Response to Potassium in the Rice-Wheat Cropping System of Red and Lateritic Soils

By Sourov Chatterjee, Sudarshan K. Dutta, Kaushik Majumdar, Probir Kr. Saha

West Bengal soils, thought to be rich in K, showed a significant increase in grain yield of rice and wheat with K addition over the existing fertilisation practice. Improved K fertilisation is required to reduce the current rice and wheat yield gap that exists between West Bengal and other parts of the Indo-Gangetic Plain.

In India, the rice-wheat crop rotation is the dominant cropping sequence in the Indo-Gangetic plain (IGP) and is important for the food security of the region (Ladha et al., 2003; Yadav et al., 2000). Approximately 9.8 million hectare (M ha) is under this cropping system and contributes about 23% of the total food grain production in the country. However, yield stagnation, and in some cases, decline in the productivity and sustainability of this system has become a major concern (Singh et al., 2013). Compared to the average rice and wheat yield from other parts of the IGP, the productivity is less in the case of West Bengal. For example, average productivity of rice and wheat could reach up to 6.8 t/ha and 5.4 t/ha, respectively, in the northwestern part of the IGP (Ladha et al., 2000; Timsina and Connor, 2001). However, the average rice and wheat yield at Birbhum district of West Bengal are 2.8 t/ha and 2.5 t/ha, respectively (http://drd.dacnet.nic.in). Therefore, there is a potential to increase the rice and wheat yield by 1.5 to two-fold in the rice- wheat cropping system of West Bengal.

A number of experiments conducted by the Agricultural universities and state-government research organisations in West Bengal have shown that there is a major depletion of K under different cropping sequences due to inadequate or no application of this nutrient. It has been shown earlier that the K balance ranged from -123 kg/ha in rice-rice cropping sequence to -310 kg/ha in rice-potato-sesame cropping sequence (Chatterjee and Sanyal, 2007) in West Bengal. This highlights the mining of the native soil K reserve at present farmers' fertilisation practices (FFP). In particular about 70% of the soil of Birbhum District is K deficient (Government of West Bengal in 2009).

The present study was undertaken to evaluate the variability in indigenous K supply capacity of soils in the wheat-rice system under red and lateritic soils in some selected farm sites of West Bengal. Specific objectives of the study were:

i) comparing grain yield achieved by FFP with recommendations provided by State government.
ii) assessing agronomic parameters of limiting nutrients using comparative omission plot study.
iii) determining plant uptake of K across different treatments for three consecutive years.

The experiment was set up at the Zonal Adaptive Research Station, Nalhati, West Bengal. The site is located in the lower Gangetic Plain at 24.29° N latitude and 87.84° E longitude. The area falls under the hot, dry sub-humid zone, 60 m above mean sea level. The soil of the experimental location is very deep, well-drained, clay loam, generally mixed Hyperthermic Typic Haplustalfs to Haplustepts, having moderate water holding capacity, acidic pH, and low fertility status. Wheat (var. K–9107) and rice (var. MTU–7029) were grown in a sequence starting from rabi 2009 with wheat cultivation followed by rice in kharif 2010; the experiment was continued for three consecutive years (2009-2012). The treatment plots included: a) 100% application of state-recommended (SR) fertiliser NPK rates (120-60-60 kg N-P_2O_5-K_2O/ha for wheat and 80-40-40 kg/ha for rice), b) omission of K from the SR (-K), and c) FFP (70-48-48 kg/ha for wheat and 90-39-39 kg/ha for rice) (**Table 1**). The treatments were replicated three times.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium.

Dr. Dutta (center) and Dr. Chatterjee (right) investigating a wheat field for any potential nutrient deficiencies.

Spatial Variation in Grain Yields

Rice and wheat grain yields were significantly ($p \leq 0.05$) higher in the SR plots compared to the FFP plots as well as the

Table 1. Details of the experimental trial conducted

Location: Z.A.R.S., Nalhati. Plot size: 5 m x 5 m		
	Wheat	Rice
Variety	K-9107	MTU-7029
Seed rate, kg/ha	100	50
Spacing, cm x cm	20 x continuous	20 x continuous
Time of sowing	Within December	Within June
Yield target	5 t/ha	7 t/ha
Plant Protection	Need based	Need based
Water management	Continuous submergence up to 5-8 cm depth for rice and for wheat irrigation was provided as per recommendations.	
Fertiliser recommendation, kg N-P_2O_5-K_2O/ha		
State Recommendation	120-60-60	80-40-40
Farmer's practice	70-48-48	90-39-39

Table 2. Different agronomic parameters of wheat crop in different treatment plots.

Treatments	No. of earhead/m²	No. of grains/ earhead	1000 grain weight, g	AE_K
		2009		
-K	240	33	28.6	12.8
SR	241	35	32.3	–
FFP	238	35	31.4	–
C.D. (p = 0.05)	7.4	3.1	NS	–
CV (%)	1.9	6.0	–	–
		2010		
-K	219	34	28.8	12.7
SR	225	36	31.6	–
FFP	223	34	31.3	–
C.D. (p = 0.05)	5.8	2.7	NS	–
CV (%)	1.7	4.9	–	–
		2011		
-K	210	32	29.8	18.2
SR	242	39	31.2	–
FFP	237	36	30.9	–
C.D. (p = 0.05)	6.4	2.1	NS	–
CV (%)	1.4	6.3	–	–

–K indicates potassium omission plot; SR indicates state-recommended fertiliser recommendation; FFP indicates farmer fertilisation practice; C.D. (p = 0.05) indicates critical difference at 5% level of significance, and CV (%) is the coefficient of variation.

K omission plots (-K) across three consecutive years (**Figure 1**). The increased rice grain yields in SR vis-à-vis FFP (with almost similar nutrient application rates) were probably due to the residual effect of higher nutrient application in previous wheat. Omission of K significantly reduced grain yield of rice and wheat by about 1.5 to 2 t/ha compared to the NPK and FFP plots. This is an interesting observation considering the common belief that West Bengal soils are rich in K and may not require external K application.

Temporal Variation in Grain Yields

The grain yield of wheat and rice decreased significantly ($p \leq 0.05$) in the omission plots from first year of study to the third year of study (**Figure 1**). This decrease could be attributed to the depletion in soil K supply capacity in the treatment plots. It is obvious that the indigenous K supplying capacity of the soil depleted under continuous rice-wheat cropping with no external supply of K. Moreover, similar rates of N, P_2O_5 and K_2O applications in the SR and FFP plots decreased rice grain yield over three years; however, the same temporal effect was not observed in wheat, probably because wheat plots received more nutrient application compared to rice (**Table 1**).

Agronomic Parameters

There were temporal differences in various agronomic parameters (e.g., number of earheads/m², number of grains/ earhead, 1000 grain weight (g) etc.) within SR, FFP and K omission plots that led to the differences in final grain yield (**Table 2**). In the case of rice, the agronomic parameters such as plant height, number of tillers per plant, number of panicles/

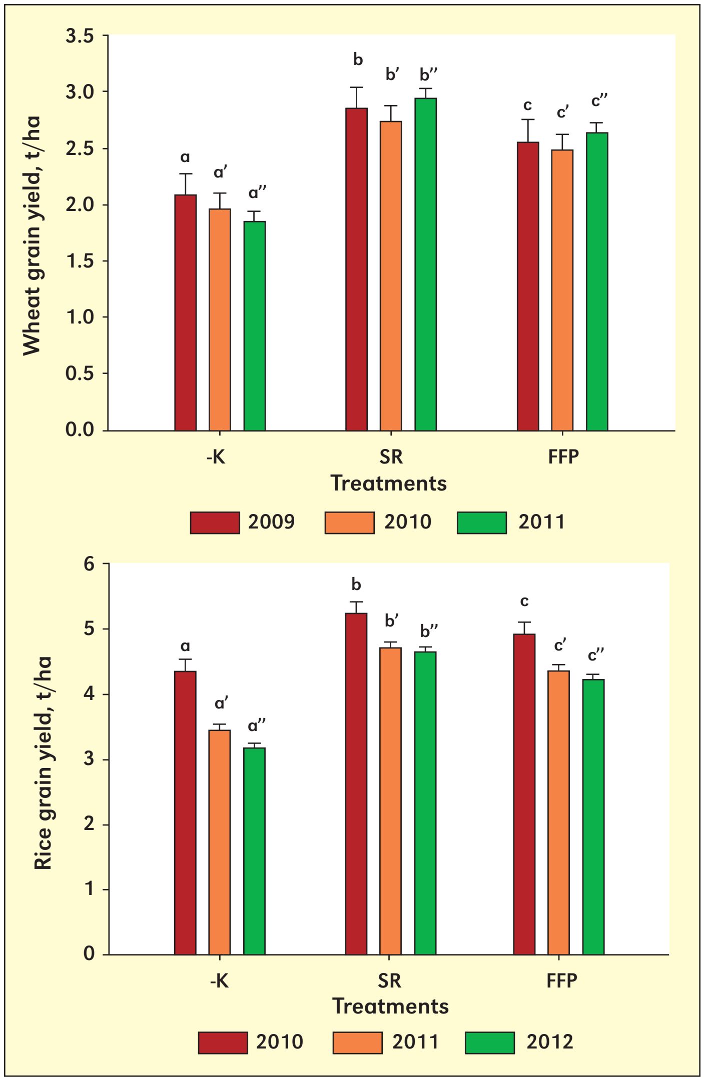

Figure 1. Average grain yields of wheat (top) and rice (bottom) in three years in the different treatment plots of the study. (–K indicates potassium omission plot, SR indicates state-recommended fertiliser recommendation, and FFP indicates farmer fertilisation practice.)

m², and grains per panicle were higher in the SR plots compared to that in FFP and K omission treatments (**Table 3**). The agronomic efficiency of K (AE_K) for both wheat and rice were calculated based on the following equation (Cassman et al., 1996):

AE_K = (Grain yield in 100% NPK Plot – Grain Yield in K Omission Plot) / Amount of K applied in 100% NPK plot.

AE_K increased over time (i.e., from the first year to the third year) for both wheat and rice (**Table 2** and **3**), suggesting increased yield differences between the SR and the -K treatment over time. This again highlights the concern for depletion of native K resources under intensive rice-wheat cropping system. The AE_K values for wheat in the current experiment were low, which could be due to a low yield of wheat. Wheat is usually sown late in the lower IGP due to late harvesting of rice. Such late sown wheat often face terminal heat stress due to high ambient temperature during flowering that causes yield loss. So besides efficient nutrient management, optimising planting time of component crops is also essential to achieve high

Table 3. Different agronomic parameters of rice crop in different treatment plots.

Treatments	Plant height, cm	Tiller no./ plant	Panicle no./m^2	Grain/ panicle	1000 grain weight, g	AE_K
2010						
-K	103	10	143	133	22.4	22.3
SR	108	13	158	149	22.8	–
FFP	105	11	155	141	22.6	–
C.D. (p = 0.05)	3.6	1.2	6.8	10.9	NS	–
CV (%)	1.9	6.7	3.9	4.7	–	–
2011						
-K	109	12	166	121	21.7	31.8
SR	113	14	183	154	23.2	–
FFP	111	13	180	146	22.6	–
C.D. (p = 0.05)	4.8	1.0	8.9	7.0	NS	–
CV (%)	2.5	4.9	4.4	5.2	–	–
2012						
-K	105	12	146	118	20.4	36.8
SR	109	14	178	148	22.8	–
FFP	107	13	173	142	21.5	–
C.D. (p = 0.05)	4.4	1.1	7.7	6.0	NS	–
CV (%)	2.3	4.6	4.2	4.4	–	–

–K indicates potassium omission plot; SR indicates state-recommended fertiliser recommendation; FFP indicates farmer fertilisation practice; C.D. (p = 0.05) indicates critical difference at 5% level of significance, and CV (%) is the coefficient of variation.

Table 4. Uptake of K (kg K_2O/ha) by wheat and rice crops in different treatment plots.

	Uptake by wheat grain			Uptake by rice grain		
Treatments	2009	2010	2011	2010	2011	2012
-K	13	8	8	7	4	3
SR	25	16	17	15	14	14
FFP	20	12	13	12	11	11
C.D. (p = 0.05)	1.7	0.8	1.6	1.0	1.1	1.3
CV (%)	6.4	4.9	9.2	5.0	7.0	8.6

–K indicates potassium omission plot; SR indicates state-recommended fertiliser recommendation; FFP indicates farmer fertilisation practice; C.D. (p = 0.05) indicates critical difference at 5% level of significance, and CV (%) is the coefficient of variation.

rice-wheat system yield in West Bengal.

Potassium uptake by rice and wheat grain was highest in the SR plots followed by FFP, and then the -K plots (**Table 4**). It was also observed that the K uptake in K omission plots decreased over time for both grain and straw of rice and wheat (**Table 4**).

Summary

Our study highlighted that K application in rice and wheat is essential in the red and lateritic soil of West Bengal and that judicious application of K could significantly ($p \leq 0.05$) increase grain yield of rice and wheat. Application of K at state recommended levels can significantly increase rice and wheat grain yields in farmers' fields. The study also highlights that current state recommended level of K application may not be adequate to maintain or improve rice-wheat system yield as rice yield in the SR treatment showed yield decline over three years of study. Lower than expected AE_K values in wheat highlights that better crop and nutrient management is necessary to improve yield and agronomic efficiency. BC-SA

Dr. Sourov Chatterjee is Assistant Agricultural Chemist, ZARS, Nalhati, Government of West Bengal; e-mail: chatterjee_sourov@yahoo.co.in. Dr. Dutta is Deputy Director, IPNI South Asia Program, Kolkata, India. Dr. Majumdar is Director, IPNI South Asia Program, Gurgaon, India. Mr. P.K. Saha is the Agronomist, ZARS, Nalhati, Birbhum.

References

Cassman, K.G., A. Dobermann, and D.T. Walters. 1996. Ambio Vol. 31, No. 2, 132-140.

Chatterjee, S., and S.K. Sanyal. 2007. Better Crops India. Pp: 22-25. Directorate of Rice Development. http://drd.dacnet.nic.in. Accessed on Oct. 20, 2013.

Directorate of Rice Development. 2013. http://drd.dacnet.nic.in. Accessed on Oct. 20, 2013.

Ladha, J.K., K.S. Fischer, M. Hossain, P.R. Hobbs, and B. Hardy. 2000. Discussion Paper No. 40. IRRI.

Ladha, J.K., H. Pathak, A.T. Padre, D. Dawe, and R.K. Gupta. 2003. *In* J.K. Ladha et al. (eds.). ASA Spec. Pub: 65. ASA, CSSA, SSSA, Madison, WI. p. 45-76.

Singh V.K., B.S. Dwivedi, R.J. Buresh, M.L. Jat, K. Majumdar, B. Gangwar, V. Govil and S.K. Singh, 2013. Agron. J. 105: 471-481.

Timsina, J. and D.J. Connor. 2001. Field Crops Research 69: 93-132.

Yadav, R.L. B.S. Dwivedi, and P.S. Pandey. 2000. Field Crops Research 65: 15-30.