[15]N studies showed that conventional application of PU resulted in low recovery and that the major portion of applied N appeared to have been lost (data not shown). The plant and total (plant + soil) recovery of [15]N improved with band placement of urea solution at 50 kg N/ha in 2 splits compared with applying PU.

Band placement of urea solution at 50 kg N/ha in 2 splits is an alternate fertilizer management strategy for reducing N losses, increasing yield, and obtaining higher NUE to achieve about a 6.5 t/ha yield potential. ■

Transformation of N in soil affected by different sources and methods of N application in a flooded rice ecosystem

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We investigated the effect of applying 60 kg N/ha through various sources and methods on rice cultivar IET4094 during 1992-93 rabi (wet) and 1993 kharif (dry) seasons at the university's farm in Kalyani, West Bengal, India.

Soil was a Haplustalf with a pH of 7.9, 0.85% organic C, 26.32 C mol (p^+)/kg CEC, and 0.993% total N. The experiment was laid out in a randomized block design with three replications. Nitrogen was applied according to the schedule in the table. We applied 13.34 kg P/ha and 24.89 kg K/ha basally across the entire area at final puddling.

Two to three 25-d-old rice seedlings were transplanted at 25- × 25-cm spacing. Various fractions of N in the soil, including ammonium-N, nitrate-N (using 10% NaCl solution as an extractant in the ratio of 1:4, soil:solution), hydrolyzable N (HL-N) (6 N HCl), and nonhydrolyzable-N (NHL-N) (acid-nonhydrolysate) were measured, as well as N losses through ammonia volatilization (trapping evolved NH_3 in 0.1 N H_2SO_4) and leaching (soil solution collected by a piezometer with a porous cup). Rice yield was also recorded.

Applying $(NH_4)_2SO_4$ basally maintained a higher concentration of ammonium N in the soil than did most treatments during kharif. Soil NO_3-N values with prilled urea (PU) as a basal application and PU as a split were similar in both seasons while green manure (GM) + PU resulted in a generally lower soil nitrate N concentration. Use of neem-coated urea applied basally maintained relatively high amounts of both HL-N and NHL-N.

The cumulative N loss through ammonia volatilization in GM + PU was similar to that of PU (split) during both seasons. The N loss through leaching was generally lower with the PU as a split than with the other treatments during both seasons (see table).

We concluded that applying PU as a split and GM + PU are the most efficient fertilization forms of those studied. They resulted in generally higher yields with relatively low N losses to volatilization and leaching. ■

Transformation of N in submerged soil in relation to yield of rice cultivar IET4094[a]. West Bengal, India. 1992-93.

Treatment	NH_4^+ - N (mg/kg)		NO_3^- - N (mg/kg)		Hydrolyzable-N (mg/kg)		Nonhydrolyzable-N (mg/kg)	
	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
Control	2.58 d	2.12 d	0.60 c	0.62 d	595.75 d	634.00 d	140.00 d	120.25 e
Prilled urea (basal)	5.34 a	4.27 b	0.89 a	0.89 a	686.25 bc	703.40 b	150.50 c	157.25 d
Prilled urea (1/2 at transplanting + 1/2 at 30 DAT[b])	4.29 b	3.26 c	0.82 ab	0.89 a	687.50 bc	691.00 bc	164.75 a	168.75 a
Neem-coated urea	3.86 c	3.85 bc	0.88 a	0.68 cd	701.75 a	738.50 a	160.45 ab	165.75 ab
Sulfur-coated urea	3.68 c	3.77 bc	0.81 ab	0.71 bc	691.30 ab	717.25 b	162.50 a	164.25 abc
$(NH_4)_2SO_4$	5.71 a	4.99 a	0.88 a	0.78 b	684.50 bc	700.75 bc	156.50 b	160.30 de
Green manure[c] + prilled urea (1:1)	4.50 b	4.42 ab	0.75 b	0.72 bc	673.25 c	681.75 c	165.25 a	163.40 bc

[a] In a column, means followed by the same letter are not significantly different (P=0.05) by DMRT. [b] DAT = days after transplanting. [c] Green manure = *Sesbania rostrata* in kharif and *Anabaena azollae* in rabi.

Effect of substituting sodium for potassium in a lowland double-rice cropping system

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We evaluated the effect of substituting sodium (common salt) for potassium (muriate of potash) in indica, japonica, and hybrid rices during 1990-91 in three soils with different K-supplying capacities.

Soils (top 0-15 cm) were Yu-yao silty-clay loam (Typic Haplaquept) with pH 6.2, 13.3 g organic C/kg, 1.83 g total N/kg, 19.3 g K/kg, 263 kg available N/ha, 20.50 kg Olsen P/ha, 77 kg exchangeable K/ha, 493 kg nonexchangeable K/ha, and 240.15 kg exchangeable Na/ha; Wen-lin loamy clay (Typic Haplaquept) with pH 5.6, 22.0 g organic C/kg, 270 kg available N/ha, 16.09 kg Olsen P/ha, 219 kg exchangeable K/ha, 614 kg nonexchangeable K/ha, and 319.47 kg exchangeable Na/ha; and Shao-Xing loamy clay (Typic Haplaquept) with pH 5.8, 23.3 g organic C/kg, 719 kg available N/ha, 6.18 kg Olsen P/ha, 137 kg exchangeable K/ha, 692 kg nonexchangeable K/ha, and 79.70 kg exchangeable Na/ha.

The field experiments were laid out in a random block design with three replications. K was applied as muriate of potash at 0 (K_0), 62.2 ($K_{50\%}$), 83.0 ($K_{66\%}$), and 124.5 ($K_{100\%}$) kg/ha. In 1990, Na was applied as common salt at 0 (K_0), 62 ($Na_{33\%}$), 93 ($Na_{50\%}$), and 186 ($Na_{100\%}$) kg NaCl/ha (Na was chemically equivalent to K); in 1991, it was applied as 83.3 ($Na_{33\%}$), 250 ($Na_{100\%}$), and 375 ($Na_{150\%}$) kg NaCl/ha (NaCl rates were equal to KCl rates). The crop also received 150 kg N/ha as urea and 19.8 kg P/ha as single superphosphate. Plant samples at full heading and ripening stages were analyzed to determine contents of N (Kjeldahl method), K (H_2SO_4-H_2O_2 digestion-ICP method), Na (1 N HCl extraction-ICP method), SiO_2 (H_2SO_4-H_2O_2 digestion-weighting method), and Cl (Mohr method).

Applying Na up to 250 kg NaCl/ha ($Na_{100\%}$) significantly increased grain yield by 4-8% compared with that of the no K and Na application control. The combined application of Na and K ($K_{50\%}$ and $Na_{50\%}$, and $K_{66\%}$ and $Na_{50\%}$ plots) gave almost the same grain yields as the $K_{100\%}$ plot in the 1991 late rice crop (Table 1). Applying NaCl usually increased N, SiO_2, Na, and Cl contents in rice plants, perhaps because more dry matter was produced with Na application than in the control (Table 2).

Applying NaCl did not markedly increase rice plants' uptake of K, and oversupplying NaCl ($Na_{150\%}$ plot in 1991 early rice crop) obviously reduced rice plants' K uptake, showing the antagonistic effect between Na and K uptake. ■

Table 1. Yields of three rice types grown with and without K and Na fertilizers.[a] Zhejiang, China. 1990-91.

Yield	(t/ha)			
Treatment	1990	1991		
	Late rice season	Early rice season	Late rice season	
	Hybrid	Indica	Japonica	Hybrid
K_0 (control)	6.7 a	6.0 a	6.7 a	8.7 a
$K_{100\%}$	7.9 e	6.6 d	7.6 b	10.2 c
$Na_{100\%}$	7.0 b	6.3 bc	7.0 a	9.4 b
$Na_{150\%}$		6.1 a	6.8 a	9.4 b
$K_{50\%}$ $Na_{50\%}$	7.4 c	6.4 c	7.3 b	9.9 c
$K_{66\%}$ $Na_{33\%}$	7.6 d	6.1 b	7.4 b	10.0 c
CV (%)	6.1	3.5	4.9	5.9

[a] In a column, means followed by the same letters are not significantly different at the 5% level by DMRT. The substitution of Na for K was chemically equivalent in 1990 and equal to the salt rates of NaCl to KCl in 1991.

Table 2. Nutrient uptake of rice[a] as influenced by applying common salt.[b] Zhejiang, China. 1990-91.

Treatment	Nutrient uptake (kg/ha)														
	N			K			SiO_2			Na			Cl		
	G	S	T	G	S	T	G	S	T	G	S	T	G	S	T
1990 late rice season Hybrid rice															
K_0	61.4	70.4	131.7	17.9	54.5	72.3	173.4	582.8	756.2	0.5	15.8	16.3	8.3	48.0	56.2
$Na_{100\%}$	70.5	78.8	149.3	23.0	52.5	75.5	216.2	658.7	874.8	0.6	26.6	27.3	10.1	62.1	72.2
1991 early rice season Indica rice															
K_0	92.0	41.3	133.2	28.4	79.2	107.6	176.0	644.6	820.5	0.5	5.6	6.1	8.8	36.5	45.3
$Na_{100\%}$	99.0	34.8	133.8	28.1	68.1	96.2	236.3	668.3	904.5	0.5	8.5	9.0	10.2	35.5	45.7
$Na_{150\%}$	89.9	33.3	123.2	25.7	67.2	92.9	117.9	518.0	695.9	0.4	8.0	8.4	11.5	29.3	40.8

[a] G = grain, S = straw, T = total rice plant. [b] In 1990 experiment, $Na_{100\%}$ = 186 kg NaCl/ha. In 1991 experiment, $Na_{100\%}$ = 250 kg NaCl/ha, $Na_{150\%}$ = 375 kg NaCl/ha.

Fertilizer management — organic sources

Algicides in *Azolla* germplasm management

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The aquatic fern *Azolla* is cultivated as a green manure for application with lowland rice in parts of Asia and the South Pacific. *Azolla* cultures are commonly maintained in the vegetative phase in germplasm collections. Free-living cyanobacteria and microalgae within the growth medium of the open cultures may contaminate these accessions. Valuable plants may die from frequent infestations if they are not periodically washed and transferred. The presence of the *Anabaena azollae* symbiont complicates eradicating these phototropic contaminants with biocides.

As a possible solution to this maintenance problem, six *Azolla* species were tested for tolerance for two Cu^{+2}-based algicides: copper sulfate and chelated copper (Cutrine-Plus[R], Applied