Foliar Potassium Nitrate Application for Paddy Rice

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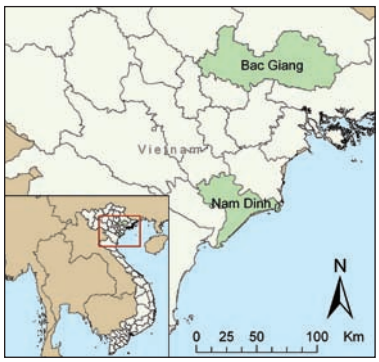
Trials conducted in Vietnam with spring and summer rice grown on soils low in soil exchangeable K showed positive yield and net income responses from one to three foliar treatments with potassium nitrate. Grain yields and net income were improved when a portion of the basal KCl was replaced with the three foliar KNO_3 sprayings.



The importance of rice in relation to Vietnam's food security, culture, and socio-economic development is evident. Total annual paddy rice production grew from 19.2 million tonnes (M t) in 1990 to 35.8 M t in 2005, and 38 M t in 2008. Thus, Vietnam has moved from being a country with a chronic food deficit to one with enough food for its population, enhanced food security and a food surplus that allows rice exports of 5 to 6 M t per year. Major constraints to improving productivity and economic performance of rice include low soil fertility, pest and disease damage, poor availability and high cost of inputs, as well as low and fluctuating rice prices.

Modern high-yielding rice varieties absorb K in greater quantities than any other essential nutrient. In fields across Asia, total K uptake for a crop yielding 5 t/ha are close to 100 kg K/ha of which more than 80% is in the straw at maturity (Dobermann and Fairhurst, 2000). For yields greater than 8 t/ha, total K uptake may even exceed 200 kg K/ha (Dobermann et al., 1996). Current K fertilizer recommendation and application rates are rarely sufficient to meet these K needs. Therefore, most intensive rice production systems have been running under negative K balances (Dobermann et al., 1998) and the negative effects of this have begun to emerge (Regmi et al., 2002; Bhanderi et al., 2003). The situation is even more aggravated when all the straw is removed from the field as per farmer practice in North Vietnam. In some locations, nutrients removed by crop are partly returned to the soil in the form of FYM. However, the use of FYM or straw may be profitable only when applied as a complement to recommended rates of NPK fertilizer (Dawe et al., 2003).

Foliar applied K can be beneficial when K uptake via the root zone is limited. This condition may be due to low K input via fertilizers, low K soil reserves, K-fixing soils (clay, high OM, peat), cation competition (sodic/saline soils with high Na; excessive NH_4 fertilizers applications; high Fe), course-textured sandy soils, vulnerability to K leaching (monsoons), or drought which limits the transport of K to roots (adapted after Weinbaum et al, 2002).

In 2009, researchers in Vietnam conducted experiments with foliar KNO_3 (13% N and 45% K_2O) sprays in paddy rice in North Vietnam to evaluate its effect on yield and yield components, nutrient uptake, as well as agronomic and economic efficiency. Four field experiments were conducted at two locations including: a degraded soil site at Bac Giang Research Station located in Hiep Hoa District, Bac Giang Province, and an alluvial soil site on the Red River Delta in Xuan Truong District, Nam Dinh Province. Soil properties in the surface soil layer of the degraded soil and alluvial soil as well as details on rice varieties and plant spacing are provided in **Table 1**. The degraded soil is prone to leaching of K, and the alluvial soil is associated with K fixation. Both of these soils displayed very low soil exchangeable K contents, making them potentially very responsive to K addition.

Common abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; Fe = iron; Na = sodium; C = carbon; KCl = potassium chloride; KNO_3 = potassium nitrate; SSP = single superphosphate; NO_3 = nitrate; NH_4 = ammonium; FYM = farmyard manure; OM = organic matter; CEC = cation exchange capacity; VND = Vietnamese dong.

Table 1. Description of the experimental sites, rice varieties, and planting density at Nam Dinh and Bac Giang.

Parameter	Bac Giang	Nam Dinh
Soil type	Degraded, sandy soil	Alluvial, clayey soil
Exc K, cmol/kg (ppm)	0.08 (31)	0.15 (59)
Organic C, g/kg	8.6	13.5
CEC, cmol/kg	4 to 5	15
pH	5.5	5.5 to 6.0
Spring rice	Inbred Khang Dan 18	Hybrid Juu 527 (China)
Summer rice	Inbred Khang Dan 18	TH3-3 (Vietnam)
Plant spacing	20 cm x 10 cm	25 cm x 13 cm

Foliar KNO_3 was provided along with combinations of basally applied urea, SSP, KCl, and 8 t/ha of FYM (spring rice only) (**Table 2**). Foliar applications occurred at one or more different growth stages: Active Tillering (AT), Panicle Initiation (PI), and End of Flowering (F), and each application provided 300 liters of a 3% concentration, equal to 9 kg KNO_3/ha, or 4 kg K_2O/ha and 1.1 kg N/ha. Hills from 4 m^2 of area centered in each replicated plot were harvested for grain yield determination with 14% moisture. Yield components were determined from 10 hills collected from the sampling zone surrounding the harvest area, as was the procedure for determining dry biomass at the AT, PI, and F stages.

The response to direct FYM application can be quantified in spring rice and was significant ($p = 0.05$) at the degraded soil site at Bac Giang, but not at the alluvial soil site at Nam Dinh (**Table 3**). In summer rice, check plots showed a significant difference between the basal NP treatment and basal NP plus foliar KNO_3 applied at each of the three growth stages selected. Reliance on basal K alone produced yields that were equal to those resulting from foliar KNO_3 alone at three of the four sites (i.e. excluding the summer rice season at Nam Dinh) where three splits of foliar KNO_3 was superior. Supplementation of the full basal K rate with three foliar KNO_3 applications (T9) produced the highest average yield response across seasons

Table 2. Fertilizer sources, timings, and rates for the two trial sites in Vietnam.

Source	Timing	Unit	Spring Rice		Summer Rice	
			Bac Giang	Nam Dinh	Bac Giang	Nam Dinh
FYM†	Basal	t/ha	8	8	-	-
Urea (46% N)	10-15 DAT	kg N/ha	30	40	20	30
Urea	25 DAT (AT)	kg N/ha	30	40	30	40
Urea	50-55 DAT (PI)	kg N/ha	30	40	30	30
Total N		kg N/ha	90	120	80	100
SSP (16% P_2O_5)	Basal	kg P_2O_5/ha	60	70	45	60
KCl (60% K_2O)	Basal	kg K_2O/ha	70	90	70	90

†FYM source at BacGiang was 0.32% N, 0.41% P_2O_5, and 0.52% K_2O which added 26 kg N/ha, 33 kg P_2O_5/ha, and 42 kg K_2O/ha; at Nam Dinh the FYM source was 0.35% N, 0.43% P_2O_5, and 0.55% K_2O which added 28 kg N/ha, 34 kg P_2O_5/ha, and 44 kg K_2O/ha.
DAT = Days after transplanting, AT = Active Tillering, PI = Panicle Initiation.

Table 3. Treatments, application stages, applied dose rates and yields for the two trial sites in Vietnam.

	Treatment description†	Foliar KNO_3 timing‡			-- Spring 2009 --		-- Summer 2009 --	
		AT	PI	F	Bac Giang	Nam Dinh	Bac Giang	Nam Dinh
					Yield††, t/ha			
T1a	NP* without FYM	0	0	0	4.74	6.59	3.75	4.62
T1b	NP	0	0	0	5.05	6.80		
T2	NP	+	+	+	5.59	7.80	4.47	5.38
T3	NP + 100% KCl (Basal)	0	0	0	5.53	7.30	4.52	4.95
T4	NP + 100% KCl (Basal)	+	0	0	5.78	7.84	4.90	5.29
T5	NP + 100% KCl (Basal)	0	+	0	5.79	8.02	4.89	5.41
T6	NP + 100% KCl (Basal)	0	0	+	5.83	7.87	4.83	5.36
T7	NP + 100% KCl (Basal)	+	+	0	5.86	8.16	5.13	5.48
T8	NP + 100% KCl (Basal)	0	+	+	5.94	8.18	5.14	5.50
T9	NP + 100% KCl (Basal)	+	+	+	6.16	8.49	5.26	5.67
T10	NP + 75% KCl (Basal)	+	+	+	6.12	8.33	5.13	5.43
T11	NP + 50% KCl (Basal)	+	+	+	6.06	8.15	5.02	5.41
T12	NP + 50% KCl (Basal) + 50% KCl (PI)	0	0	0	5.74	7.97	4.78	5.21
	LSD (p = 0.05)				0.14	0.58	0.11	0.34

†In spring rice, all treatments received FYM except T1a. In summer rice, no FYM was applied
‡0 = no foliar K, + = 9 kg KNO_3/ha/application, AT = Active Tillering (20 to 25 DAT), PI = Panicle Initiation (50 to 55 DAT), F = End of Flowering (25 to 28 days before harvest).
††Grain yields are adjusted to 14% moisture.
* Rates for N and P are described in Table 2.

and sites. This treatment produced 11% more spring rice and 16% more summer rice on degraded soil; 16% more spring rice and 15% more summer rice on alluvial soil compared to use of basal KCl alone (T3). Single sprays resulted in a more modest yield response of 7% averaged over sites and seasons, while two sprays generated an average yield response of 11%. Interestingly, significantly higher yields (10% average response) were also obtained with the combination of three foliar KNO_3 sprays and up to 50% less KCl provided through a base dressing (T10 and T11). While in this study no disease ratings were carried out on the rice crops, the authors suggest that foliar KNO_3 applications may have increased the plants' disease and pest tolerance.

The corresponding agronomic efficiencies (AE) for K declined with increased frequency of foliar KNO_3 spray as a result of diminishing gains in yield per unit of K input (data not shown). Thus at the degraded soil site, AE averaged across both seasons varied from 25 kg rice grain/kg KNO_3 with three sprayings (T9) to 27 kg rice grain/kg KNO_3 with two sprayings (T7 and T8) to 35 kg rice grain/kg KNO_3 with a single foliar spray (T4, T5, and T6). On alluvial soil, average AE values were 56 kg, 39 kg, and 35 kg/kg KNO_3 for the single, double, and triple applications of foliar spray. Higher AE values at the alluvial soil site are most likely related to growing hybrid varieties at that location. Foliar spraying tended to increase the number of panicles/m^2, numbers of grain/panicle, 1,000 grain weight, and decreased the ratio of unfilled grain (data not shown). However, the significance of these responses depended on season and location.

As expected, the higher yields with foliar KNO_3 increased uptake of N and K in both grain and straw at harvest (data not shown). For example, on the degraded soil, average uptake in spring rice increased by 3.5 kg N/ha and 10.5 kg K_2O/ha for the single sprays, while uptake in summer rice was increased by 8.2 kg N/ha and 13.9 kg K_2O/ha. Nutrient removal per t of grain ranged between 15 to 17.2 kg N and 22 to 24 kg K_2O for the inbred variety at Bac Giang and 14.6 to 15.1 kg N and 18.1 to 19.3 kg K_2O for the Juu 527 hybrid (spring) and 16.2 to 17.2 kg N and 23.5 to 24.1 kg K_2O for TH3-3 hybrid (summer) at Nam Dinh.

Economic analysis found a steady increase in net income under single, double, and triple sprayings at both the degraded and alluvial sites (**Table 4**). In addition, net income was maintained when basal KCl was decreased by up to 50% in combination with three foliar KNO_3 spray applications, as well as for the treatment that completely substituted basal KCl with three foliar applications of KNO_3 (T2).

Summary

On these severely K deficient soils, foliar application of KNO_3 provided an increase in paddy rice grain yields and net incomes over basal KCl application across two seasons and sites. The best response was achieved when the maximum basal rate of KCl was applied along with three foliar KNO_3 applications. Reducing the basal dressing of KCl by 25% or 50%, while compensating for this reduction with three foliar KNO_3 sprayings, also achieved higher yields and net incomes than those achieved with strictly basal KCl. BC

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Table 4. Economics of foliar KNO_3 application on rice (average of two seasons) at Bac Giang and Nam Dinh.

Treatment	Gross Income†	Total Fertilizer Cost	Total Fertilizer Cost over T3	Net Income over fertilizer cost	Net over T3
			USD/ha		
			Bac Giang (degraded, sandy soil)		
T2	1,397	248	-35	1,149	36
T3	1,396	283	0	1,113	-
T4	1,483	306	23	1,177	65
T5	1,483	306	23	1,177	65
T6	1,481	306	23	1,175	62
T7	1,526	329	46	1,198	85
T8	1,539	329	46	1,210	97
T9	1,586	352	68	1,235	122
T10	1,563	327	44	1,235	122
T11	1,539	303	20	1,236	123
T12	1,461	289	6	1,172	60
			Nam Dinh (Alluvial soil)		
T2	1,648	285	-62	1,363	178
T3	1,531	347	0	1,184	-
T4	1,641	370	23	1,271	87
T5	1,679	370	23	1,309	125
T6	1,654	370	23	1,284	100
T7	1,705	393	46	1,312	128
T8	1,710	393	46	1,317	133
T9	1,770	415	68	1,355	170
T10	1,720	384	37	1,336	152
T11	1,695	353	6	1,342	158
T12	1,648	353	6	1,295	111

†1 kg of rice grain = 5,000 VND (Kang Dan variety in Bac Giang), 1 kg of rice grain = 4,500 VND (hybrid rice in Nam Dinh); 1 kg KNO_3 = 23,400 VND, 1 kg urea = 7,000 VND, 1 kg SSP = 3,500 VND, 1 kg KCl = 15,000 VND, 1 USD = 18,000 VND (November 2009).