303	361	340	383
CD for V at same source					35	47					CD (P = 0.05)		25	30
CD for V at same N splits					NS	NS					CV (%)		9	10
Mean of sources			Y_1	Y_2			Mean of N splits			Y_1	Y_2			
		Urea	378	401				N 3splits		338	373			
		CAN	303	361				N 4splits		343	388			
		CD	48	33				CD		NS	NS			
		CV	14	8				CV		6	12			

Y_1: 1994; Y_2: 1995

Table 2. Effect of N sources and timing on number of spikelets/panicle

Treatment	Urea						CAN						Mean of varieties	
	N 3splits		N 4splits		Mean		N 3splits		N 4splits		Mean		Y_1	Y_2
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2		
'MGR 1'	125	131	118	143	122	137	116	146	120	153	118	150	120	143
'KRH 1'	107	142	117	161	112	152	119	156	112	156	115	156	114	154
'Rasi'	105	126	127	138	116	132	99	120	104	114	102	117	109	125
'APRH 1'	220	196	230	241	225	219	222	218	169	213	196	216	210	217
'APRH 2'	196	162	162	181	179	172	153	159	187	161	170	160	174	166
'Jaya'	179	170	171	159	175	165	161	179	181	180	171	179	173	172
Mean	155	155	154	170	155	163	145	164	145	163	145	163	150	163
CD for V at same source					NS	NS					CD (P = 0.05)		15	13
CD for V at same N splits					NS	NS					CV (%)		12	10

Mean of sources	Y_1	Y_2
Urea	155	163
CAN	145	163
CD (P = 0.05)	NS	NS
CV (%)	11	7

Mean of N splits	Y_1	Y_2
N 3splits	150	160
N 4splits	150	167
CD (P = 0.05)	NS	NS
CV (%)	15	10

Y_1, 1994; Y_2, 1995

Table 3. Effect of N sources and timing on filled grain percentage

Treatment	Urea						CAN						Mean of varieties	
	N 3splits		N 4splits		Mean		N 3splits		N 4splits		Mean		Y_1	Y_2
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2		
'MGR 1'	89	90	95	94	92	92	90	91	94	96	92	93	92	93
'KRH 1'	91	84	92	89	91	86	81	87	87	89	84	88	88	87
'Rasi'	90	95	95	97	93	96	87	92	96	94	91	93	92	95
'APRH 1'	48	51	58	55	53	53	56	53	61	55	59	54	56	53
'APRH 2'	69	75	78	79	74	77	69	72	79	80	74	76	74	76
'Jaya'	86	80	95	86	90	83	83	82	90	89	86	86	88	84
Mean	79	79	86	83	82	81	78	80	85	84	81	82	82	81
CD for V at same source					4.75	NS					CD (P = 0.05)		3.4	3.7
CD for V at same N splits					NS	NS					CV (%)		5	6
Mean of sources			Y_1	Y_2			95		Mean of N splits		Y_1	Y_2		
		Urea	82	81				N 3sp		78	79			
		CAN	81	81				N 4sp		85	84			
	CD (P = 0.05)		NS	NS			CD (P = 0.05)			2	3			
	CV (%)		4	4				CV (%)		4	6			

Y_1, 1994; Y_2, 1995

Table 4. Effect of N sources and timing on 1,000-grain weight (g)

Treatment	Urea						CAN						Mean of varieties	
	N 3splits		N 4splits		Mean		N 3splits		N 4splits		Mean		Y_1	Y_2
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2		
'MGR 1'	22.8	23.4	23.7	24.0	23.3	23.7	23.2	24.1	23.7	24.3	23.5	24.1	23.4	23.9
'KRH 1'	23.1	23.7	24.1	24.8	23.6	24.3	23.0	23.8	23.0	24.2	23.0	24.0	23.3	24.2
'Rasi'	22.7	23.9	23.2	24.8	23.0	24.3	23.2	24.3	23.5	24.0	23.3	24.1	23.1	24.2
'APRH 1'	22.5	23.0	22.4	23.5	22.5	23.2	22.4	22.4	22.8	22.8	22.6	22.6	22.5	22.9
'APRH 2'	23.5	23.4	22.9	24.1	23.2	23.7	21.2	22.2	22.8	24.6	22.0	23.4	22.5	23.5
'Jaya'	26.6	27.0	27.2	28.5	26.9	27.7	24.9	26.9	26.0	27.4	25.5	27.1	26.2	27.4
Mean	23.5	24.1	23.9	25.0	23.7	24.5	23.0	24.0	23.6	24.6	23.3	24.3	23.5	24.4
CD for V at same source					0.73	NS					CD (P = 0.05)		0.51	0.66
CD for V at same N splits					NS	NS					CV (%)		3	3

Mean of Sources	Y_1	Y_2	Mean of N splits	Y_1	Y_2
Urea	23.7	24.5	N 3splits	23.2	24.0
CAN	23.3	24.3	N 4splits	23.8	24.8
CD (P = 0.05)	NS	NS	CD (P = 0.05)	0.46	0.319
CV (%)	3	2	CV (%)	3	2

Y_1, 1994; Y_2, 1995

Table 5. Effect of N sources and timing on grain yield (tonnes/ha)

Treatment	Urea						CAN						Mean of varieties	
	N 3splits		N 4splits		Mean		N 3splits		N 4splits		Mean		Y_1	Y_2
	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2	Y_1	Y_2		
'MGR 1'	6.74	5.91	7.06	5.84	6.90	5.88	5.95	4.85	6.14	5.45	6.05	5.15	6.47	5.51
'KRH 1'	5.65	5.63	5.98	5.70	5.82	5.67	5.26	4.67	5.75	5.00	5.51	4.84	5.67	5.25
'Rasi'	5.47	5.04	5.64	4.81	5.54	4.93	5.29	4.15	5.48	4.30	5.38	4.23	5.46	4.58
'APRH 1'	5.61	3.91	5.65	4.50	5.63	4.21	5.23	2.49	5.20	3.64	5.22	3.06	5.43	3.64
'APRH 2'	7.18	5.70	7.25	6.38	7.22	6.04	5.66	5.24	6.67	5.53	6.17	5.38	6.69	5.71
'Jaya'	7.21	5.83	7.34	6.04	7.27	5.94	5.89	4.17	6.13	5.53	6.01	4.85	6.64	5.40
Mean	6.31	5.34	6.48	5.55	6.40	5.44	5.54	4.26	5.90	4.91	5.73	4.59	6.06	5.01
CD for V at same source					0.41	0.61					CD (P = 0.05)		0.29	0.43
CD for V at same N splits					0.41	0.61					CV (%)		6	10

Mean of Sources		Y_1	Y_2	Mean of N splits		Y_1	Y_2
	Urea	6.4	5.44		N 3splits	5.87	4.81
	CAN	5.73	4.59		N 4splits	6.20	5.23
	CD (P = 0.05)	0.22	0.44		CD (P = 0.05)	0.274	0.31
	CV (%)	8	10		CV (%)	7	10

Y_1, 1994; Y_2, 1995

Among the hybrids in the early group, 'MGR 1' and 'KRH 1' had higher spickelet/panicle than 'Rasi' though not significatn in 1994, whereas it was significantly higher in 1995. 'APRH 1' had significantly higher spikelets/panicle, whereas 'APRH 2' and 'Jaya' were at par. During vegetative growth, hybrid rice accumulates more dry matter which might have resulted in more spikelets/panicle, as was also reported by Virmani (1996).

Filled grain percentage

The source of N did not influence the filled grain percentage, but the N applied in 4 splits increased the filled grain percentage than 3 splits (Table 3). 'Rasi' and 'MGR 1' had similar filled grain percentage and 'KRH 1' had significantly less in short-duration group. In mid-duration group, 'Jaya' exceeded the 2 hydrids, 'APRH 1' and 'APRH 2' in filled grain percentage. Late application of N at flowering could have resulted in the improved grain filling percentage by increasing leaf N concentration, Rubisco content, photosynthetic rate of flag leaves and by delayed leaf senescence, as was also reported by Peng *et al.* (1996) and Jiang *et al.* (1993).

1,000-grain weight

The 1,000-grain weight was not influenced by the source of N, and late application of N (in 4 splits) increased the 1,000-grain weight compared with 3 splits (Table 4). There was no significant difference in 1,000-grain weight of early group hybrids and check, whereas in the mid-duration group, 'Jaya' had significantly higher grain weight than the other 2 hybrids which were on par 'APRH 1' and 'APRH 2'. Non-significant influence of N source and equal preference to NH_4-N and $NH_4 + NO_3$-N in the late stage as reflected by similar filled grain percentage and 1,000-grain weight could be well explained that in the late growth stages, NO_3-N source may be equally suited once the root system of the rice plants is well esablished. These results are in confirmity with those of Yang and Sun (1991). Increase in filled spikelet number and grain weight by application of N at flowering was also reported by Peng *et al.* (1996).

Grain yield

For grain yield NH_4-N (urea) was found to be significantly superior to $NH_4 + NO_3$-N (CAN) (Table 5).Significant yield increase was obtained when N was applied in 4 splits compared with usually recommended 3 splits. Among the hybrids in early group, 'MGR 1' yielded significantly higher than 'Rasi' followed by 'KRH 1'. In mid-duration group, 'APRH 2' was at par with 'Jaya' and another hybrid 'APRH 1' yielded significantly less than 'APRH 2' and 'Jaya'.

The ammonical N which resulted in higher number of tillers and panicles was mainly responsible for higher grain yields as evident from the significant positive correlation of grain yield with tiller number ($r = 0.48^*$ and 0.68^{**} in 1994 and 1995) and panicle number ($r = 0.47^*$ and 0.66^{**} in 1994 and 1995). Increased yields due to late N application at flowering could be attributed to the increased filled grain percentage and 1,000-grain weight (Peng *et al.*, 1996) which is evident from the posiive correlation of grain yield with filled grain percentage ($r = 0.36$ and 0.53^{**} in 1994 and 1995) and 1,000-grain weight ($r = 0.48^*$ and 0.39 in 1994 and 1995). Split application of N at varous stages increased grain yield-attributing characters due to continuous availability of N in sufficient quantities from planting to ripening. The 'MGR 1' with more tillers,panicles and spikelets resulted in higher yield than 'Rasi', though there was no difference in filled grain percentage and 1,000-grain weight in the early group. But in the mid-duration group, though 'APRH 2' had higher number of tillers and panicles than 'Jaya', due to the significantly higher filled grain percentage and 1,000-grain weight, the grain yield of 'Jaya' was almost on par a with 'APRH 2'. 'APRH 1', though had higher number of tillers, panicles and spikelets, due to its poor filled grain percentage (56 and 53%) and low 1,000-grain weight recorded very low grain yields. Thus, none of the hybrids tested could surpass the best check, 'Jaya'. The multiple linear regression analysis indicated that 67% of the total variation ($R^2 = 0.672^{**}$ and 0.670^{**} in 1994 and 1995) in yield is explained by the linear function of the 5 yield attributes and 49% of the variation out of 67% is influenced by filled grain percentage and 1,000-grain weight.

Thus, NH_4-N source was found superior to $NH_4 + NO_3$-N for rice hybrids also by influencing the yield attributes and yield positively. The N application in 4 splits coinciding the last one with flowering also contributed to higher yield increase.

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