Variability in Potassium Concentrations of Irrigation Waters in India

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Potassium concentrations in irrigation waters varied greatly across different locations in India (spatial), different times of the year (temporal), and different sources of irrigation used. Therefore, local assessment of K contribution from irrigation water, including K leaching losses, is required in determining field-specific fertiliser K application rate.

Irrigation water contains beneficial constituents including essential plant nutrients, which upon addition to soil improve soil fertility (Singh and Bishnoi, 2001). Presence of K in irrigation water constitutes an important source of indigenous supply of K to plants. In addition to its nutritive value, the presence of K in irrigation water also mitigates the adverse effect of Na in the soil. Paliwal and Yadav (1976) reported that less Na is adsorbed on soil particles if sufficient K is present, possibly because of the higher bonding energy of K to soil clay surfaces than Na. Potassium, when present in amounts up to one-tenth of the total concentration of Na in irrigation water, greatly reduces Na hazard (Heimann, 1966).

The K input from irrigation water depends primarily on (a) K concentration in the added water and (b) the quantity of water added during the entire crop production cycle, i.e., from the onset of land preparation to harvest (Bijay-Singh et al., 2004). However, K concentration in irrigation water varies with different sources of irrigation (canals, bore wells, farm ponds, community tanks, open wells etc.) and also with its time of application at different stages of crop growth. This leads to uncertainty in quantifying the K input to a specified crop (Yadvinder-Singh et al., 2005). Nature of the parent material, presence of soluble minerals releasing K into water aquifers, and surface runoff of the top fertile soil with irrigation water increase the variability in K content in irrigation water from ground water sources. Singh and Kumar (2009) surveyed 500 irrigation water samples from Ferozepur district of Punjab and reported that K concentrations varied from 1.95 to 96.3 mg/L, with an average concentration of 10.14 mg/L. This average concentration supplied 31.2 kg of K per one ha foot of irrigation water. In another recent study (Buresh et al., 2010), K concentrations in irrigation water within a rice-growing area of the Cauvery Delta in Tamil Nadu varied from 1.0 to 9.5 mg/L, and K input through irrigation water to rice fields ranged from 10 to 95 kg/ha in the study area with 50% of the fields receiving 13 to 30 kg K/ha. Rajput and Polara (2013) surveyed 220 underground water samples in Bhavnagar district of Gujarat, and found that K concentrations in the collected irrigation water samples varied from 0.0 to 54.6 mg/L with an average concentration of 4.29 mg/L. They also reported a significant difference in K concentrations between well and tubewell sources of irrigation.

This paper examines the variability in K contents across different sources of irrigation water sampled in India and the extent of K addition through irrigation water that is useful in determining field-specific fertiliser K rates for crops.

Geo-referenced irrigation water samples were collected from 32 districts of Uttar Pradesh representing the upper Gangetic plain (UGP) region (Singh et al., 2013) and four blocks (Nalhati I, Rampurhat I, Muraroi I and Muraroi II) of Birbhum district of West Bengal in the lower Gangetic plain (LGP) region. Potassium concentrations in irrigation water samples (124 from Uttar Pradesh and 142 from West Bengal) were determined by flame emission spectrophotometer following standard procedure (APHA, 1998). For comparative studies, we also incuded K concentrations in 30 irrigation water samples from the semi-arid tropical region of India including watersheds of ICRISAT and Kothapalli in Andhra Pradesh, Kolar and Haveri in Karnataka, Semli and Shyamapura in Madhya Pradesh and Thana and Govardhanapura in Rajasthan (Srinivasarao et al. 2012) and 70 irrigation water samples from bore wells in Nanded district of Maharashtra (Juned and Arjun, 2011). Surface maps of irrigation water K contents were prepared with Inverse Distance Weighted (IDW) method using ArcGIS 10.1 (ESRI, 2012).

Table 1. Distribution (%) of K concentrations in irrigation water samples across different regions of India.

K Concentration (mg/L)	Distribution (%)
Upper Gangetic Plain region (n = 124)	
< 2	2.4
2.0 - 4.0	11.3
4.0 - 5.0	16.9
5.0 - 6.0	21.8
6.0 - 7.0	14.5
7.0 - 13	21.0
> 13	12.1
Birbhum, West Bengal (n = 142)	
> 0.5	4.9
0.5 - 1.0	43.0
1.0 - 1.5	26.8
1.5 - 2.0	11.3
2.0 - 2.5	2.8
> 2.5	11.3
Dry land region (n = 30)	
< 1	16.7
1.0 - 2.0	33.3
2.0 - 5.0	33.3
> 5	16.7
Nanded, Maharashtra (n = 70)	
≤ 0.1	20.0
0.2	21.4
0.3	11.4
0.4	20.0
0.5	17.1
≥ 0.6	10.0

Results

Distribution of K concentrations in irrigation water samples was highly variable across different regions in India. Of the total 124 samples analysed in UGP, 13% samples had K concentrations below 4 mg/L, about 40% of samples had K concentrations between 4 to 6 mg/L, and 47% samples had K concentrations above 6 mg/L (**Table 1**). In the Birbhum district of West Bengal (LGP region), 48, 38, and 14% samples had K concentrations of ≤ 1 mg/L, 1 to 2 mg/L, and ≥ 2 mg/L, respectively. Similar variations in the distribution of K con-

Abbreviations and notes: K = potassium; Na = sodium.

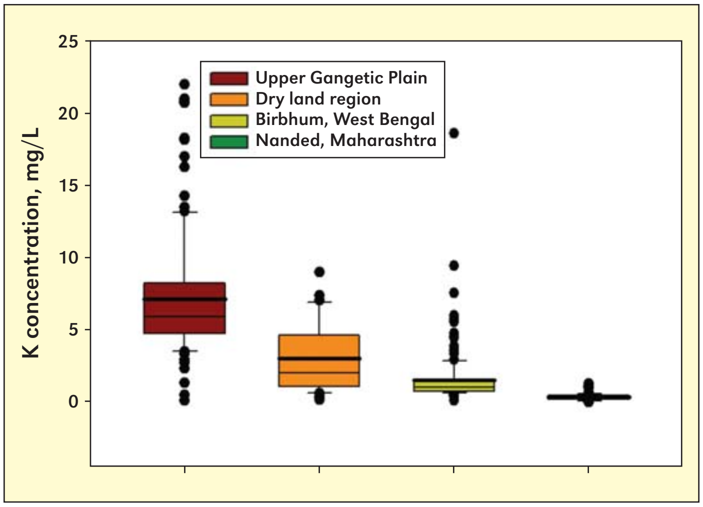

Figure 1. Irrigation water K concentrations (mg/L) in different regions of India. Boxes represent data within the first and third quartiles (interquartile range). The thin line denotes the second quartile or median, while the thick line represents the mean. Lines extending beyond the interquartile range denote the 10th to 90th percentile of the data. Statistical outliers are plotted as individual points outside these lines.

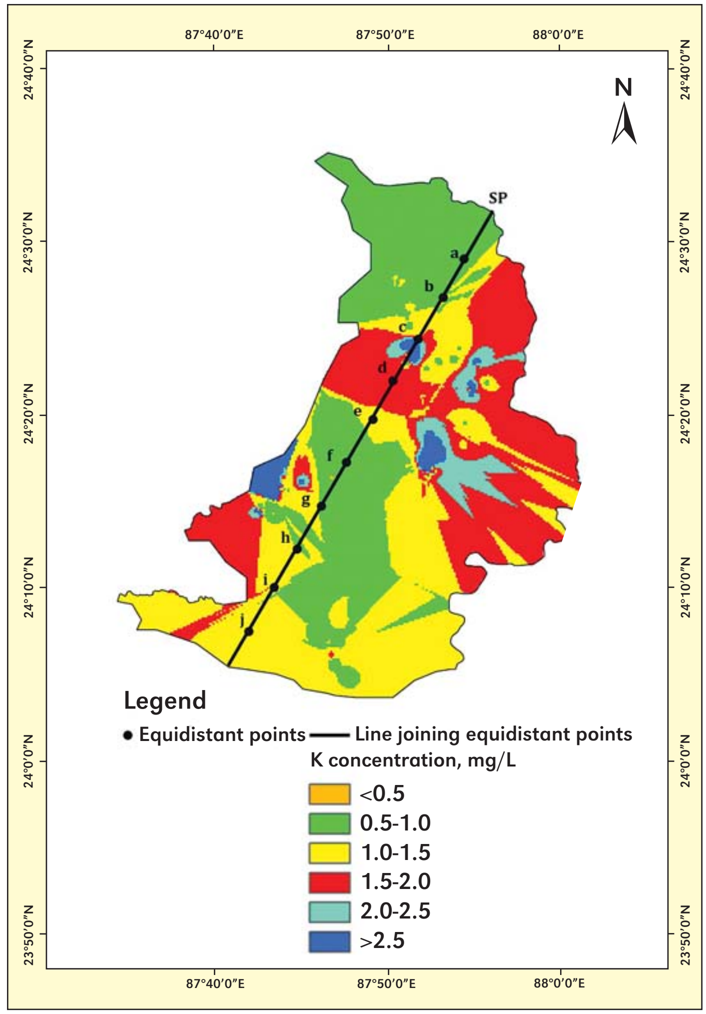

Figure 2. Spatial variability of irrigation water K contents in the lower Gangetic plain region.

centrations was also observed in semi-arid tropical region and Nanded region of Maharashtra. In the semi-arid tropical region, K concentrations in irrigation water ranged from 0.14 to 9 mg/L, with an average concentration of 3.04 mg/L, while the Nanded region of Maharashtra indicated lower K concentrations (0.01 to 1.3 mg/L), with an average concentration of 0.35 mg/L (**Figure 1**). Some possible reasons for lower K contents in irrigation waters of Nanded could be intensive agricultural activities and slow release of K in the groundwater from silicate minerals that are abundant in this region (Juned and Arjun, 2011). Comparatively higher K concentrations were observed in the irrigation water samples of the UGP region, 0.1 to 22 mg/L with an average K concentration of 7.1 mg/L (**Figure 1**). These higher values could be attributed to the presence of illitic minerals and extremely fertile, deep layers of alluvium spread in this region, which could have deposited K rich sediments in the irrigation water through the slow-moving rivers of the Ganges system. Earlier studies also reported large variability in irrigation water K input under rice-based systems in the IGP (Bijay-Singh et al., 2004; Buresh et al., 2010).

Irrigation water K contents also varied significantly with time. Srinivasarao et al. (2012) reported that K content in ground water differed significantly from monsoon to post monsoon seasons and was higher in monsoon season. Ashraf et al. (2006) also reported that in the gravity fed tube well water, highest K concentration was observed in the last two fortnights of winter season, whereas it was the lowest during the second fortnight of winter season.

Among the surveyed watersheds in semi-arid tropical India, K concentration of irrigation water varied with the sources of irrigation. The highest average K content of 4.99 mg/L was recorded in farm ponds followed by open wells (2.49 mg/L), bore wells (1.73 mg/L) and finally, in community tanks (1.57 mg/L) (Srinivasarao et al., 2012). These results are in slight contrast to the findings of Ashraf et al. (2006) as they reported highest K concentrations in the tube well irrigation water.

The input of K in the studied watersheds of semi-arid tropical regions (Srinivasarao et al., 2012) was of the order of Govardhanapura (3.6 kg/ha) and Thana (3.0 kg/ha) in Rajasthan followed by ICRISAT (2.8 kg/ha) in Andhra Pradesh. Using these K contents, Srinivasarao et al (2012) reported that irrigation water in the region would supply 25 to 30% of the K requirement of cotton, 15 to 20% of sorghum and wheat, 10 to 15% of maize, and 5 to 10% of pulses (pigeon pea, chickpea and soybean). Buresh et al. (2010) reported a contribution of 18 kg K/ha from the irrigation water, having a median K concentration of 1.8 mg/L, collected from rice-rice cropping systems across Asia. However, the data from Uttar Pradesh and West Bengal showed that there is large variability in K content in irrigation water, both within and between regions. And it may not be prudent to assume a blanket K contribution value from irrigation water, particularly at regional or continental scale. Assuming an addition of 1000 mm of irrigation water to rice grown in UGP with a median K content of 5.9 mg/L, this would add 59 kg K/ha. However, a similar amount of irrigation water added to rice crop in West Bengal with a median K concentration of 1.02 mg/L would contribute 10.2 kg K/ha, which is only 17% of the K input received in Uttar Pradesh.

Data from West Bengal (**Figure 2**) and Uttar Pradesh (**Figure 3**) were used to develop irrigation water K content

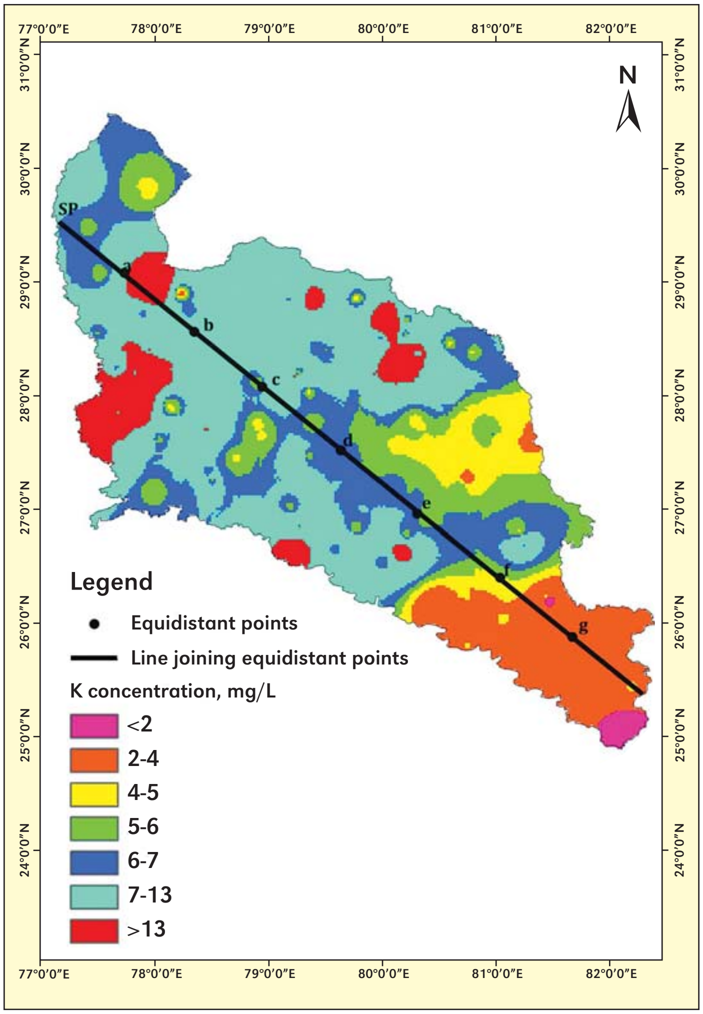

Figure 3. Spatial variability of irrigation water K contents in the upper Gangetic plain region.

surface maps of study areas. The surface maps showed that K concentration in irrigation water changed within short distances. Transects connecting equidistant points within the study areas were drawn across the maps. The transect length of the study area in West Bengal was about 55 km, while the length of transect in Uttar Pradesh was over 750 km. Potassium content of equidistant points on the transects were measured and reported in **Tables 2 and 3**, and this data also showed that K content of irrigation water varied within short distances. This suggests that assuming blanket K concentration in irrigation water, even within such small areas, may give incorrect information on K input from irrigation water.

Current data and the studies referred to here suggest that a portion of crop K requirement may be contributed by irrigation water, and this contribution varies spatially and temporally as well as with sources of irrigation. However, while discussing input of K from irrigation water, it must be understood that all the K input to the field *via* irrigation water may not be available to plants. A portion of the K and other basic cations added to the field through irrigation water may be lost *via* leaching from fields with adequate drainage. Leaching losses of K can be substantial in highly permeable soils with low cation-exchange capacities. Yadvinder-Singh et al. (2005) found that leaching losses of K were 22% and 16% of the applied K in sandy loam and loamy soils, respectively, maintained at submerged moisture regimes. Such losses in Bangladesh rice soils were as high as 0.1 to 0.2 kg K/ha/day (Timsina and Connor, 2001). Therefore, leaching losses of K from the effective root zone must also be taken into account while making field specific K recommendation for a crop.

Table 2. Potassium concentrations at equidistant points across a transect over the study area in West Bengal in the lower Gangetic plain zone.

Location on map	K concentration, mg/L
Starting Point (SP)	0.95
SP + 5.5 km (a)	0.98
a + 5.5 km (b)	0.98
b + 5.5 km (c)	1.82
c + 5.5 km (d)	1.83
d + 5.5 km (e)	1.18
e + 5.5 km (f)	0.675
f + 5.5 km (g)	0.97
g + 5.5 km (h)	1.16
h + 5.5 km (i)	1.07
i + 5.5 km (j)	1.05

Table 3. Potassium concentrations at equidistant points across a transect over the study area in Uttar Pradesh in the upper Gangetic plain zone.

Location on map	K concentration, mg/L
Starting Point (SP)	6.96
SP + 80 km (a)	10.68
a + 80 km (b)	8.87
b + 80 km (c)	6.57
c + 80 km (d)	6.50
d + 80 km (e)	6.24
e + 80 km (f)	4.8
f + 80 km (g)	3.22

Summary

Potassium concentrations in irrigation waters varied significantly among the surveyed regions. Such variations, both at spatial and temporal scales, lead to uncertainties in estimating the contribution of K from irrigation water for a specific crop in a given region. Studies have assumed blanket irrigation water K contents while estimating fertiliser K requirements of crops, which may lead to inadequate K application to crops. Potassium content of irrigation water from studied areas showed that the K contribution of irrigation water is far below the total crop K requirement and that external K application through fertiliser sources would be required to sustain and improve crop yields while also maintaining soil K fertility levels. BC-SA

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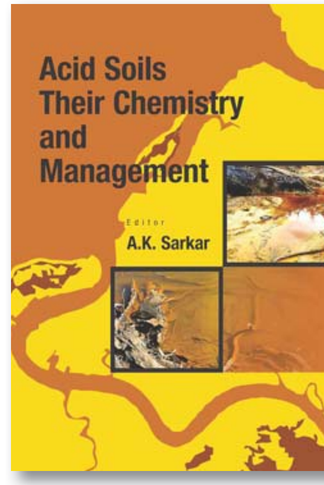
BOOK REVIEWS

Acid Soils: Their Chemistry and Management



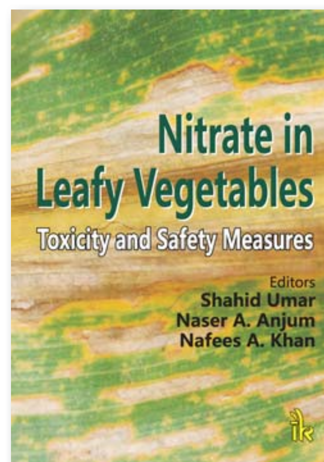
Edited by Dr. A.K. Sarkar, Former Dean & Professor & Head (Soil Science), Birsa Agricultural University, Ranchi and Published by New India Publishing Agency (NIPA), New Delhi.

About 25 million ha of cultivated soils in India are affected by soil acidity (pH < 5.5), mainly in the Himalayan region and areas with red and lateritic soils. Crops grown on acid soils, such as maize, jute, pulses, oilseeds, wheat, millets and vegetables, generally produce less than 50% of the yields obtained in neutral soils (pH 6.5 to 7.0). Eastern and Northeastern parts of India are of greater concern in this regard.

The book outlines theoretical as well as practical aspects of soil acidity and it's management. It not only deals with the genesis of acid soils through the variety of chemical reactions involved, but also provides scientific support for the technique of lime application in furrows of direct seeded crops and the economic benefits farmers can derive from the implementation of this technique in their fields. The book emphasises on using locally available, low cost and efficient liming materials for ameliorating soil acidity and provides on-farm results from several states of India on the efficacy of lime and nutrient application in acid soils in different crops. It also attempts to draw a strategic framework for sustainable development of acid soil regions.

The book consists of 10 chapters, viz., Introduction, Concepts and Applications, Chemistry of Acid Soils, Genesis and Classification of Acid Soils, Field Studies on Acid Soils, Acid Soils of Northeastern states, Jharkhand, Odisha, Secondary and Micronutrients in Acid Soils, Paper Mill Sludge as an Acid Soil Ameliorant, and Way Forward. This multi-authored book from experienced scientists is a valuable contribution in the field of Soil Science. BC-SA

Nitrate in Leafy Vegetables: Toxicity and Safety Measures



Edited by Shahid Umar, Naser A. Anjum and Nafees A. Khan and Published by I.K. International Publishing House Pvt. Ltd., New Delhi.

Vegetables, especially the green leafy vegetables, constitute a major dietary source of nitrate. Although nitrate itself is relatively non-toxic, and even beneficial within permissible limits for their role in vascular and immune functions, the possible harmful effects of nitrate-derived compounds on human health arouse public concern. The use of excessive nitrogenous fertilizers has been regarded as one of the major reasons leading to accumulation of nitrate in leafy vegetables, which is wrongly considered by farmers as reasonable insurance against yield loss. Therefore, vegetable nitrate content is of great interest to governments and regulators as well as to plant scientists and health professionals.

This book is a comprehensive compilation of the latest science on dietary nitrate sources and provides practical and scientific data-driven resources on the potential human health effects and sustainable remedial strategies for nitrate in plants and humans. The book attempts to provide a wealth of information and a common platform for plant scientists and health professionals working towards sustainable solutions to nitrate-led human and environmental health consequences. The 8 chapters in this book have been written by eminent researchers and scientists working in the field of nitrate in soils and plants. The book is sure to enlighten readers from various disciplines and at various levels, and should prove useful for advanced students, researchers, faculty of both plant and animal sciences, and environmentalists and policy makers. BC-SA