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Assessment of distribution of different forms of potassium in soil of Hittnalli micro-watershed of Vijayapura district of Karnataka

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Abstract
Potassium is the major plant nutrient essential for various metabolic activities in living cell, it is the dominant cation in the plant cell it acts as a catalyst for enzymatic reaction of living cells so the study was conducted to assess the physico-chemical properties, different forms of potassium in the soil. The sixty surface samples (0-20 cm) at 320 × 320 m grid intervals were collected in Hittnalli micro-watershed of Vijayapura district in Karnataka were studied in UASD. The soil reaction in the soil were ranged from 7.89 to 8.95 with mean value of 8.42, EC values of samples ranged from 0.16 to 0.42 dS m^{-1} with the mean value of 0.25 dS m^{-1}. The different forms of potassium in the soil were *viz.,* water soluble K, exchangeable K, non-exchangeable K, mineral (lattice) –K and Total K were ranged from 2.36 to 12.84 mg kg^{-1}, 206.77 to 321.71 mg kg^{-1}, 534.91 to 887.60 mg kg^{-1}, 1.24 to 2.52 per cent and 1.34 to 2.64 per cent respectively. The fractions of potassium were found in the order of Total K > Lattice K > Non exchangeable K > Exchangeable K > Water soluble K.

Keywords: Potassium dynamics, micro-watershed, lattice potassium and forms of potassium

Introduction

Potassium (K) is the one of the major plant nutrient for crop growth; it is the dominant cation in plant cell and is the second most abundant nutrient after nitrogen in leaves. Potassium is more abundant than phosphorus (Sardans *et al.,* 2008) [15]. The potassium content in soils mainly depends on parent material from which soil is derived, its degree of weathering, particle size distribution. Soils having minerals such as feldspars and mica are rich in potassium. In general 98 per cent of total K is bound in the mineral form, whereas 1-2 per cent in soil solution and exchangeable form (Berstch and Thomas, 1985) [1]. However the fraction of soil potassium directly available to plants is usually a small proportion (0.1–0.2 %) of the total potassium. Potassium in soil dominantly present in three pools of availability for uptake by roots; it is dissolved in soil water, adsorbed to clay particles and organic matter and held within the crystalline structure of secondary silicate clay minerals. The organic matter in soils contain negligible amount of potassium because it is not a constituent of biomolecule (Britzke *et al.,* 2012) [3].

Soil potassium is present in different forms *viz.,* water soluble K, exchangeable K, non-exchangeable K and mineral (lattice) -K. Dynamic equilibrium exists among these different forms upon their use by the crops and potassium fertilizer application. The importance of potassium in Indian agriculture is increasing with the passage of time because its content in soil is getting depleted with the use of high yielding varieties, high cropping intensity, higher dose of nitrogen and phosphate fertilizers application and increased crop responses to potassium application.

For critical appraisal of potassium supplying power of soil, it is essential to have knowledge of all the four forms of potassium, potassium supplying capacity of soil; it varies with different soil types. The decrease in soil solution potassium would be made up by the exchangeable potassium, which is further maintained by the release of non-exchangeable potassium.

Material and Methods

Study area description

The Hittnalli micro-watershed is located in Vijayapura taluk of Vijayapura district which comes under Northern Dry Zone (Zone 3) of Karnataka. The soils of this micro-watershed belong to order *Vertisol.* The study area receives an average rainfall of about 765.5 mm. Water is the major constraint in this area due to low rainfall, the major crops of this area are red gram, sorghum and chickpea. The selected Hittnalli micro-watershed is located 10 km away from Vijayapura, district which locate 15° 48' 9.014" N to 15° 49' 26.003" N latitude, 75° 35' 23.398" E to 75° 36' 28.813" E longitude and mean elevation ranged from 441.5 to 541.5 m above MSL. The location of micro-watershed is shown in Fig. 1 and 2.

The Hittnalli micro-watershed has nearly level to gentle sloping topography *i.e.* nearly flat terrain. Soils are slight to moderately erodible under the influence of intensive rainfall. The basalt is the major parent rock which develops deep black soils. The 2:1 types of clay minerals were observed in this area and soil belongs to *Vertisol* order.

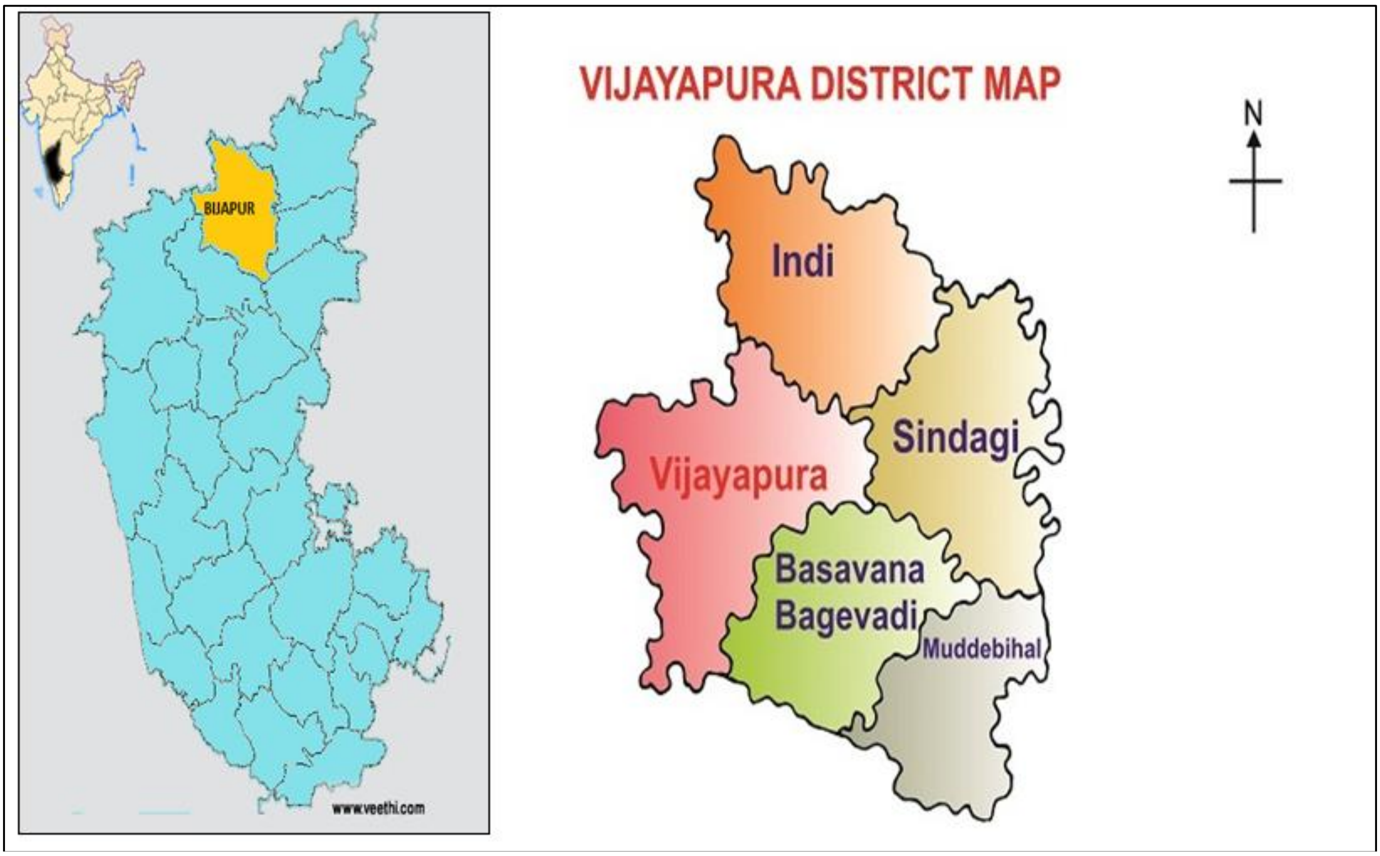

Fig 1: Vijayapura district map

Fig 2: Codastral map of Hittnalli village

Collection and preparation of soil sample

Grid soil sampling at 320 × 320 m intervals was made using base maps from 0-20 cm depth and GPS readings were recorded. The surface samples were collected and labeled according to grid number and survey number and packed in polythene bag. The collected soil samples were air dried under shade, grinded by using wooden pestle and mortar and passed through 2 mm sieve. The sieved samples were stored in polythene bag for further analysis.

Chemical Properties of soil

Soil reaction was determined in 1:2.5 soil water suspensions after stirring for 30 minutes by using glass rod and then pH is measured using pH meter (Jackson, 1973) [7]. EC was determined in 1:2.5 soil: water suspension after obtaining supernatant as described by Jackson (1973) [7] using conductivity meter. Organic carbon was determined by Walkley and Black's wet oxidation method as described by Piper (2002) [13]. Available potassium was determined by extracting soil with *N N* Ammonium acetate and the contents of K in solution were estimated by flame photometer (Jackson, 1973) [7].

Determination of various forms of soil potassium
Water-soluble potassium
Water-soluble potassium was extracted by shaking 1:5 soil: water suspension for two hours and allowing to stand for an additional 16 hours (Black, 1965) [2] and filtered by using Whatman No. 42 filter paper. The potassium in the extract was determined by flame photometer.

Exchangeable potassium
Exchangeable potassium was determined by shaking ten gram of soil with 50 ml *N N* Ammonium acetate solution for a period of 10 minutes. The supernatant liquid was filtered by using Whatman No. 42 filter paper. The filtered extract was fed to flame photometer as outlined by Knudsen *et al*. (1982) [9].

The exchangeable potassium content of the soil was calculated by subtracting the water soluble K from Ammonium acetate extractable K (Available K) to get the exchangeable potassium content of the soil. (Exchangeable K = Available K – Water soluble K).

Non exchangeable potassium
The two and half grams of soil were boiled gently with 25 ml of 1*N* Nitric acid (HNO_3) for a period of 10 minutes. The content was cooled and filtered. The filtrate was collected in a 100 ml volumetric flask. The soil residue on the filter paper was washed four times with 15 ml of 0.1 *N* HNO_3. After making up the volume to 100 ml, the potassium in the extract was determined by flame photometer and expressed as HNO_3 extractable K. The quantity of K obtained with the NH_4OAc extract was subtracted to get the non-exchangeable potassium content in the soil (Knudsen *et al*., 1982) [9].

The non exchangeable potassium content of the soil was calculated by subtracting the ammonium acetate extractable K from HNO_3 extractable K. (Non-exchangeable K = 1*N* HNO_3 Extractable K – 1*N* NH_4OAc extract K).

Total potassium
Total potassium content was determined by digesting the samples with hydrofluoric acid in a closed vessel (Lim and Jackson, 1982) [10]. Two grams of finely ground soil sample was transferred to 250 ml wide mouth polypropylene bottle and two ml of aqua regia was added to disperse the samples. Later 10 ml hydrofluoric acid was added by means of plastic pipette and after capping the bottle, the contents were shaken to dissolve the sample for a period of 8 hours. The white residue remaining after the treatment was dissolved in 100 ml of saturated boric acid solution. The contents were diluted and final volume was made up to 250 ml and subsequently used for analysis of total potassium by flame photometer.

Lattice potassium
The lattice potassium in the soil was calculated by taking difference between total potassium and the sum of water soluble, exchangeable and non-exchangeable K fractions.

Lattice K= Total K - ∑ (Water soluble + Exchangeable - K + Non exchangeable - K).

Results and discussion
Soil reactions were moderately alkaline to strongly alkaline and it ranged from 7.89 to 8.95, the mean and standard deviation were 8.42 and 0.21, respectively. The high pH was due to moderate to high level of $CaCO_3$, high CEC and base saturation. The similar results were obtained by Patil *et al.* (2017) [12] in Bedwatti sub-watershed under Northern transition zone of Karnataka. The EC values of the surface soil samples ranged from 0.16 to 0.42 dS m^{-1}, the mean and standard deviation were 0.25 and 0.06 dS m^{-1} respectively, the entire area under the study was non-saline nature. The EC values were low due to leached soluble salts during rainy season. The similar observations were made by Naik and Anil Kumar (2015) [11] in Kannur micro-watershed of Kollegal taluk of Chamarajnagar. The soil organic carbon content in surface soil samples ranged from 3.16 to 6.52 g kg^{-1}, the mean and standard deviation were 5.12 and 0.90 g kg^{-1}, respectively. The area was low to medium in organic carbon in the soil is due to low input of FYM and crop residues as well as rapid rate of decomposition due to high temperature. The organic matter degradation and removal taken place at faster rate coupled with low vegetation cover thereby leaving less chance of accumulation of organic matter in the soil. The similar observations were made by Prabhavati *et al.* (2015) [14] for the soils of Northern dry zone of Karnataka.

Forms of potassium in surface soils
Water soluble potassium
The water soluble potassium varied from 2.36 to 12.84 mg kg^{-1}, the mean and standard deviation were 5.59 and 2.35 mg kg^{-1} respectively. The variation in the values of water soluble potassium might be due to addition of water soluble potash fertilizers at surface zone, intensive weathering of potassium bearing minerals. The lower status of water soluble potassium in soils might be attributed to the water soluble-K being soluble, highly mobile, readily available to plants and also susceptible to leaching losses (Govindarajan and Venkatarao, 1976) [5].

Exchangeable potassium
The exchangeable potassium in surface soils of Hittnalli micro-watershed varied from 206.77 to 321.71 mg kg^{-1}, the mean and standard deviation were 278.01 and 27.91 mg kg^{-1} respectively. The value of exchangeable potassium in the soils was high due to presence of 2:1 type of expanding clay minerals. The variation in the content of exchangeable potassium may be due to the variation in the clay and organic matter content of the soils as indicated by positive correlation between exchangeable potassium and clay and organic matter of soil (Jagadeesh, 2003) [8]. Surface layer was high exchangeable sites offered for potassium fertilization and also addition of organic manures which might have enhanced the exchangeable K in solution phase (Divya *et al*., 2016) [4]. The higher amount of exchangeable potassium in soils may be due to the preferential adsorption of potassium compared to other bases by soil colloids (Venkataratan, 1971) [19].

Non-exchangeable potassium
The non-exchangeable potassium was varied from 534.91 to 887.60 mg kg^{-1} the mean and standard deviation were 743.22 and 75.18 mg kg^{-1} respectively. The status non-exchangeable potassium was found to be high, the variation among the soils may be due to intensive weathering, difference in the clay content and organic carbon status of these soils. Subbarao and Sekhon, (1900) [17] reported that soil texture had a great influence on available-K and non-exchangeable-K.

Lattice potassium
Among the different forms of potassium found in the soil lattice potassium were recorded the dominant fraction of soil it varied from 1.24 to 2.52 per cent with a mean value of 1.91 per cent and standard deviation of 0.33 per cent this indicated

that majority of the total potassium was present as structural constituents of mineral. The soils have high lattice K which may be due to soil derived from very rich reserves of potassium bearing minerals (Hebsur and Gali, 2011) [6]. The variation in lattice-K content among the soils was attributed to the type of clay mineral and extent of weathering of potassium bearing minerals in soils (Sparks and Haung, 1985) [16].

Total potassium

The total potassium varied from 1.34 to 2.64 per cent with a mean value of 2.01 per cent and the standard deviation of 0.33 the degree of weathering is important for total potassium content of the soils. Depending on clay minerals like feldspar, micas and illite, lattice K content, organic matter content the total potassium varies. The results are in comparison with those of research findings of Hebsur and Gali (2011) [6] and Divya *et al*. (2016) [4].

Abundance of K bearing minerals in these soils might have contributed to increase in total-K content of soil. Similar results also observed by Thippeswamy (1995) [18]. The higher value of total-K in these soils could also be due to less removal of K by crop and lack of leaching loss.

The fractions of potassium were found in the order of decreasing status, Total K > Lattice K > Non exchangeable K > Exchangeable K > Water soluble K.

Table 1: Chemical properties of surface soil samples of Hittnalli micro-watershed

Sl. No.	pH (1:2.5)	EC (dS m^{-1}) (1:2.5)	OC (g kg^{-1})	Sl. No.	pH	EC (dS m^{-1})	OC (g kg^{-1})
1	8.36	0.23	5.21	33	8.34	0.18	5.84
2	8.37	0.21	4.63	34	8.46	0.2	5.29
3	8.26	0.19	3.49	35	8.73	0.26	5.16
4	8.31	0.34	3.24	36	8.26	0.32	6.43
5	8.29	0.25	4.62	37	8.36	0.24	5.92
6	8.18	0.22	5.32	38	8.49	0.26	3.98
7	8.26	0.23	5.21	39	8.54	0.26	3.72
8	8.27	0.17	5.28	40	8.71	0.18	4.92
9	8.48	0.18	4.51	41	8.66	0.23	3.47
10	8.49	0.16	3.87	42	8.62	0.21	4.83
11	7.89	0.36	3.16	43	8.65	0.21	4.95
12	8.38	0.19	5.93	44	8.29	0.23	4.84
13	8.16	0.36	5.35	45	8.53	0.29	5.32
14	8.43	0.42	5.43	46	8.64	0.25	4.25
15	8.56	0.25	4.83	47	8.34	0.23	4.29
16	8.13	0.22	4.18	48	8.72	0.26	4.43
17	8.36	0.2	5.91	49	8.49	0.24	6.29
18	8.42	0.19	6.34	50	8.84	0.16	5.57
19	8.37	0.24	5.37	51	8.34	0.39	4.49
20	8.28	0.23	6.22	52	8.67	0.26	3.71
21	8.24	0.18	4.26	53	8.95	0.32	6.45
22	8.29	0.32	6.11	54	8.06	0.26	5.38
23	8.24	0.25	6.29	55	8.46	0.35	6.24
24	8.37	0.23	6.34	56	8.26	0.25	6.51
25	8.08	0.22	5.48	57	8.85	0.32	5.39
26	8.45	0.21	5.24	58	8.37	0.26	4.98
27	8.31	0.19	5.82	59	8.39	0.23	5.63
28	8.41	0.2	6.22	60	8.73	0.26	4.88
29	8.42	0.23	6.52	Range	7.89-8.95	0.16-0.42	3.16-6.52
30	8.36	0.28	5.10	Average	8.42	0.25	5.12
31	8.67	0.29	4.25	SD	0.21	0.06	0.90
32	8.57	0.27	4.32				

Table 2: Potassium fractions in the surface soils of Hittnalli micro-watershed

Sl. No.	Water soluble K	Exchangeable K	Non-exchangeable K	Lattice K	Total K
	(mg kg^{-1})			(%)	
1	6.48	266.43	697.87	1.25	1.35
2	4.98	249.34	735.49	1.32	1.42
3	3.82	256.50	726.23	1.29	1.39
4	7.02	292.51	845.36	2.10	2.21
5	3.18	308.00	650.42	1.77	1.87
6	2.36	265.00	750.61	2.11	2.21
7	3.12	261.62	650.74	1.58	1.67
8	9.36	296.01	759.88	1.87	1.98
9	5.40	274.91	710.64	2.07	2.17
10	8.04	289.35	749.37	2.06	2.16
11	4.38	307.09	864.66	2.27	2.39
12	4.30	270.05	816.70	2.20	2.31
13	6.70	309.14	755.93	2.07	2.18
14	8.52	239.28	716.49	2.21	2.31
15	2.76	276.85	680.50	1.87	1.97

16	6.94	236.86	684.55	1.90	1.99
17	3.24	277.75	751.67	2.26	2.36
18	4.54	257.66	630.54	1.74	1.83
19	4.06	314.80	698.40	2.27	2.37
20	11.70	226.60	594.57	1.71	1.79
21	2.50	270.67	642.00	2.13	2.22
22	9.00	251.72	672.46	1.84	1.93
23	3.34	306.19	699.10	1.99	2.09
24	3.34	243.69	657.80	1.77	1.86
25	5.14	314.12	849.83	2.29	2.41
26	6.48	302.14	884.30	2.27	2.39
27	2.68	261.80	534.91	1.57	1.65
28	8.02	309.85	760.34	2.22	2.33
29	4.28	277.15	740.22	2.02	2.12
30	4.14	301.99	751.82	2.08	2.19
31	7.14	315.71	722.65	2.18	2.28
32	12.84	289.05	805.64	1.83	1.94
33	6.52	302.06	869.47	2.05	2.17
34	5.42	313.94	720.24	2.44	2.54
35	6.50	283.13	750.98	2.31	2.41
36	4.22	310.01	733.76	1.32	1.42
37	5.60	280.47	650.24	1.25	1.34
38	7.38	309.64	836.45	1.86	1.98
39	3.24	290.40	798.42	1.41	1.52
40	2.38	321.71	671.63	1.24	1.34
41	3.20	264.18	728.37	1.39	1.49
42	5.80	276.72	754.98	1.67	1.77
43	5.98	294.59	857.63	1.87	1.99
44	4.68	259.99	729.63	1.73	1.83
45	5.64	266.25	732.81	2.11	2.21
46	4.12	246.22	824.72	2.32	2.43
47	2.96	288.72	798.12	2.00	2.11
48	7.94	310.01	789.67	1.98	2.09
49	6.72	241.02	687.34	1.77	1.86
50	5.48	238.67	734.26	1.71	1.81
51	3.74	265.59	726.75	1.57	1.67
52	5.14	306.68	887.60	2.52	2.64
53	2.98	312.49	729.85	1.87	1.97
54	7.48	206.77	650.63	1.79	1.88
55	8.30	253.12	770.56	2.05	2.15
56	3.98	281.42	700.90	1.74	1.84
57	11.04	209.13	794.54	2.14	2.24
58	5.72	293.25	869.72	2.31	2.43
59	6.40	267.71	847.61	2.28	2.39
60	7.04	267.17	754.45	1.76	1.86
Range	2.36-12.84	206.77-321.71	534.91-887.60	1.24-2.52	1.34-2.64
Average	5.59	278.01	743.22	1.91	2.01
SD	2.35	27.91	75.18	0.33	0.33

Conclusion

The study of potassium dynamics in Hittnalli micro-watershed of Vijayapura district revealed that maximum amount of potassium present in soil is in bound form then compare to water soluble form. The variation in the level of potassium is due to parent material from which soil derived, type of clay minerals and weathering of clay minerals, cultural practices and other physico-chemical properties. Among the different forms of potassium water soluble potassium is lowest and lattice potassium is the dominant form. The knowledge of different forms of potassium in soil together with their distribution has greater relevance in assessing the long-term K supplying power of soil to crops.

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