The Pharma Innovation Journal 2022; 11(12): 6271-6276

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(12): 6271-6276

www.thepharmajournal.com
Received: 02-09-2022
Accepted: 06-10-2022

Ramesh
Department of Soil Science, UAS, Dharwad, Karnataka, India

Vijay Kumar C
Scientist (Soil Science) ICAR-Krishi Vigyan Kendra, UAS, Dharwad, Karnataka, India

KK Math
Professor, Department of Soil Science, Dharwad, Karnataka, India

Shubha S
KVK Head, College of Agriculture, Dharwad, Karnataka, India

Corresponding Author:
Ramesh
Department of Soil Science, UAS, Dharwad, Karnataka, India

Fertility status and potassium fractions under different land use systems of Alnavar taluk of Dharwad district

Ramesh, Vijay Kumar C, KK Math and Shubha S

Abstract
Sixty composite soil samples from surface (0-20 cm) were collected and analyzed for pH, EC, OC, available nitrogen, phosphorous, potassium, sulphur and different forms of potassium. The soils were acidic to neutral (4.86-7.50) and The soils of the forestry ecosystem have a somewhat low pH. The EC is normal in range (0.17 to 1.58 dSm^{-1}) and the cation ion exchange of the soils was low to medium (8.48 to 31.74 cmol (p+) kg^{-1}). The taluk's soils had low to medium levels of organic carbon, medium levels of nitrogen that was readily accessible, low levels of phosphorus, and medium to high levels of potassium. Higher SOC (7.28 to 12.62 g kg^{-1}), available N (193 to 322 kg ha^{-1}) and available P (19.3 to 32.8 kg ha^{-1}) were recorded in the soils of forest ecosystem followed by sugarcane, maize and paddy-based land use system.
Sugarcane-based land use system recorded higher potassium fractions content *i.e.* WS-K (3.01 to 5.11 mg kg^{-1}), exchangeable-K (105.09 to 182.09 mg kg^{-1}), non-exchangeable K (214.95 to 452.15 mg kg^{-1}), lattice-K (8685 to 13160 mg kg^{-1}) and total-K (9181 to 13750 mg kg^{-1}).

Keywords: Potassium fractions, fertility status, different land use systems, exchangeable-K

Introduction
The most fundamental tool for making decisions in order to implement effective nutrient management techniques is the assessment of soil fertility (Brady and Weil, 2002) [2]. There are several methods for assessing soil fertility, but the most popular one globally is soil testing (Havlin *et al*., 2010) [4]. In order to maximise crop output and to maintain appropriate fertility for a longer length of time, fertiliser recommendations are based on information about the nutrient availability in soils that is obtained via soil testing. There are several forms of potassium in soil, including total potassium, lattice potassium, exchangeable potassium, and potassium that is water soluble.
Understanding the inherent ability of the soil to provide vital plant nutrients for consumption by crops is made easier with knowledge of the condition of the soil's nutrients and how they relate to its physical and chemical properties. Different soil-forming minerals release potassium in soluble and exchangeable form at different rates, which helps with carbohydrate translocation, stomatal opening, membrane permeability, and improving the plant's resistance to diseases. Potassium is a component of a variety of soil-forming minerals, an activator of enzymes involved in protein and carbohydrate metabolism, and a component of various soil-forming minerals. Water soluble, exchangeable, non-exchangeable, and lattice K are the four forms of soil potassium that exist in dynamic equilibrium, with the first two being essential for the growth of plants and microorganisms. Along with soil features, land use pattern is essential for controlling the dynamics of nutrients and soil fertility (Venkatesh *et al*., 2003) [14]. The physico-chemical characteristics of soils under a specific land use system can change their fertility status and the amount of nutrients available to plants. As a result, it may be crucial to determine these soil characteristics as well as the nutritional status and various potassium forms of major land use systems.

Material and Methods
Site description
Alnavar is located at 15.43°N 74.73°E. It has an average elevation of 563 metres (1847 feet). The area falls under North Transition Zone (zone 8) of Karnataka and the average rainfall of Alnavar is 2423 mm.

Collection and analysis of soils

In each land use system, 15 locations were selected from sugarcane, paddy, maize and forest-based land use systems, respectively. A total of 120 composite soil samples were collected in which 60 composite soil samples from surface layer (0-20cm depth) and 60 composite soil samples from sub-surface layer (20- 40cm depth) were collected in the Alnava taluk of Dharwad district. The samples were air dried in shade, ground with wooden mortar, passed through a 2 mm sieve and stored in polythene bags for analysis

Results and Discussion

Physicochemical properties of soils

The average pH and EC values of the soils in the Alnavara taluk ranged from 5.50 to 6.33 and 0.48 to 0.74 dSm^{-1} demonstrating that the soils are acidic in response without noticeably accumulating soluble salts, regardless of the land use regimes (Table 1). Average pH and EC values of the soils under maize (5.74, 0.48 dSm^{-1}), paddy (5.67, 0.59 dSm^{-1}), sugarcane (5.92, 0.56 dSm^{-1}) and forest-based land use system (5.50, 0.52 dSm^{-1}) were recorded. In comparison to other habitats, the soils in the forest ecosystem had a somewhat lower pH and EC. Acidity in these soils may be brought on by excessive bases being washed out of the soil profile by heavy rainfall (Sharma and Singh, 2002) [10]. Less soluble salt buildup in the soil profile may be caused by the soluble salts that are released when the heavy rainfall weathers the minerals that make up the soil. Amenla *et al*. (2010) [1] have also reported findings that are similar. Mean CEC of the soils of maize, paddy, sugarcane and forest-based land use systems varied from 10.05 to 24.59, 8.48 to 26.79, 8.51 to 25.26 and 10.24 to 24.26 cmol (p^+) kg^{-1} with an average of 18.20, 17.55, 14.26 and 17.50 cmol (p^+) kg^{-1} respectively. The results also showed that the soils in the forest environment had greater CEC values than those in other systems, which may be related to their high levels of organic carbon. Irrespective of land use systems, the mean SOC content in soil samples of Alnavar taluk ranged from 4.82 to 10.06 g kg^{-1}. Average SOC under maize, paddy, sugarcane and forest-based land use systems were 4.82, 6.22, 8.48 and 10.06 g kg^{-1} respectively. The results also showed that when maize, rice, and sugarcane continued to be grown in the same areas, they hastened the depletion of SOC, whereas soils under forest ecosystems tended to increase SOC accumulation. No matter the land use systems, all of the samples had a moderate level of SOC.

Table 1: The pH, EC, CEC, organic carbon and available N, P, K and S status of soils under maize-based land use system

Sl. No.	pH (1:2.5)	EC (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p+) kg^{-1}]	Available nutrients (kg ha^{-1})			
					N	P	K	S
1.	6.10	0.46	4.55	14.66	205	27.7	388	24.4
2.	5.06	0.68	6.02	23.54	271	21.3	223	32.8
3.	6.20	0.28	5.21	10.05	234	19.7	395	28.2
4.	5.99	0.24	5.18	15.92	233	28.7	279	28.0
5.	5.09	0.27	6.71	22.63	292	28.1	335	36.7
6.	5.95	0.67	3.33	15.65	195	24.2	330	23.2
7.	5.65	0.52	5.90	17.85	266	24.6	231	32.1
8.	5.64	0.52	4.92	16.24	221	33.5	393	26.5
9.	5.67	0.78	3.02	13.27	136	25.9	334	19.7
10.	5.85	0.45	3.08	22.94	139	26.4	272	20.1
11.	5.75	0.62	6.32	18.32	284	25.0	377	34.5
12.	5.89	0.46	3.78	24.37	146	28.0	311	21.0
13.	5.64	0.24	3.54	16.81	154	22.9	305	22.0
14.	5.95	0.27	6.84	16.19	296	30.1	265	33.5
15.	5.74	0.67	5.57	24.59	251	36.1	248	30.2
Range	5.06-6.20	0.24-0.78	2.42-6.84	10.05-24.59	136-296	19.7-36.9	222-395	19.7-36.7
Mean	5.74	0.48	4.82	18.20	221	26.9	312	27.5
S.Em±	0.08	0.05	0.38	1.14	14.71	1.15	15.17	1.45
C.V(%)	5.59	38.54	33.25	8.72	21.80	16.60	18.79	20.46

Table 2: The pH, EC, CEC, organic carbon and available N, P, K and S status of soils under paddy-based land use system

Sl. No.	pH (1:2.5)	EC (dS m^{-1})	OC (gkg^{-1})	CEC [cmol(p+) kg^{-1}]	Available nutrients (kg ha^{-1})			
					N	P	K	S
1.	5.90	0.53	5.21	19.44	234	24.7	265	28.2
2.	5.95	0.67	8.52	8.48	299	31.4	227	29.1
3.	5.77	0.54	7.82	19.24	292	23.7	330	28.1
4.	5.09	0.27	4.37	22.06	197	22.6	276	23.4
5.	5.75	0.56	8.91	9.41	297	28.7	261	32.3
6.	5.25	0.39	6.57	12.04	266	25.9	267	29.9
7.	5.84	0.74	6.56	23.30	295	24.8	326	30.9
8.	6.10	0.75	3.92	24.71	176	26.4	261	20.8
9.	6.21	1.02	3.77	21.14	170	30.3	339	20.0
10.	5.78	0.88	7.10	8.90	280	35.4	303	32.0
11.	5.09	0.56	3.77	11.94	170	26.8	312	20.0
12.	6.08	0.61	7.40	26.79	283	24.5	272	32.7
13.	5.78	0.35	7.44	15.94	295	26.7	255	32.9
14.	5.08	0.78	6.80	24.98	286	25.9	241	29.3

15.	5.36	0.26	5.21	14.93	234	33.2	367	28.2
Range	5.08-6.21	0.26-1.02	3.77-8.91	8.48-26.79	170-299	22.6-35.5	227-367	20-32.9
Mean	5.67	0.59	6.22	17.55	252	27.4	287	27.9
S.Em±	0.10	0.06	0.45	1.63	13.02	0.95	10.38	1.19
C.V(%)	6.90	37.01	27.85	36.00	13.02	13.42	14.00	16.52

Table 3: The pH, EC, CEC, organic carbon and available N, P, K and S status of soils under sugarcane-based land use system

Sl. No.	pH (1:2.5)	EC (dS m^{-1})	OC (gkg^{-1})	CEC [cmol(p+) kg^{-1}]	Available nutrients (kg ha^{-1})			
					N	P	K	S
1.	6.70	0.39	6.45	18.94	230	26.7	449	30.3
2.	5.98	0.35	9.51	9.17	248	33.7	375	43.2
3.	5.88	0.22	6.02	13.46	261	25.4	328	27.8
4.	6.12	0.78	6.41	17.24	238	24.7	296	30.0
5.	5.90	0.43	10.88	14.26	230	33.2	417	47.0
6.	6.20	0.18	9.77	15.55	270	37.6	349	44.7
7.	5.99	1.39	6.65	11.57	269	24.7	436	31.4
8.	6.40	0.49	10.20	11.21	269	30.9	419	43.1
9.	6.03	0.17	8.93	8.51	252	32.4	374	44.4
10.	5.75	0.56	6.90	20.96	271	28.0	359	32.8
11.	5.93	0.43	8.55	14.64	185	29.8	360	42.2
12.	5.98	0.28	9.87	25.26	284	34.0	292	44.3
13.	5.22	1.39	7.59	9.21	262	35.4	324	36.8
14.	5.29	0.69	8.67	14.02	280	36.6	353	42.9
15.	5.36	0.65	10.80	9.87	276	25.5	263	48.6
Range	5.22-6.70	0.17-1.39	6.02-10.80	8.51-25.26	185-284	24.7-37.6	263-4499	27.8-48.6
Mean	5.92	0.56	8.48	14.26	255	30.6	360.0	39.3
S.Em±	0.10	0.10	0.44	1.23	6.68	1.15	14.04	1.81
C.V(%)	6.72	68.39	19.96	33.50	9.98	14.59	15.11	17.83

Table 4: The pH, EC, CEC, organic carbon and available N, P, K and S status of soils under forest-based land use system

Sl. No.	pH (1:2.5)	EC (dS m^{-1})	OC (gkg^{-1})	CEC [cmol(p+) kg^{-1}]	Available nutrients (kg ha^{-1})			
					N	P	K	S
1.	4.86	0.24	8.57	15.62	257	29.5	299	34.8
2.	5.03	0.48	8.78	21.43	263	26.1	281	36.0
3.	4.99	0.32	7.28	17.34	218	23.5	245	27.5
4.	5.91	0.49	12.30	21.87	319	19.3	362	52.1
5.	5.13	0.29	10.76	14.11	193	29.9	267	47.3
6.	5.66	0.65	9.57	16.61	287	31.5	334	40.5
7.	5.33	0.52	12.62	14.74	299	19.7	266	53.9
8.	5.75	0.89	12.59	13.17	308	28.9	357	53.8
9.	4.99	0.63	12.00	16.68	310	28.0	337	54.4
10.	5.67	0.39	9.93	21.68	298	22.4	238	42.6
11.	5.98	0.22	7.85	19.17	236	31.1	327	30.7
12.	6.01	0.95	12.06	10.14	322	24.1	282	54.7
13.	5.39	0.79	8.09	21.97	243	32.8	293	32.1
14.	5.84	0.46	7.38	24.26	221	21.5	346	28.1
15.	5.92	0.54	11.06	13.73	272	27.4	351	49.0
Range	4.86-6.01	0.22-0.95	7.28-12.62	10.24-24.26	193-322	19.3-32.8	238-362	27.7-54.7
Mean	5.50	0.52	10.06	17.50	270	26.4	306.1	42.5
S.Em±	0.11	0.06	0.51	1.05	10.49	1.13	10.80	2.66
C.V(%)	7.53	42.92	19.71	23.25	14.70	16.60	13.66	24.28

Fertility Status

Higher values available N (193 to 322 kg ha^{-1}) and available P_2O_5 (19.3 to 32.8 kg ha^{-1}) content were recorded in the soils of forest ecosystem followed by sugarcane, maize and paddy-based land use system. Mean available N and P contents of the soils under maize, paddy, sugarcane and forest-based land use systems ranged from 136 to 296, 170 to 299, 185 to 284 and 193 to 322 kg ha^{-1} and 19.7 to 36.9, 2.6 to 35.5, 24.7 to 37.6 and 19.3 to 32.8 kg ha^{-1} with an average of 221, 252, 255 and 270 kg ha^{-1} and 26.9, 27.4, 30.6 and 26.4 kg ha^{-1} respectively. According to the mean available nitrogen, all of the villages with various land use systems had low to medium nitrogen levels in their soils. The low level of mineralizable N fraction under these types of climatic conditions and in such an acidic environment is indicated by the medium class of accessible N. Due to the greater status of SOC within the forest ecosystem, the forest ecosystem displayed a higher amount of available N when compared to other ecosystems. These findings concur with those of Mandal *et al*. (2013) [9] and Somasundaram *et al*. (2009) [9]. The mean sulphur content in the soils under maize, paddy, sugarcane and forest ecosystems varied from 19.7 to 36.7, 20.0 to 32.9, 27.8 to 48.6 and 27.7 – 54.7 kg ha^{-1} with an average of 27.5, 27.9, 39.3 and 42.5 kg ha^{-1} respectively. As with SOC, available N, soils under the forest land use system had more sulphur than soils under other land use systems. Regular mining and

inadequate nutrient recycling, which tend to decrease soil nutrients, may be to responsible for the lower amounts of these nutrients under the maize, rice, and sugarcane-based land systems. Variations in the available NPS contents under various land use systems may be caused by variations in the soils' organic carbon state. The mean available K content in the soils under maize, paddy, sugarcane and forest ecosystems varied from 222 to 395, 227 to 367, 263 to 449 and 238 to 362 kg ha^{-1} with an average of 312, 287, 360 and 306 kg ha^{-1} respectively. Among the different land use system sugarcane-based land use system recorded highest in surface as compared to other land use system. The higher amount of potassium present in cropland may be due to application of potassic fertilizers that might have increased available potassium content (Keogh and Maples, 1972) [8].
The available K status of soils of study area were medium to high in status, the variation in K status might be due to cultural practices, application of fertilizers, organic manures and other inputs may be due to high clay content.
It has been noted that a rise in organic carbon led to an increase in the amount of potassium that was readily accessible. This could be as a result of the soil's positive soil environment being created by the high soil organic matter level. Availability of potassium in soil is influenced by the process of weathering and the type of clay minerals present. Such results were also reported by Tundup *et al*. (2015) [13].

Fractions of Potassium

1. Water soluble K

The higher water soluble K ranging from 3.01 to 5.11 mg kg^{-1} was recorded in sugarcane-based land use system followed by maize-based land use system 2.94 to 4.14 mg kg^{-1} and forest-based land use system 1.14 to 4.11 mg kg^{-1}. The lowest water-soluble K was recorded in paddy-based land use system 1.16 to 3.60 mg kg^{-1}. Similar findings were reported by Das *et al*. (2000) [3] and Tarafdar and Mukhopadhyay (1986) [12].
Among the different land use systems sugarcane recorded higher water-soluble potassium due to frequent addition of potassic fertilizers and of organic manures and residues and incorporation of sugarcane trash under intensive cultivation might have led to higher water-soluble K in these soils (Hebsur, 1997) [6].

2. Exchangeable potassium

This fraction was found to be maximum in samples of sugarcane-based land use system wherein it varied from 105.09 to 182.09 mg kg^{-1}. In maize and paddy-based land use system the exchangeable K varied from 89.33 to 161.19 mg kg^{-1} and 91.49 to 149.92 mg kg^{-1} respectively. The forest-based land use system varied from 95.65 to 148.60 mg kg^{-1}.
Higher exchangeable K in surface soils of forest-based land use system may be due to the fact that rich organic matter and continuous litter fall.

3. Non-exchangeable K

The non-exchangeable K in soil under the maize, paddy, sugarcane and forest land use systems varied from 293.60 to 511.23 mg kg^{-1}, 177.8 to 355.92 mg kg^{-1}, 214.95 to 452.15 mg kg^{-1} and 336.13 to 577.28 mg kg^{-1} respectively. The higher non-exchangeable potassium was recorded in sugarcane-based land use system followed by forest, maize and paddy-based land use system respectively.

4. Lattice potassium

The lattice potassium varied from 7754 to 11476 mg kg^{-1} in maize, 7828 to 10942 mg kg^{-1} in paddy, 8685 to 13160 mg kg^{-1} in sugarcane and 7792 to 12523 mg kg^{-1} in forest-based land use system respectively.

5. Total potassium

The total K in different land use systems varied from 8432 to 12110 mg kg^{-1} in maize, 8182 to 11340 mg kg^{-1} in paddy, 9181 to 13750 mg kg^{-1} in sugarcane and 8450 to 13100 mg kg^{-1} in forest-based land use system, respectively. Depending on clay mineralogy like 2:1 clay mineral, lattice K content and organic matter content, variation in the depth wise distribution of total potassium depends upon the relative effect of factors such as, soil texture, intensity of weathering of surface soils, organic carbon content and release of soluble potassium from organic residues, application of potassic fertilizers and leaching of potassium to lower horizons. The results are in comparison with those of research findings reported by Hebsur and Gali (2011) [5].

Table 5: Different forms of potassium of the soils under various land use ecosystem (mg kg^{-1})

Sl. No.	WS-K	Ex-K	Non-ex-K	Lattice -K	Total-K
Maize-based land use system					
1.	3.02	158.78	499.20	11149	11810
2.	3.47	89.33	364.40	9962	10420
3.	3.46	161.19	511.23	7754	8432
4.	3.94	112.66	469.80	8653	9241
5.	3.98	135.62	446.48	8013	8601
6.	3.47	134.33	495.81	11476	12110
7.	3.39	93.01	444.43	10279	10820
8.	3.62	160.23	417.80	9298	9880
9.	4.14	135.16	405.30	11195	11740
10.	2.94	110.46	458.20	9928	10500
11.	3.59	153.56	355.10	8797	9313
12.	3.43	126.37	407.85	7932	8471
13.	2.96	124.24	380.80	11172	11680
14.	3.36	107.24	329.40	8650	9095
15.	3.26	100.14	293.60	8153	8555
mean	3.47	126.82	418.63	9494	10044
Paddy based -land use system					
1.	2.36	108.04	335.05	8164	8615
2.	3.01	91.49	293.78	8781	9172
3.	2.92	134.78	177.80	9864	10180

4.	3.04	112.06	355.92	8968	9441
5.	3.60	105.50	211.17	9529	9852
6.	1.85	109.65	192.05	10256	10560
7.	1.38	134.52	285.86	9048	9473
8.	1.26	107.74	242.99	7828	8182
9.	1.63	139.77	185.40	10413	10740
10.	3.57	122.63	302.34	7971	8405
11.	1.75	128.55	188.26	10741	11060
12.	1.16	112.44	341.32	9765	10220
13.	1.66	104.94	267.27	8056	8436
14.	1.16	99.54	296.42	10942	11340
15.	3.08	149.92	298.97	10048	10500
mean	2.23	117.44	264.97	9358	9745
Sugarcane-based land use system					
1.	5.11	182.09	432.40	12580	13200
2.	4.94	151.36	370.90	11422	11950
3.	4.25	132.65	452.15	13160	13750
4.	3.59	119.91	438.23	8738	9302
5.	3.22	170.78	426.00	11530	12130
6.	3.70	141.90	261.30	11933	12340
7.	4.29	177.51	376.48	11221	11780
8.	3.13	171.67	268.17	11047	11490
9.	4.84	151.36	371.15	10742	11270
10.	3.01	146.79	293.01	12667	13110
11.	3.55	146.65	343.98	8685	9181
12.	3.90	118.00	398.47	12179	12700
13.	3.83	131.17	326.36	11368	11830
14.	4.36	142.74	214.95	11627	11990
15.	4.81	105.09	295.97	10834	11240
mean	4.04	145.98	351.30	11316	11817
Forest based-land use system					
1.	4.11	120.61	478.48	10196	10810
2.	2.28	114.84	362.88	9170	9650
3.	2.79	99.48	480.13	9217	9805
4.	2.42	148.60	453.58	10725	11330
5.	3.67	107.60	492.13	10546	11150
6.	2.94	136.38	577.28	11233	11950
7.	3.43	107.59	418.18	11630	12160
8.	4.09	144.98	510.33	10850	11510
9.	1.14	139.53	415.93	8943	9510
10.	3.82	95.65	418.13	9732	10250
11.	1.70	134.57	439.93	12523	13100
12.	1.48	116.24	385.48	9146	9650
13.	1.30	121.17	336.13	8191	8650
14.	3.75	140.72	559.33	12306	13010
15.	2.40	144.07	510.73	7792	8450
mean	2.75	124.80	455.91	10147	10732

Conclusions

The results of the present study lead to a conclusion that the soils of study area differed in nutrient status. Soils are low to medium in organic matter, medium in available N and high in K, adequate in available sulphur and available phosphorus content. Available nutrients content was relatively low in soils under paddy, maize and sugarcane-based land use system than soils of forest ecosystem and sugarcane-based land use system recorded higher potassium fractions content as compared to other land use systems and forest have capacity to maintain sufficient range of available nutrients through addition of huge amount of organic matter, whereas soils under cereal crops cultivated fields showed more mining of nutrients. In general, the soil had a major problem of acidity and poor fertility.

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