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Short Communication

Forms of Potassium in Mango, Citrus and Guava Orchard Soils under Rainfed Foothill Region of Jammu

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Soil potassium (K) supply to plants is a complex phenomenon involving inter-relationships among its chemical forms. The dynamic equilibrium among the forms directs the release of K from non-exchangeable to slowly available forms to available forms under K stress environment. Srinivasarao *et al*. (1999) reported that continuous cropping for 20 years reduced the release rates significantly as plants feed on non-exchangeable source of K. Potassium in soils is usually considered to exist in four different forms *viz.,* water soluble, exchangeable, non-exchangeable and structural forms. Potassium is readily soluble in nature and as such can move with relative ease to the exchange sites on clay colloids, release into the soil solution, diffuse out towards plant roots to be adsorbed and move up in the plant system, be converted into non-exchangeable or exchangeable forms, and leach out of the soil with drainage water. Potassium is an important input in horticultural crops contributing not only towards increased production, but also has a strong bearing on fruit quality (Pasricha 2004). It has been widely proven to have a crucial role in many crop quality parameters. The term quality refers to several aspects which affect the marketability of the product that includes attractiveness (uniform size, big size, good color); organoleptic (enhanced flavor, enhanced aroma); nutritional value (% protein, % oil, vitamin C, *etc*.); intact state (free of blemishes or unusual markings, free of any sign of disease); long shelf life; adequate processing quality for industry (Imas 1999). In spite of known benefits of K nutrition, the farmers in this region rarely go for application of K-fertilizers (Sharma *et al*. 2012b). Potassium fertilization is not practiced in these soils of rainfed subtropics as these soils are assumed to have sufficient K reserves for agriculture and hence do not need external K supply (Sharma *et al*. 2010, 2012a). However, to have merely sufficient reserves does not mean that these reserves will readily available to the crops (Sharma *et al*. 2010).

However, under continuous and exhaustive cropping, which is being followed in rainfed subtropics of northwestern India, huge K removals by crops have made the soils deficient in K. The practice of removing the entire aboveground biomass adds to the K-deficiency problems, as this system of crop production leads to a more rapid depletion of soil K, thereby increasing the K requirement of crops (Sharma *et al*. 2012a).

The orchards are generally grown on marginal lands as an alternate where normal crop are not taken up. The resource poor farmers of the region do not apply K-fertilizers and are dependent on native K (Sharma *et al*. 2009; Sharma *et al*. 2017). This is more so in case of guava orchards. The yield and quality is, therefore, expectedly poor and not competitive. Knowing soil K reserve and distribution of K forms can help in comprehending K replenishment capacity of soils under intensive cropping. Thus, the inherent K status of the orchard soils in terms of its different forms makes for a valuable study.

Soil samples were collected from more than 10-year-old orchards in the rainfed Jammu region up to depths of 0-30 cm at twenty seven locations (nine each from mango, citrus and guava orchards). Each soil sample was air-dried, ground in a wooden pestle with mortar and passed through a 2-mm stainless steel

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sieve for determining various soil properties. The pH and electrical conductivity (EC) of the soils was determined in 1:2.5 soil:water suspension with glass electrode pH meter and solubridge, respectively. Organic carbon (OC) was determined by dichromate oxidation of organic matter. Cation exchange capacity (CEC) and particle size analysis was carried out as per the standard methodology.

The soil samples were analyzed for water soluble K (1:5 ratio of soil and water by shaking for five min), available K (NH_4OAc-K), exchangeable K (subtracting water soluble K from available K), 1*N* HNO_3-K and non-exchangeable K (subtracting 1*N* HNO_3-K from available K) (Pratt 1982).

Properties of orchard soils

Mild variation was noticed in pH of the soils. The OC content ranged for mango soil from 3.9 to 9.2 g kg^{-1} whereas for citrus growing soils it was 3.6 to 13.1 g kg^{-1} and for guava soils it ranged from 3.2 to 13.5 g kg^{-1} (Table 1). Mean values of CEC were the highest for citrus [11.5 cmol(p^+)kg^{-1} soil] orchards followed by guava orchards [9.72 cmol(p^+)kg^{-1} soil] and the least for mango orchards [8.27 cmol(p^+)kg^{-1} soil]. Majority of the soils studied were sandy clay loam in texture followed by sandy loam textural class. The clay content varied from 14.9 to 28.4%.

Forms of potassium in orchard soils

Water-soluble K in mango, citrus and guava orchards averaged at 15.2, 13.1 and 16.7 mg kg^{-1} of soil, respectively (Table 2-4). Highest water-soluble K was observed in guava orchard at Birpur (G3) (55.5 mg kg^{-1} of soil) followed by mango orchard at Ranjan (23.5 mg kg^{-1} of soil). Excluding site G3 (Birpur) the mean value for guava orchards was reduced to 11.8

Table 1. Physicochemical properties of orchard soils in the Jammu region

Soil	pH	EC (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+)kg^{-1}]	Clay	Silt (%)	Sand
Mango							
Min	6.12	0.06	3.9	5.0	14.9	8.0	45.7
Max	7.10	0.25	9.2	15.1	25.0	30.0	77.1
Mean	6.42	0.12	6.1	8.2	20.8	18.1	61.1
Citrus							
Min	6.35	0.08	3.6	5.7	18.3	10.0	43.6
Max	7.40	0.23	13.1	18.5	28.4	28.0	69.7
Mean	6.90	0.13	6.4	11.5	22.2	17.6	60.3
Guava							
Min	6.40	0.06	3.2	7.1	17.6	10.0	52.4
Max	7.71	0.23	13.5	14.9	27.6	22.0	72.4
Mean	6.86	0.12	6.9	9.7	22.4	16.2	61.3

*scl: sandy clay loam; sl: sandy loam; l: loam

Table 2. Distribution of different forms of K in mango orchard soils

Soil	Location	WS-K	Ex-K	Av-K (mg kg^{-1})	NEK	HNO_3-K	K saturation (%)	Leaf K (%)
M1	Jassocahk	10.0	68.0	78.0	1247	1325	1.15	1.00
M2	Rajendrapura	17.5	39.0	56.5	974	1030	1.76	0.51
M3	Birpur	13.5	73.0	86.5	1049	1135	1.90	0.64
M4	Purmandal	5.0	20.5	25.5	355	380	1.03	0.61
M5	Nud	19.5	58.0	77.5	668	745	1.41	0.57
M6	Udheywala	15.5	16.5	32.0	698	730	0.84	0.41
M7	Nagbani	18.0	25.5	43.5	1007	1050	0.83	0.74
M8	Padmi	14.5	27.5	42.0	798	840	1.15	0.59
M9	Ranjan	23.5	85.0	108.5	1762	1870	2.39	0.56
Min		5.0	16.5	25.5	355	380	0.83	0.41
Max		23.5	85.0	108.5	1762	1870	2.39	1.00
Mean		15.2	45.8	61.1	951	1012	1.39	0.63

WS-K: water soluble K; Ex-K: exchangeable K; Av-K: available K; NEK: non-exchangeable K; HNO_3-K: nitric acid extractable K

Table 3. Distribution of different forms of K in citrus orchard soils

Soil	Location	WS-K	Ex-K	Av-K	NEK	HNO_3-K	K saturation	Leaf K
				(mg kg^{-1})			(%)	(%)
C1	Khara	15.0	62.0	77.0	618	695	1.32	1.07
C2	Mandal	13.5	40.5	54.0	506	560	0.70	1.88
C3	Kotalta	12.0	35.5	47.5	338	385	0.78	1.61
C4	Dhora	18.0	88.5	106.5	394	500	1.83	1.14
C5	Nud	11.5	38.5	50.0	300	350	1.47	0.26
C6	Kupri	13.5	47.0	60.5	490	550	0.97	0.58
C7	Parthari	8.2	41.8	50.0	500	550	1.16	0.21
C8	Karalta	6.3	53.4	59.6	465	525	0.74	0.56
C9	Serote	20.0	58.5	78.5	662	740	2.61	0.95
Min		6.3	35.5	47.5	300	350	0.70	0.21
Max		20.0	88.5	106.5	662	740	2.61	1.88
Mean		13.1	51.7	64.8	475	539	1.29	0.92

Table 4. Distribution of different forms of K in guava orchard soils

Soil	Location	WS-K	Ex-K	Av-K	NEK	HNO_3-K	K saturation	Leaf K
				(mg kg^{-1})			(%)	(%)
G1	Chatha	11.0	22.0	33.0	457	490	0.75	0.63
G2	Rajindernagar	21.5	73.5	95.0	990	1085	2.03	0.76
G3	Birpur	55.5	191.5	247.0	1003	1250	3.28	1.20
G4	Purmandal	5.7	18.1	23.8	181	205	0.47	0.28
G5	Dhanth	8.8	22.8	31.5	264	295	0.82	0.60
G6	Udheywala	10.0	33.3	43.3	647	690	0.84	0.60
G7	Nagbani	18.0	39.0	57.0	378	435	0.91	1.20
G8	Doomi	10.5	22.5	33.0	612	645	0.67	0.62
G9	Serote	9.5	22.7	32.2	808	840	0.65	0.58
Min		5.7	18.1	23.8	181	205	0.47	0.28
Max		55.5	191.5	247.0	1003	1250	3.28	1.20
Mean		16.7	49.5	66.2	593	659	1.16	0.72

mg kg^{-1} soil, respectively, indicating that guava orchards were having the least overall water-soluble K content. At least 33% of the guava growing soils recorded less than 10.0 mg kg^{-1} soil.

Barring sample G3 (191.5 mg kg^{-1} soil), the exchangeable K content of all other soil samples was below 100 mg kg^{-1} soil, with the range being 16.5 to 88.5 mg kg^{-1} soil (Table 2-4). Site G3 have been recently fertilized. Overall, guava growing soils were the most deficient in K. Exchangeable K content of less than 25 mg kg^{-1} of soil was observed in guava orchards at Chatha, Purmandal, Dhanth, Doomi and Serote.

Similar was the case with the available K content. The overall range for available K was 23.5 to 108.5 mg kg^{-1} of soil, excluding sample G3. The mean values for available K content in mango, citrus and guava orchards were 61.1, 64.8 and 66.2 mg kg^{-1} of soil. About 50% of the samples tested were found low in available K status. Only one samples *i.e.* G3 (247.0 mg kg^{-1} soil) recorded available K content in the high range, probably due to recent fertilization. None of the other soils studied had a recent K fertilization history. Available K content ranged from 41.5 to 314.0 mg kg^{-1} in the surface and 32.0 to 243.0 mg kg^{-1} in the sub-surface soils with an average value of 76.0 mg kg^{-1} in benchmark soils of Punjab (Arora and Chahal 2003).

Among all the samples, the highest amount of non-exchangeable K was observed at Ranjan (1762 mg kg^{-1}) followed by Jassochak (1247 mg kg^{-1} soil), both of them being under mango orchards. The least amount of non-exchangeable K was observed in samples G4 (181 mg kg^{-1} soil) and G5 (264 mg kg^{-1} soil). Both these soils were under guava orchards. Nearly 50% of the samples were in low to medium category as per limits given by Subba Rao *et al.* (1993) for non-exchangeable K in Indian soils. Majority of theses soils were from citrus and guava orchards. Continuous K uptake by the fruit trees without external fertilization seems to be depleting K from these soils. At least 55.5% of the mango growing

Table 5. Correlation of coefficient (r) between different forms of K and physicochemical properties of orchard soils

	WS-K	Ex-K	Av-K	NEK	HNO_3-K	K saturation	Leaf K
pH	0.292	0.316	0.318	-0.277	-0.223	-0.022	0.526**
EC	0.343	0.520**	0.494**	0.065	0.120	0.236	0.371
OC	0.581	0.657**	0.657**	0.326	0.385*	0.458*	0.131
CEC	0.183	0.485*	0.431*	0.023	0.073	0.007	0.485*
Clay	0.124	0.200	0.189	0.089	0.106	-0.081	0.045
Silt	0.140	0.027	0.052	0.344	0.330	-0.081	0.092
Sand	-0.149	-0.100	-0.113	-0.279	-0.276	0.090	-0.083
WS-K		0.858**	0.910**	0.437*	0.519*	0.790**	0.312
Ex-K			0.994**	0.434*	0.526**	0.831**	0.318
Av-K				0.445*	0.537**	0.843**	0.324
NEK					0.994**	0.524**	-0.028
HNO_3-K						0.593**	0.011
K saturation							0.112

*Indicates significant relationship at 5% level of significance; ** Indicates significant relationship at 1% level of significance

soils had more than 1000 mg kg^{-1} of 1*N* HNO_3-K, whereas as the percentage of samples for guava orchards was only 22.2%. None of the soils of citrus orchard were having more than 1000 mg kg^{-1} of 1*N* HNO_3-K. Soils under guava orchard at Purmandal (205 mg kg^{-1} soil) and Dhanth (295 mg kg^{-1} soil) recorded the least amount of 1*N* HNO_3-K indicating severe K depletion.

More than 77% of the guava soils were having K saturation percentage of <1.0, whereas only two (M6 and M7) of the mango growing soils and four (C2, C3, C6 and C8) of the citrus growing sites recorded <1% K saturation. Higher mean CEC of guava growing soils coupled with K depletion could have resulted in low K saturation percentage in these soils.

Relationship between potassium forms and soil properties

A highly significant and positive correlation was observed between OC and both exchangeable (r = 657**) and available K (r = 657**). Dhillon and Dhatt (1988) also observed a positive correlation between OC and available K in soils. The significant correlation with OC indicates the possible role of some of the components of organic matter in fixation and release of native K, showing the beneficial effect of organic matter on K availability (Prakash and Siddaramappa 2001). A significant and positive relationship was observed between exchangeable K and CEC (r = 0.485*). The relationship between exchangeable K and CEC have been well established (Pal and Mukhopadhyay 1992; Tiwari and Nigam 1994; Arora and Chahal 2003). In benchmark soils of Punjab, Arora and Chahal (2003) also reported that available K content was positively and significantly correlated with silt (r = 0.34*), clay (r = 0.42*) and CEC (r = 0.42*) while negatively and significantly correlated with sand content (r = -0.44*). This shows that the finer fraction governed availability of K in these illite mineral dominant soils. More CEC means more exchange sites and subsequently more exchangeable K.

All the forms of K were positively and significantly correlated with each other indicating that there existed a dynamic equilibrium between them implying thereby that if available K was depleted there was a likelihood of K release from difficultly available fractions. Similar relationships have been reported by other workers (Singh *et al.* 1985; Sharma and Sharma 2002). Leaf K content was positively related with water soluble, exchangeable and available K, although the relationship obtained in this study was slightly short of being significant. Leaf K was, however, significantly and positively correlated with the clay content of the soil, indicating to a certain extent its dependence on the nutrient holding capacity of clay.

Conclusions

The study reveals that there is wide spread deficiency of K in orchard soils of the region. Among different orchards, the guava orchard soils were most deficient, with very low values of non-exchangeable K indicating potential K mining. The farmers in the region usually take-up orchards on marginal lands, especially those of guava, where other field crops cannot be taken up. Proper management and K fertilization, except for some manuring, of these crops is generally ignored. Potassium from the soils, however, is continuously utilized resulting in K depletion of these soils.

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