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Physical and chemical properties of salt affected soils of Vani Vilas command area of Hiriyur taluk, Chitradurga district

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Abstract
Salt affected soils of Vani Vilas command area of Hiriyur taluk, Chitradurga district was investigated to know the physical and chemical properties for effective management to improve the soil health. Physical properties like BD, PD, per cent pore space and texture were analysed and it was observed that majority of the soils had the texture of sandy loam to sandy clay loam, BD varied from 1.38 to 1.60 Mg m^{-3}, PD varied from 2.60 to 2.68 Mg m^{-3} and per cent pore space of soil samples from 39.85 to 48.51. The soils were found to be moderate to strongly alkaline in reaction with pHs ranging from 8.31 to 8.88. The soil salinity ECe ranged from 1.76 to 3.38 dS m^{-1} indicating low to moderate saline nature. Organic carbon content was low to medium ranging from 2.94 to 4.99 g kg^{-1}. Available nitrogen content was low to medium (287.38 to 425.42 kg ha^{-1}), available phosphorus content was medium in range from 30.86 to 43.27 kg ha^{-1}. The soils were high in available potash with values ranging from 363.48 to 498.64 kg ha^{-1} and available sulphur was above critical limit indicating higher sulphur availability 37.6 to 45.67 mg kg^{-1}, Exchangeable sodium percentage of the soils ranged from 9.13 to 25.79 per cent, when ESP more than ten in black soil it is sufficient to cause problem to soil.

Keywords: Vani Vilas, pHs, ECe, ESP, Bulk density (BD), particle density (PD)

Introduction

Increasing soil salinity and sodicity are serious worldwide land degradation issues, and may even increase rapidly in the future (Wong *et al.*, 2009) [37]. The problem of salt affected soils is pronounced in the many Indogangetic plains, arid and semiarid regions of the world and increasingly threatening agricultural expansion and productivity. It is estimated that 1.5 billion hectare of lands, all over the world, are salt-affected (Yuan *et al.*, 2010) [38]. Salinity induced land degradation is one of the major obstacles to sustainable agricultural production in many arid and semi-arid regions of the world (Bossio *et al.*, 2007) [8]. In India, about 6.9 million hectares of sodic soils are found, of which 1.63 million hectares occurs in Uttar Pradesh only (Pandey *et al.*, 2011) which is the largest area found in any single state in the country. Only a negligible portion of soils in UP is saline, the bulk suffering from alkalinity, associated with excess of available sodium, poor porosity, low nutrient content, indifferent drainage and high water-table. The excessive salt accumulation adversely affects soil physical and chemical properties, as well as microbiological processes (Lakhdar *et al.*, 2009) [16].

All soils contain some amount of soluble salts, which is indeed essential for the healthy growth of plants. If the quantity of soluble salts in a soil exceeds a certain value, the growth and yield of most crops is adversely affected. Such soils, which contain excess soluble salts, adversely affect the plant growth, are called the salt-affected soils. These soils are grouped into two classes depending upon the nature of soluble salts, physico-chemical characteristics, plant response and the management practices required for their reclamation namely, saline and alkali soils (Anonymous, 2004) [1]. In most parts of the world, salt-affected soil is one of the principle cause of soil degradation, consequently resulting reduction in biomass production. The most unfavorable properties of these soils, which restrict plant growth and human settlement are high soil pH, high soluble salts, high exchangeable and soluble sodium, a hard and compact $CaCO_3$ concretion layer restricting root proliferation, a moderate and strong blocky soil structure, low infiltration rates, low exchangeable and soluble Ca, poor to imperfect drainage conditions, limited microbial activity and low fertility (Sharma *et al*., 2000a) [29].

The information on nutrient recommendation to reclaimed salt affected soils is also very sparse, and similarly the efficacy of commercially available amendment in correcting the

sodicity problem of soil also vary. Vani Vilas sagar dam was constructed in Hiriyur taluk of Chitradurga district, Karnataka during 1906, to provide irrigation for parts of Hiriyur and Challakare taluks. During initial years the area was occupied by paddy and sugarcane and due to monsoon vagaries the storage capacity pattern also decreased and the cropping pattern also got changed. Due to alkaline nature of Vani Vilas sagar irrigation water, the soils which are irrigated have gradually become sodic and another reason is inadequate drainage. Around 50,000 ha of salt affected area is present in Chitradurga district out of which 30,000 ha is present in Hiriyur taluk alone (Chitradurga chapter IV). Hence, it was felt therefore necessary to take up a study on Characterisation of salt affected soils of Vani Vilas command area of Hiriyur taluk, Chitradurga district.

Material & methods

The present investigation was carried out by identifying the salt affected soils of Hiriyur through survey. In order to characterize Vani Vilas command area soils, soil samples were collected from 10 villages at 0-15 cm depth surface soil and in each village 10 sample were collected with a total of 100 samples were analyzed for characterization. The study area covered Nagenahalli, Hale Yelnadu, Babur farm, Alur, Samudradahalli, Kasavanahali, Kudalahalli, Pithlali, Maskal and Maskalmatti villages covering 1500 ha areas of Vani Vilas command area Hiriyur taluk, Chitradurga. Hiriyur taluk is located at 13.95° N and 76.62° E and it has an altitude of 630 meters above mean sea level. It is located in the midst of the central dry zone IV of Karnataka.

The climate of the study area is tropical climate with maximum temperature of 38°C in the month of April and minimum temperature of 19°C in the month of December and annual average relative humidity in the study area is 85 per cent. Rainy period commences from last week of May and continues up to the end of October. The average rainfall in the study area is 590 mm.

The collected soil samples were analysed for physical and chemical characteristics, as per the standard procedures for physical properties such as Particle size distribution (soil texture) analysis, Particle density, Bulk density and per cent pore space (Piper, 1966) [21] and Baruah and Barthakur (1999). Chemical properties such as Soil reaction (pHe), Electrical conductivity (ECe), Organic carbon (Walkley and Black, 1934) [35], available nitrogen by Subbaiah and Asija (1956) [33], available P_2O_5 in the soil was extracted by Olsen extractant (0.5 *M* $NaHCO_3$) as described by Jackson, 1973 [14] and the available K_2O was extracted by using neutral normal ammonium acetate and the content was determined by aspirating the extract into flame photometer (Jackson, 1973) [14], available sulphur Williams and Steinbergs (1959), and Exchangeable sodium percentage (ESP) (Jackson, 1973) [14] were also calculated.

Results and discussion

Physical properties

Soil texture

The physical properties of surface soil samples revealed that the lowest mean value of sand was observed in Maskalmatti (64.84 per cent) and the highest mean value of sand was recorded in Nagenahalli (71.51 per cent). Lowest mean value of silt was noticed in Babbur farm (7.74 per cent) and the highest mean value of silt was recorded in Hale yelnadu (12.34 per cent). Lowest mean value of clay was noticed in Hale Yelnadu (17.78 per cent) and the highest mean value of clay was recorded in Alur (26.86 per cent), presented in (Table 1). This may be due to the fact that those soils are derived from coarse grained and granitic-gneisses parent materials which normally exhibit coarse texture with higher sand particles. The soils were dominant in sand content but small amount of clay and silt was also observed in the soils. Thus the soil texture ranged from sandy loam to sandy clay loam. Similar results of clay, clay loam, sandy clay, sandy clay loam, sandy loam and loam were reported by Chaudhary *et al*. (2006 a) [11].

Bulk density

The results on BD of surface soil samples were revealed that lowest mean value of BD in Alur (1.43 Mg m^{-3}) and the highest mean value of BD was recorded in Samudradahalli (1.53) (Table 7). However, the variation in BD among different villages is not significant since the CV is 0.95 per cent. Soil bulk density could be used as an indicator of soil quality parameter. The bulk density depends on several factors such as compaction, consolidation and amount of soil organic carbon present in the soil, but it is highly correlated to the organic carbon content of the soil. However, in sandy soils, organic matter content is generally low, the solid particles lie close together and the bulk density is commonly higher than in fine textured soils and also BD of soil may increase with increase in TSS and ESP. Similar relations were reported by Muhammad *et al.* (2002) [18].

Particle density

The results on PD of surface soil samples values revealed that the lowest mean value of PD was recorded in Maskal (2.63 Mg m^{-3}) and the highest mean value of PD was recorded in Samudradahalli (2.65 Mg m^{-3}) (Table 1). Particle density of soil did not vary much among the villages, but with decrease in organic matter content of the soil the particle density increases and also PD of soil may also decrease with increase in TSS and ESP and decrease is more due to ESP and similar results are in agreement with Muhammad *et al.* (2002) [18].

Per cent pore space

The results on per cent pore space of surface soil samples revealed that the lowest mean value of per cent pore space in Maskal (41.82) and the highest mean value of per cent pore space in Alur (45.89) was observed (Table 1).

Table 1: Mean values of Physical properties of soils of Vani Vilas command area, Hiriyur taluk, Chitradurga district

Villages		Particle Size Distribution (%)			BD	PD	Pore space (%)
		Sand	Silt	Clay	← (Mg m^{-3}) →		
Nagenahalli	Range	66.2-79.67	2.98-17.4	14.1-25.16	1.4-1.58	2.6-2.68	40.15-47.37
	Mean	71.51	8.36	19.82	1.45	2.64	45.09
Hale Yelnadu	Range	61.7-80.87	3.98-17.00	13.40-25.95	1.40-1.60	2.62-2.68	39.39-47.37
	Mean	69.86	12.34	17.78	1.52	2.65	42.40
Babbur farm	Range	51.23-77.18	2.4-13.0	14.10-44.62	1.38-1.56	2.60-2.68	41.67-48.51
	Mean	67.79	7.74	24.45	1.47	2.64	44.32

Alur	Range	58.39-72.98	2.73-12.35	21.8-38.88	1.40-1.48	2.61-2.68	43.3-47.37
	Mean	65.15	7.94	26.86	1.43	2.65	45.89
Samudradahalli	Range	64.70-79.41	4.48-16.9	14.1-25.2	1.44-1.60	2.60-2.68	39.85-45.45
	Mean	70.30	10.88	19.81	1.53	2.64	41.82
Maskal	Range	61.9-71.43	4.97-18.0	13.30-31.00	1.44-1.54	2.6-2.66	41.67-45.45
	Mean	67.52	9.99	22.47	1.48	2.63	43.77
Kudalahalli	Range	61.5-71.65	5.45-16.4	14.4-26.8	1.4-1.58	2.60-2.68	40.6-47.01
	Mean	66.69	11.18	22.12	1.48	2.64	43.98
Kasavanahali	Range	50.75-73.15	3.65-16.5	15.15-45.6	1.38-1.56	2.60-2.68	41.35-48.51
	Mean	66.49	9.41	24.06	1.48	2.64	43.80
Pittalahalli	Range	65.4-76.68	1.9-14.0	18.15-26.25	1.48-1.56	2.6-2.68	40.91-44.36
	Mean	69.49	8.16	22.34	1.51	2.64	42.68
Maskalmatti	Range	56.41-70.1	2.23-13.0	18.3-40.18	1.4-1.58	2.62-2.68	40.46-47.37
	Mean	64.84	8.31	26.83	1.48	2.65	44.07
	S.Em±	1.60	1.34	1.94	0.01	0.65	0.29
	CV (%)	7.43	44.70	27.07	0.95	4.66	28.26

The higher porosity in Alur village is due to the lower BD values and higher sand content. The variation was around 28 per cent indicating slight variability in porosity. The per cent pore space varies indirectly with the bulk density of the soil and gives a good estimate of the porosity of the soil. Per cent pore space of soil may decrease with increase in TSS and ESP and decrease was more due to ESP, but also due to more percentage of sand the per cent pore space of soil samples were high. Results are in confirmation with the findings of Muhammad *et al.* (2002) [18] and Pravin *et al*. (2013) [24].

Chemical properties

Soil reaction (pHs)

The results on pHs of the surface soil samples revealed that lowest and highest mean value were recorded in Babbur farm village (8.31) and Alur (8.88) respectively (Table 2). Majority of the soil samples studied were in the range of moderately alkaline to strongly alkaline pHs, which may be due to the presence of more exchangeable sodium, calcium and magnesium on the soil exchangeable complex contributing to alkaline nature. The irrigation water quality also contributes to the development of alkaline nature in soils due to continuous use of this water for high water requiring crops like paddy and sugarcane. In addition, poor drainage results in accumulation of the salts in the soils resulting in alkalinity. These results are in agreement with Sharma *et al*. (2008a) [28] and Polara *et al*. (2006). The high pH in soils may be due to presence of sodium carbonate and bi-carbonates, which precipitate as calcium and magnesium carbonates during evaporation, Bhaskar and Nagaraju (1998) [7].

Electrical conductivity (ECe)

The results on ECe of the surface soil samples revealed that lowest mean and highest mean value were observed in Babbur farm (1.76 dS m^{-1}) and Nagenahalli (3.38 dS m^{-1}) respectively (Table 2). Higher salinity in Nagenahalli village samples may be due to the presence of higher chlorides which contribute to higher ECe values. Higher evaporation during summer months also brings the soluble salts to the surface by capillary rise. Similar results were reported by Mandal and Sharma (2001) [17] and Sharma *et al*. (2004) [31].

Organic carbon (OC)

The organic carbon content of the surface soil samples revealed that lowest and highest mean value were noticed in Hale Yelnadu (2.94 g kg^{-1}) and Samudradahalli villages (4.99 g kg^{-1}) respectively (Table 2). Low organic carbon may be due to the factors like high temperature and poor management of soil as reported by Chalwade *et al*. (2006) [9] and Polara *et al*. (2006). The low organic carbon content of these soils could due to rapid decomposition of organic matter in semi-arid climatic condition. Majority of the soils studied fall in the category of lower organic matter indicating poor soil fertility status. Similar findings were reported by Rama Krishna Prasad *et al*. (1998) [26] and Babar and Kaplay (2004) [2].

Available Nitrogen

The available Nitrogen status of the surface soil samples revealed that lowest and highest mean value were found in Nagenahalli (287.32 kg ha^{-1}) and Samudradahalli villages (425.42 kg ha^{-1}) respectively (Table 2). Majority of soil samples showed medium status of available nitrogen which could be due to low amount of organic carbon as similar findings reported by Prasuna Rani *et al*. (1992) [23] and Rajeshwar and Khan (2007) [25]. The poor available nitrogen status of salt-affected soils is due to poor vegetative cover and high decomposition rate of organic matter, Singaravel *et al*. (1996) [32]. The decrease of nitrogen availability might be due to the low organic matter in the surface soils and also the semi-arid climatic condition which have favoured rapid oxidation and lesser accumulation of organic matter which resulted in low nitrogen content, Bandopadhyay *et al*. (2004) [3].

Available phosphorus

Available phosphorous status of the surface soil samples revealed that lowest mean (30.86 kg ha^{-1}) and highest mean (43.27 kg ha^{-1}) value were found in Maskalmatti and Samudradahalli respectively (Table 2). Majority of soil samples showed medium status of available phosphorous which may be due to continuous application of phosphatic fertilizers to crops which resulted in build-up of phosphorus as efficiency of applied P is very low and it comes in available form very slowly, mainly due to the fixation as Ca-phosphate. The similar results are reported by Sharma *et al*. (2008b). Farmers are using only DAP as a source of phosphorus nutrient in adequate quantity and as a result, P is available in medium range. The organic matter on the surface favoured the solubilisation of insoluble phosphorus releasing more quantity to the surface as reported by Chaudhary *et al*. (2006b) [12] and also supplementing the depleted phosphorus through external sources *i.e.*, fertilizers. Similar results were reported by Thangaswamy *et al*. (2005) [34] and Rajeswar and Khan (2007) [25].

Available potassium

The lowest and highest mean value of available potassium were recorded in Samudradahalli (363.48 kg ha^{-1}) village and

Hale Yelnadu (498.64 kg ha^{-1}) respectively (Table 2). Majority of soil samples showed higher status of available potassium**.** The higher content may be due to the predominance of potash rich micaceous and feldspar minerals present in parent rocks and the similar findings were reported by Ravi Kumar *et al*. (2007a) [27]. Surface soil samples have high available potassium content which could be due to more intense weathering, release of K from organic residues, application of K fertilizers and upward translocation of potassium from lower depth along with capillary rise of ground water Basavaraju *et al*. (2005) [5]. Similar results were reported by Hirekurabar *et al*. (2000) [13]. The available K in soils may also be attributed to the prevalence of potassium-rich minerals like feldspars. Similar findings were reported by Ravi Kumar *et al*. (2007a) [27] and Sharma *et al*. (2008a) [28].

Available sulphur

Available sulphur content of the surface soil samples varied from 37.6 mg kg^{-1} in Maskalmatti village to 45.67 mg kg^{-1} in Kudalahalli village respectively (Table 2). Majority of the soil samples showed higher content of available sulphur which may be due to the presence of soluble salts present in the soil and addition of S through fertilizers like single super phosphate to meet the requirement of the growing plants. Similar results were reported by Sharma *et al*. (2008a) [28] in Amritsar district of Punjab, Kour and Jalali (2008) [15] and Nega *et al*. (2001) [19].

Table 2: Soil pHs, ECe, organic carbon, avail N, P_2O_5, K_2O and avail sulphur status in soils of Vani Vilas command area, Hiriyur taluk, Chitradurga district (range and mean values)

Villages		pHs	ECe (dS m^{-1})	O.C (g kg^{-1})	Avail. N ←	Avail. P_2O_5 (kg ha^{-1})	Avail. K_2O →	Avail. S (mg kg^{-1})	ESP
Nagenahalli	Range	7.68-9.11	0.61-6.71	1.50-6.30	188.16-450.88	20.50-62.63	297.96-542.30	35.50-48.25	11.52-42.19
	Mean	8.67	3.38	2.94	287.32	35.70	405.57	44.12	20.96
Hale Yelnadu	Range	7.92-8.81	0.74-5.00	1.50-6.50	213.60-439.04	14.80-61.49	396.48-647.40	26.50-48.50	1.28-27.93
	Mean	8.44	2.44	3.26	320.22	37.41	498.64	41.32	9.13
Babbur farm	Range	7.87-8.97	1.00-3.39	1.5-6.8	250.88-485.88	12.53-60.92	436.26-532.76	31.00-48.00	4.67-27.18
	Mean	8.31	1.76	3.98	373.73	38.32	494.22	41.52	12.83
Alur	Range	7.92-9.38	1.25-4.60	2.80-6.30	250.88-476.32	13.67-60.35	164.77-538.94	38.50-45.5	5.51-54.56
	Mean	8.88	2.61	4.50	336.14	31.15	367.97	42.42	25.79
Samudradahalli	Range	8.01-9.12	0.85-3.51	3.90-6.50	313.60-476.32	23.91-59.22	194.34-548.08	38.00-45.00	11.33-34.32
	Mean	8.60	2.09	4.99	425.42	43.27	363.48	41.35	22.45
Maskal	Range	7.72-9.14	1.46-4.81	1.90-6.90	201.76-491.76	21.64-41.00	167.73-501.31	35.25-39.75	4.72-39.31
	Mean	8.61	2.84	4.33	369.22	31.37	391.67	37.60	19.60
Kudalahalli	Range	7.98-8.82	0.81-5.01	3.00-6.60	313.60-476.32	18.22-61.49	225.52-539.48	41.50-49.75	7.22-30.55
	Mean	8.46	2.74	4.44	408.88	33.59	382.76	45.67	17.46
Kasavanahali	Range	7.94-9.08	1.27-4.66	1.40-6.90	125.44-481.76	18.22-60.35	291.38-526.31	41.50-48.50	13.18-38.46
	Mean	8.38	2.83	3.81	352.68	35.13	400.08	45.07	21.03
Pittalahalli	Range	8.21-9.29	1.25-4.63	1.80-6.00	189.92-462.88	4.56-64.91	293.26-453.47	37.75-43.00	5.37-38.37
	Mean	8.81	2.13	3.00	306.96	40.43	394.87	39.32	16.09
	Range	8.02-9.24	1.94-4.59	2.10-4.60	164.48-376.32	20.50-41.00	183.59-566.50	33.50-46.50	10.94-27.17
Maskalmatti	Mean	8.67	3.18	3.20	288.86	30.86	430.25	40.70	19.56
	S.Em±	0.11	0.40	0.61	26.71	4.65	29.25	1.06	2.97
	CV (%)	4.22	48.87	39.43	24.34	41.13	22.40	7.98	50.76

Exchangeable sodium percentage (ESP)

The lowest exchangeable sodium percentage of surface soil samples were recorded in Hale Yelnadu (9.13) village and highest in Alur (25.79) respectively (Table 2). The increase in sodium content and decrease in calcium and magnesium content due to precipitation, such a reaction is enhanced under semi-arid climatic condition with low partial pressure of CO_2 and low content of organic matter in soil might be the reason for high ESP values as reported by Basavaraju *et al*. (2007) [6]. The relatively medium and heavier texture of the soils, soil erosion and low lying area with poor drainage could be attributed as probable reasons for the higher ESP Polara *et al*. (2006). ESP values of 10 in blacks soils are sufficient to cause damage to soil health and needs reclamation.

Conclusion

The study of physical and chemical properties of Vani Vilas command area Chitradurga soils revealed that soil texture ranged from sandy loam to sandy clay loam and bulk density variation was not significant among the different villages. The soil pHs indicated that majority of the samples were in the range of moderate to strongly alkalinity. Similarly the organic carbon content was low in majority of the soil samples indicating low fertility status. The available nutrient status revealed that nitrogen availability was low, phosphorous was medium and potassium is higher in range. The Exchangeable sodium percentage of soils is good indicator of alkalinity and it ranged from 9.13 to 25.79 per cent. Majority of the soils were alkaline in nature reflecting the necessity of reclamation measures to improve the soil health.

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