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Surface and Sub-Surface Distribution of Available Potassium in Rice Growing Soils under Western Central Table Land Agro-Climatic Zones of Odisha

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Abstract—*Knowledge regarding the available nutrient status in soils is a prerequisite tool for successful crop production. The present study was designed to know the distribution of available potassium (K) in both the surface and sub-surface rice growing soils of western central table land agro-climatic zones of Odisha. Soil samples up to 0.30m depth (0-0.15 & 0.15-0.30m) were collected from twenty eight (28) geo-referenced sites. Results showed that the soils were slightly acidic to neutral in reaction. The mean soil organic carbon (SOC) content was found to be in medium range. The cation exchange capacity (CEC) varied from 8.5 to 18.6 cmol (P^+) kg^{-1} in surface and 10.5 to 20.4 cmol (P^+) kg^{-1} in the sub-surface soils respectively. Available potassium content was found to be in medium range. A decrease trend of SOC and available K was witnessed along the soil depth while the soil pH showed reverse trend. Following the soil pH, CEC of soils showed an increase trend along the soil depth although exceptions were witnessed at two sites. Correlation matrix was drawn between available potassium and other soil properties to find out their relationships.*

Keywords*: Geo-referenced sites, SOC, CEC, available K and soil pH.*

1. INTRODUCTION

Nutrient elements present in soils play an important role in plant growth and development. These elements are directly involved in nutrition of plant and the role played by one element cannot be replaced by any other [1]. Nutrition is a factor of paramount importance that regulates growth, development and reproduction of animals. Potassium is one of the three main pillars of balanced fertilizer use, along with nitrogen (N) and phosphorus (P). It plays vital roles in enzyme activation, water relations (osmotic regulation), energy relations, translocation of assimilates, photosynthesis, protein and starch synthesis and underpinning agronomic productivity and sustainability [2]. Importance of potassium in plant growth and development has been known for over 150 years [3]. Plants differ in their ability to take up K depending on several factors viz. soil factors, plant factors, and fertilizer and management practices which affects availability of K in soil and subsequently its uptake by the plants. Most crops take up as much or more K than N About 70 to 75% of the K absorbed is retained by leaves, straw, and stover. The remainder is found in harvested portions such as grains, fruits, nuts, etc. [3]. Potassium content of soil is dependent on thousands of years of geological and climatic conditions that have resulted in the weathering of potassium-containing minerals. Therefore, areas that receive higher levels of precipitation, the total soil potassium reserves will become lower and lower over time. Even in areas that have higher potassium reserves, the amount of potassium that is available for plant growth may be low due to the activity of clay minerals and cation exchange capacity (CEC) of soils. Both soil clay type and CEC are intrinsic physical properties of the soil that cannot be changed. However, these factors can be managed for making the potassium reserve available for plant growth.

Availability of soil K to plant is controlled by dynamic interactions among its different chemical forms [4] and mainly governed by the physicochemical properties of soils. The components of dynamic interactions are: water soluble K, which is taken up directly by plants; exchangeable K, held by negatively charged sites of clay particles; non-exchangeable K, which is trapped between layers of expanding lattice clays; and lattice K, an integral part of the primary minerals [5]. Availability of potassium in soil depends on parent material, degree of weathering, K gains through manures and fertilizers and losses due to crop removal, erosion and leaching [6]. Severe depletion of potassium partly results from the average crop removal of 1.5 times more K than that of N, while the K application is much lower than that of N or P, with the misconception that the soils of country are relatively rich in potash [7]. Apart from this, relatively low cost per unit of nitrogen, its widespread availability, and quick and evident response of the plant has further accentuated the low application of potassic fertilizers [8]. Continuous cropping with inadequate potash application, K requirement of crops is met from the inherent potassium reserve (the non-exchangeable potassium pool) of soil. Such depletion may denude the interlayer potassium of the illitic clay minerals of soils which are sufficient for the clay lattice to collapse [8]. This in turn will adversely affect the potassium dynamics in soil, rendering the entrapment of excess K (e.g., from the applied K fertilizer) in soil rather difficult, causing thereby excessive loss of the applied potassium through leaching.

Some of the crops have deep root system and they meet their K requirement from lower soil depth too. Therefore, knowledge regarding the depth distribution of available potassium will be an important tool in formulating a sound fertilization program for improving the crop yields and soil sustainability. Studies on the distribution of available K and the soil factors affecting its availability in soils of the study areas are scanty.

Therefore, an attempt was taken to study the distribution of available K along the depth and its relationship with different soil properties in paddy soils under the western central table land agro-climatic region of Odisha.

2. MATERIALS AND METHODS:

Twenty eight (28) geo-referenced soil samples up to 0.30m depth (0-0.15 & 0.15-0.30m) were collected from rice fields of Saharapali village which falls under the western central table land agro-climatic region of Odisha. Composite soil samples were taken before puddling of the fields. The study area lies between 20°43' N to 21°41' N and longitude of 82°39' E to 83°58' E, experiencing an annual rainfall of around 1350mm and mean annual temperature around 30-35^{0}C. Representative soil samples after collection were air dried and sieved for further analysis of different soil parameters.

Soil pH was measured in suspension of 1:2.5:: soil: 0.1M $CaCl_2$ solution by the method as described by Jackson [9]. Oxidisable organic carbon of the soil samples were estimated by Walkley and Black method (1934) as described by Jackson [9]. Available K was determined by extracting soil with neutral normal NH_4OAC (1:5) as described by Schollenberger and Simon [10]. Cation exchange capacity (CEC) of soils was determined by the method outlined by Jackson [9].

Statistical calculations were made by using the SPSS software version 20.0. Correlation matrix was drawn between available potassium and other soil parameters.

3. RESULT AND DISCUSSION:

Soil pH:

The soil pH is an important parameter which determines the availability of nutrient elements in soils and also controls the soil biological activities. The soil pH ranged from 6.53 to 7.35 and 6.78 to 7.45 with mean values of 6.90 and 7.10 in the surface and surface soils of the study areas respectively (table.1). It seems that in both soil layers, the soil reaction varied from slightly acidic to neutral range. In general, an increase in soil pH along the soil depth was witnessed in all the study sites. Similar observations were also reported by [11, 12]. The increase in soil pH along depth could be due to the accumulation of leached basic cations from surface soils through irrigation water. Organic acids released from the decomposition of organic residues in the surface soils may be the reason for low soil pH values. Soil pH maintained significant positive correlation with CEC of soils (0.534**) and positive but non-significant with available K (table.2).

Soil Organic Carbon (SOC) content:

Soil productivity is closely linked with soil organic matter (SOM) status, which is important for nutrient mineralization, soil structural improvements, and favorable soil water relations [13]. Soil organic carbon (SOC) content (gkg^{-1}) ranged from 3.5 to 6.5 with mean value 4.8 and 2.8 to 5.8 with mean value 4.1 in the surface (0-0.15m) and sub-surface (0.15-0.30) soils respectively (table.1). The higher SOC content of surface soils was because of the addition of root biomass whereas lower SOC content in the lower soil depth could be due to lower recycling of organic residues owing to poor aeration and microbial activity. The decline trend of SOC content along the soil depth was reported by many workers [11, 12, 14]. SOC content didn't show any significant agreement with soil properties. However, it maintained positive but non-significant correlation with available potassium content of soils.

Cation Exchange Capacity (CEC):

Cation exchange capacity of soils [cmol (P^+) kg^{-1}] varied from 8.5 to 18.6 with mean value 12.3 in the surface and 10.5 to 20.4 with mean value 15.5 in the sub-surface soils respectively (table.1). Such magnitude of CEC in soils of Haryana was reported by [14]. There was an increase trend of CEC of soils along the depth except in two sites where a reverse trend was witnessed. The increase trend could be due to the high clay content of soils at lower depth. Another possible reason for such increase in CEC could be the presence of smectite minerals in lower depth which has higher CEC values. Cation exchange capacity of soils plays a predominant role in controlling the availability of potassium for plant uptake. Presence of functional group like -OH, -COOH liberated due to decomposition of organic residues could be the controlling factor for maintaining the CEC of surface soils. The CEC of soils maintained significant correlation with pH of soils but showed very poor relationship with SOC content of soils (table.2).

Table 1: Available potassium status and soil properties along the soil depth

Serial No.	pH		SOC (gkg^{-1})		CEC [$cmol(P+)kg^{-1}$]		Available K($kgha^{-1}$)	
	Depth (m)							
	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30	0-0.15	0.15-0.30
1	6.62	6.79	4.3	3.8	10.5	13.2	145.6	145.6
2	6.58	6.87	4.4	3.9	11.2	13.8	151.4	147.8
3	6.92	6.95	3.8	3.1	11.5	10.5	158.9	155.9
4	7.02	7.05	3.9	3.0	8.5	11.5	168.4	187.9
5	7.35	7.45	4.2	3.8	14.8	16.9	162.5	152.4
6	7.22	7.38	4.1	3.5	10.2	13.4	169.5	167.4
7	7.02	7.24	5.6	4.8	11.5	14.2	165.4	162.5
8	6.53	7.15	5.9	5.1	12.4	20.4	175.2	172.6
9	6.88	7.04	3.8	2.9	12.6	13.2	162.5	162.3
10	6.54	7.10	4.8	3.4	9.8	14.2	178.4	189.8
11	6.78	6.95	6.2	5.8	12.4	12.4	155.4	153.2
12	6.65	6.78	5.6	4.2	11.5	14.5	184.6	178.8
13	7.03	7.21	3.9	3.2	11.5	15.2	145.5	142.5
14	6.44	6.92	4.2	3.1	12.7	14.6	165.8	161.3
15	6.85	7.24	4.0	3.5	10.2	16.1	188.7	182.4
16	6.66	6.98	3.6	3.2	11.6	16.5	178.9	175.4
17	6.78	7.24	5.2	4.5	10.4	15.6	184.5	179.2
18	6.62	6.95	5.4	4.6	10.5	16.5	183.4	179.8
19	7.06	7.16	5.7	4.8	13.2	14.6	192.1	184.5
20	7.12	7.18	6.5	5.8	12.9	15.8	194.5	188.4
21	6.78	7.06	4.7	4.2	12.4	18.2	172.5	169.8
22	7.20	7.28	4.5	3.9	10.8	14.5	143.2	141.5
23	6.92	7.12	3.5	2.8	13.2	16.5	193.4	190.6
24	6.88	7.18	4.2	3.5	15.2	17.5	190.5	187.2
25	7.05	7.2	5.1	4.7	12.4	17.2	188.7	185.2
26	7.15	7.38	5.3	4.6	18.6	18.5	178.5	174.2
27	7.09	7.36	5.8	5.1	14.2	18.6	180.7	175.4
28	6.95	7.17	5.9	5.0	18.5	20.1	198.2	192.6
Mean	**6.90**	**7.10**	**4.8**	**4.1**	**12.3**	**15.5**	**173.5**	**170.9**
Range	**6.53-7.35**	**6.78-7.45**	**3.5-6.5**	**2.8-5.8**	**8.5-18.6**	**10.5-20.4**	**143.2-198.2**	**141.5-192.6**

\# SOC- Soil Organic Carbon, CEC- Cation Exchange Capacity

Table 2: Relationship between available potassium and soil properties

	Available K	pH	SOC	CEC
Available K	1			
pH	0.19	1		
SOC	0.258	-0.133	1	
CEC	0.260	0.534**	0.04	1

**. Correlation is significant at the 0.01 level (2-tailed).
\# SOC- Soil Organic Carbon, CEC- Cation Exchange Capacity

Available Potassium

Available potassium (kg ha^{-1}) in the soil profiles ranged from 143.2 to 198.2 with mean value 173.5 and 141.5 to 192.6 with mean value of 170.9 in the surface and sub-surface soils of the study areas respectively (table.1). Similar magnitude of available potassium in soils of western central table land agro-climatic zones of Odisha was reported by [15]. This amount of available potassium content seemed to be quite inadequate to meet the crop requirement especially fast growing short duration crops. The values of available potassium showed a decrease trend along the soil depth. The high amount of available potassium in the surface soils could be due to the application of potassic fertilizers in the previous crop. Available potassium showed positive but non-significant correlations with pH (0.190), SOC (0.258) and CEC (0.260) of soils (table.2).

4. CONCLUSION

For maintaining the available potassium status at its optimum for plant growth, it needs external supplemental application of K through chemical fertilizers based on soil test values. In the present investigation, all the study sites were found to be medium in available potassium status. Though, the availability of potassium is controlled by so many soil factors, continual application of potassic fertilizers maintains the available pool in soils. Whenever, the soil cannot adequately supply the K required to produce high yields, farmers must supplement soil reserves with fertilizer K to meet the crop demand.

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