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Effect of foliar application of potassium nitrate and calcium nitrate on performance of rainfed lowland rice (*Oryza sativa*)

CHAITY KUNDU* AND R.K. SARKAR

Department of Agronomy, Institute of Agricultural Science, University of Calcutta, Kolkata, West Bengal 700 019

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2005 and 2006 at Baruipur to evaluate the effect of foliar nutrition of potassium nitrate (KNO_3) and calcium nitrate $Ca(NO_3)_2$ on growth and yield of rice (*Oryza sativa* L.) in Gangetic alluvial land. Foliar application of 0.406% $Ca(NO_3)_2$ followed by 0.50% KNO_3 during 50% flowering stage increased the growth parameters and yield attributes which ultimately resulted in higher grain yield than foliar spray of 0.25 and 1.00% KNO_3 and 0.203 and 0.812% $Ca(NO_3)_2$ and water spray. Foliar spray of 0.406% $Ca(NO_3)_2$ resulted in maximum grain yield (5.47 t/ha), net returns (Rs 14,733/ha) and benefit cost ratio (1.38). Hence foliar spray of 0.406% $Ca(NO_3)_2$ should be practised to obtain maximum grain yield and net monetary returns from rainfed lowland rice in West Bengal.

Key words : Calcium nitrate, Foliar application, Potassium nitrate, Rice, Yield

At present, most of the research is directed to irrigated environments, even in countries where rainfed rice predominates. Barker *et al.* (1985) found that research investment was lower in countries with a high proportion of rainfed rice when compared with countries with predominately irrigated rice. The yield of rice under lowland conditions almost always will be lower than under irrigated in otherwise optimum conditions (Mackill *et al.*, 1996) because of many constraints in rainfed lowlands such as stresses related to shortage or excess of water, nutrient stress, low solar radiation as it is grown during the rainy season with high night temperature.

Management of nitrogen in rice is very difficult in submerged soil conditions. Since the late application of nitrogen delays the synthesis of abscisic acid, promotes cytokinin activity and causes higher chlorophyll retention and thereby higher photosynthesis activity in leaves for supply of photosynthates to grains (Sarkar *et al.*, 2007). Potassium helps in photosynthesis, carbohydrate distribution and starch synthesis in storage organs (Imas and Magen, 2007) which in turn helps in higher grain yield. Calcium (Ca^{2+}) may substantially increase N and P uptake and this may prove to be helpful in promoting root growth (Friessen *et al.*, 1980). Prevalence of Ca^{2+} cation which is a constituent of cell wall and plays a key role in cellular functions and activity of enzymes (Bush, 1995). Presence of Ca^{2+} may result in more rational utilization of soil N and more active assimilation of NO_3^- N in roots and leaves (Kondratev *et al.*, 1984). Hence, the present study was initiated to investigate the effect of foliar application of potassium nitrate and calcium nitrate on rice.

***Corresponding author:** (E mail: kunduchaity@gmail.com)

MATERIALS AND METHODS

The field experiment was conducted during the *kharif* 2005 and 2006 at the experimental farm of Calcutta University, Baruipur in a Gangetic alluvial soil having 0.73% organic carbon, 255, 29.1, 259 and 66 kg available N, P, K and Ca^{2+}/ha, respectively with pH 6.0. The treatments consisted of foliar application of 3 concentrations each of KNO_3 (0.25, 0.50 and 1.00%) and $Ca(NO_3)_2$ (0.203, 0.406 and 0.812%) along with water spray as control and four stages of foliar spray (panicle initiation, flowering, milking and dough stage). Foliar spray of potassium nitrate, calcium nitrate at their respective concentrations supplied equal amounts of NO_3^-N to the crop. KNO_3 contained 38.7% K and 61.3% NO_3 whereas $Ca(NO_3)_2$ contained 24.4% Ca and 75.6% NO_3. Total 28 treatments were tried in factorial randomized block design replicated thrice. A basal dose of 45-26.5-50 kg N-P-K/ha was applied in all the treatments before puddling and 45 kg N/ha was applied at active tillering stage by top dressing. Rice 'Sabita' (NC 492) was transplanted on 10 August 2005 and 12 August 2006 at 20 cm x 10 cm crop geometry. Dilute solutions of nutrient salts as per treatments were applied @ 800 litres water/ha as foliar spray. The crop was grown in lowland situation where submergence of water occurred between 25 cm and 50 cm. Plot size was 8 m x 5 m. The observations for growth and yield attributing parameters were recorded from 10 randomly selected plants in each plot. Samples of 0.5 m row length from two places in each plot were removed from border rows for data collection on physiological parameters. Grain and straw yields were recorded on net plot size. The economic parameters like net monetary returns and benefit cost ratio were worked out by using prevailing market price of inputs and outputs. The required quantities of KNO_3 were 2, 4 and 8 kg/ha for 0.25, 0.50, 1.00% KNO_3 respectively whereas $Ca(NO_3)_2$ were 1.62, 3.24 and 6.48 kg/ha for 0.203, 0.406, 0.812% of $Ca(NO_3)_2$ respectively.

RESULTS AND DISCUSSION

Growth attributes

The various growth and physiological characters of rice were significantly influenced by different foliar spray treatments applied at different growth stages (Table 1). The sprays of 0.406% $Ca(NO_3)_2$ followed by 0.50% KNO_3 at 50% flowering stage were found superior to other foliar spray treatments as well as stages of sprays. Spray of 0.406% $Ca(NO_3)_2$ followed by 0.50% KNO_3 i.e., at intermediate concentration improved growth parameters like plant height, leaf area index (LAI) and crop growth rate (CGR) and consequently overall crop growth in terms of dry matter accumulation. Spray at intermediate concentration influenced the vigour of the plant through effective absorption of nutrients at critical stage, resulting in enhanced physiological activity and increased dry matter production. Increase in growth and physiological attributes due to application at intermediate concentrations during 50% flowering stage could be ascribed to greater synthesis of photosynthates from a relatively large photosynthetic surface and subsequent translocation and accumulation in different organs of the plant as evidenced by increased LAI and dry matter production (Table 1). The values of relative growth rate (RGR) and net assimilation rate (NAR) under different treatments were found to be insignificant.

Yield attributes

Foliar application as well as stages of application significantly affected the yield attributes and yield of rainfed lowland rice (Table 2). Foliar application of 0.406% $Ca(NO_3)_2$ followed by 0.50% KNO_3 during 50% flowering stage resulted in significantly and appreciably more length of panicle and filled grains/panicle. However, 1,000-grain weight did not show significant variation. Such increase in yield attributes may be owing to altered physiological and reproductive growth of the crop induced by foliar spray of nitrate salts through enhanced activities of enzymes and photosynthetic capacity (Sarkar and Pal, 2006).

Yield

Potassium nitrate and calcium nitrate at moderate concentration when sprayed during 50% flowering gave sig-

Table 1. Effect of foliar application of potassium nitrate and calcium nitrate on growth parameters of rice

Treatment	Plant height (cm)	Tillers /m²	LAI at 75 DAT	Dry matter (g/plant)	CGR (g/plant/day) at 0-75 DAT	RGR (g /g day) at 0-75 days	NAR (10^{-5} g / cm²/d) at 75-92 DAT
Foliar spray (N)							
Water spray	150.6	285	4.01	64.2	0.584	0.0107	102.7
0.25% KNO_3	153.3	290	4.21	66.4	0.629	0.0111	101.2
0.50% KNO_3	156.6	315	5.99	70.2	0.573	0.0097	54.7
1.00% KNO_3	154.9	305	4.84	67.8	0.599	0.0104	81.2
0.203% $Ca(NO_3)_2$	154.0	300	4.43	66.6	0.592	0.0112	94.6
0.406% $Ca(NO_3)_2$	157.9	320	6.49	72.0	0.562	0.0092	67.1
0.812% $Ca(NO_3)_2$	155.9	310	5.33	68.9	0.567	0.0095	71.1
SEm±	0.1	1.2	0.047	0.4	0.022	0.0002	3.5
CD (P=0.05)	0.1	2.3	0.094	0.8	0.045	NS	NS
Stages of spray (S)							
Panicle initiation	157.8	300	5.48	70.4	0.432	0.0067	57.6
Flowering	159.3	320	4.92	74.8	0.778	0.0126	103.8
Milking	151.6	295	4.88	64.7	0.550	0.0105	80.3
Dough	150.3	295	4.88	62.2	0.594	0.0111	85.0
SEm±	0.1	1.7	0.04	0.3	0.017	0.0002	4.3
CD (P=0.05)	0.2	3.3	0.07	0.6	0.034	NS	NS
Interaction (NxS)							
CD (P=0.05)	1.0	4.6	0.19	1.6	0.090	NS	NS

nificantly higher grain yield than lower as well as higher concentration as they become insufficient or phytotoxic at relatively lower and higher concentration, respectively. Foliar spray of 0.406% $Ca(NO_3)_2$ registered 35% higher grain yield over water spray. Foliar spray of nitrate salts at 50% flowering stage gave 18.5, 31.9 and 53.6% higher grain yield over foliar spray at panicle initiation, milking and dough stages respectively. Spraying at 50% flowering stage might have helped the plants better absorption and consequent assimilation of nutrients supplied through foliar application resulting in luxuriant growth and development which led to higher dry matter and consequently improved yield attributes like filled grains, test weight and higher grain yield in rice. In fact spraying of 0.406% $Ca(NO_3)_2$ supplied Ca^{2+} and NO_3^--N which were effectively absorbed as cation and anion by plants, assimilated and translocated more efficiently to developing grains for proper filling by increasing leaf nitrogen content, chlorophyll synthesis and by regulating cellular functions (Ward and Shroeder, 1994) and increasing enzyme activities (Bush, 1995) which were reflected in higher values of yield attributes and resulted in higher grain yield. Similarly, in case of foliar spray of KNO_3, besides the beneficial functions of NO_3^--N, prevalence of K^+ enhanced photosynthetic activity and facilitated partitioning of photosynthates (Batra,1982), resulting in higher grain yield. Foliar spray of 0.406% $Ca(NO_3)_2$ with equal amount of NO_3^--N basis proved better than 0.50% KNO_3 possibly due to prevalence of Ca^{2+} cation which is a constituent of cell wall and plays a key role in cellular functions and activity of enzymes (Bush,1995).

Interaction effect

The interaction effect between nitrate salts and stages of foliar application, was found to be statistically significant (Table 3). The results indicated that spraying of either of KNO_3 or $Ca(NO_3)_2$ during 50% flowering stage proved to be more effective. Foliar application of 0.406% $Ca(NO_3)_2$ during 50% flowering stage registered 111.7% higher yield over the lowest as recorded under water spray during milk stage. Foliar application of

Table 3. Grain yield (t/ha) as influence by interaction effect of foliar spray of nitrate salts and stages of foliar spray (pooled data)

Doses of nitrate salt	Stages of spray			
	Panicle initiation	Flowering 50%	Milking	Dough
Water spray	4.20	4.32	3.78	3.90
0.25% KNO_3	4.50	4.60	4.27	4.16
0.50% KNO_3	5.00	6.41	4.79	4.45
1.00% KNO_3	4.70	5.30	4.39	4.28
0.203% $Ca(NO_3)_2$	4.50	5.22	4.15	4.29
0.406% $Ca(NO_3)_2$	5.25	7.02	4.97	4.65
0.812% $Ca(NO_3)_2$	5.18	5.44	4.53	4.30
SEm±		0.057		
CD (P=0.05)		0.111		

Table 2. Effect of foliar application of potassium nitrate and calcium nitrate at different growth stages on yield character and yield of rice

Treatment	Panicle length (cm)	Number of grains/panicle	1,000-grain weight (g)	Grain yield (t/ha)			Biological yield (t/ha) (pooled)	Harvest index (pooled)
				2005	2006	Pooled		
Foliar spray (N)								
Water spray	21.8	106.5	27.0	3.87	4.23	4.05	14.65	0.276
0.25% KNO_3	22.0	113.1	27.8	4.29	4.46	4.38	15.89	0.276
0.50% KNO_3	22.8	135.5	30.3	5.02	5.29	5.16	18.59	0.278
1.00% KNO_3	22.5	123.6	28.9	4.55	4.78	4.67	16.98	0.275
0.203% $Ca(NO_3)_2$	22.3	117.1	28.4	4.44	4.63	4.54	16.50	0.275
0.406% $Ca(NO_3)_2$	23.1	142.1	31.5	5.31	5.62	5.47	19.44	0.281
0.812% $Ca(NO_3)_2$	22.6	129.4	29.6	4.75	4.97	4.86	17.68	0.274
SEm±	0.04	0.67	0.06	0.06	0.05	0.03	0.06	0.002
CD (P=0.05)	0.08	1.34	0.12	0.11	0.09	0.06	0.11	0.005
Stages of spray (S)								
Panicle initiation	22.8	126.3	29.0	4.79	4.73	4.76	17.42	0.273
Flowering	24.1	143.5	31.9	5.61	5.33	5.47	19.54	0.280
Milking	21.9	123.5	27.8	4.34	4.47	4.41	16.24	0.272
Dough	21.0	102.3	27.6	4.17	4.41	4.29	15.85	0.271
SEm±	0.05	0.9	0.09	0.04	0.04	0.04	0.08	0.002
CD (P=0.05)	0.10	1.9	0.18	0.09	0.07	0.08	0.16	NS
Interaction (NxS)								
CD (P=0.05)	0.16	2.6	0.25	0.23	0.19	0.11	0.22	NS

0.406% $Ca(NO_3)_2$ and 0.50% KNO_3 although gave higher grain yield, but harvest index did not show any increasing trend probably due to higher availability of nitrogen which is an effect of heavy vegetative growth on light relationship within canopy (Donald and Hamblin, 1976). Interaction effect between doses and stages of spray was found to be significant.

Nutrient uptake and nutrient use efficiency

Foliar application of nitrate salts significantly affected the nitrogen uptake by rice (Table 4). As the nutrient uptake values were influenced greatly by the grain and straw yields of the crop, these followed a similar trend. Foliar spray of 0.50% KNO_3 and 0.406% $Ca(NO_3)_2$ increased the uptake of N over water spray treatment. However, foliar fertilization of 0.406% $Ca(NO_3)_2$ showed higher uptake of N over 0.50% KNO_3 possibly due to significant role of Ca^{2+} in more rational utilization of soil nitrogen and active assimilation of NO_3 in roots and leaves. Foliar spray of 0.406% $Ca(NO_3)_2$ recorded more nitrogen uptake than others owing to substantially higher concentration of N in grain and straw as well as greater grain yield of rice. Better uptake of nutrient during flowering stage of the crop was possibly due to greater concentration of nitrogen in grain and straw as well as higher yield.

Table 4. Effect of foliar application of potassium and calcium nitrate at different growth stages on nitrogen uptake of rice

Treatment	N uptake (kg/ha)	Physiological efficiency (PE) (kg grain/kg nutrient uptake)
Foliar spray (N)		
Water spray	42.0	
0.25% KNO_3	47.5	60.0
0.50% KNO_3	49.8	142.3
1.00% KNO_3	49.5	82.6
0.203% $Ca(NO_3)_2$	48.8	72.0
0.406% $Ca(NO_3)_2$	52.6	133.9
0.812% $Ca(NO_3)_2$	51.3	87.0
SEm±	0.42	
CD (P=0.05)	0.84	
Stages of spray (S)		
Panicle initiation	47.0	
Flowering	50.0	
Milking	49.8	
Dough	49.3	
SEm±	0.34	
CD (P=0.05)	0.68	
Interaction (NxS)		
CD (P=0.05)	1.62	

Physiological efficiency of nitrate salts increased by 59.7 kg grain / kg KNO_3 salt at 0.50% KNO_3 over 1.00% KNO_3. Foliar nutrition of 0.406% $Ca(NO_3)_2$ recorded 61.9 kg grain and 46.9 kg grain / kg $Ca(NO_3)_2$ salt over 0.203 and 0.812% $Ca(NO_3)_2$ respectively. Foliar nutrition of 0.50% KNO_3 and 0.406% $Ca(NO_3)_2$ gave higher physiological efficiency possibly due to efficient absorption and utilization of foliage applied nutrient for grain formation.

Economics

Among the foliar spray treatments, the highest monetary return and benefit : cost ratio (Table 5) were obtained with application of 0.406% $Ca(NO_3)_2$, which involved lesser cost for per unit nutrient salt and was most economical among the nitrate salts. The highest net return (Rs 14,733/ha) with foliar spray of 0.406% $Ca(NO_3)_2$ was due to highest yield in the treatment. The lowest net return (Rs. 8,713/ha) was obtained from the water spray treatment.

Consequently foliar application of 0.406% $Ca(NO_3)_2$ is necessary to rice to realize sustained productivity and profitability of rainfed lowland rice.

Table 5. Economics of foliar spray of potassium nitrate and calcium nitrate (pooled data)

Treatment	Amount of salt required (kg/ha)	Cost of nitrate salts (Rs./ha)	Cost of cultivation (Rs./ha)	Net return (Rs./ha)	Net benefit cost ratio
Water spray			10,120	8,713	0.86
0.25% KNO_3	2.00	540	10,660	9,707	0.91
0.50% KNO_3	4.00	1,080	11,200	12,794	1.14
1.00% KNO_3	8.00	2,160	12,280	9,436	0.77
0.203% $Ca(NO_3)_2$	1.62	292	10,412	10,699	1.03
0.406% $Ca(NO_3)_2$	3.24	583	10,703	14,733	1.38
0.812% $Ca(NO_3)_2$	6.48	1,166	11,286	11,313	1.00

Prevailing market rate of produce and nitrate salts (Rs/kg) : Rice, Rs 4.65/-, Potassium nitrate, Rs 270/-; Calcium nitrate, Rs180/-

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