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Soil Physico-chemical Properties in Central and Southern Dry Zones of Coconut Growing Areas in Hassan District of Karnataka

GAGAN B. SHETTY AND S. CHANNAKESHAVA
Department of Soil Science and Agricultural Chemistry, College of Agriculture, UAS, GKVK, Bengaluru - 560 065
e-Mail : gaganbshetty1997@gmail.com

AUTHORS CONTRIBUTION

GAGAN B. SHETTY :
Carried out research work, data analysis and manuscript preparation;
S. CHANNAKESHAVA :
Provided guidance in manuscript preparation and editing

Corresponding Author :
GAGAN B. SHETTY

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ABSTRACT

The research work was conducted in order to get an insight about the soil physico-chemical properties in central and southern dry zones of coconut growing areas of Hassan district, Karnataka during 2022-23. The soil samples from surface (0-30 cm) and sub-surface (30-60 cm) were collected under central and southern dry zones of Hassan district for the study. Soil samples collected from different agro-climatic zones were analyzed for both physical and chemical properties. The present investigation revealed that soil texture was sandy clay loam to sandy loam in surface soil and sandy clay in sub-surface depths. The soil pH was neutral to mildly acidic in soils of both the agro-climatic zones and the mean electrical conductivity value were normal. The organic carbon content in surface and sub-surface depths ranged from low to high in coconut growing soils of both the agro-climatic zones. Soil pH and electrical conductivity increased with increase in soil depth whereas, the organic carbon content decreased with depth. The average available nitrogen, phosphorus and sulphur status in surface soils of coconut gardens of study area were observed to bemedium and decreased with depth. Whereas the available potassium status was recorded to be higher and decreased with depth. Among the micronutrients, the mean available iron, manganese and copper content were observed to be sufficient where as, insufficient zinc content was noticed in the study area. The study enlightend the varied nature and properties of the coconut growing soils of central and southern dry zones of Hassan district and represented fertility status of the soils to enhance coconut palm health and productivity.

Keywords : Soil properties, Soil depth, Central dry zone, Southern dry zone, Coconut, Major nutrients, Micronutrients

THE Coconut palm (*Cocos Nucifera* L.) is one of the most fascinating and beautiful palms in the world. The palm is looked upon with reverence and affection and is referred to by such eulogistic epithets as 'Kalpavriksha', 'Tree of heaven', 'Nature's super market' and 'King of palms' (Reginald child, 1974). From its sap, leaves, fruits, stem and even from roots, over hundreds of products of domestic, industrial and medicinal importance can be obtained directly or manufactured. Recent estimates indicated that in the world coconut is grown in an area of about 11.97 m ha and India ranks third in area and production, with Indonesia and Philippines ranking first and second respectively. In India, the crop is grown in an area of about 2 million ha with an annual production of about 20425.6 million nuts (Anonymous, 2021). Karnataka ranks 2nd position both in the area under cultivation and production of coconut after Kerala, with a monopoly of desiccated coconut industry and tender coconuts in the country.

Coconut has unique feature among the plantation crops that it flowers and fruits throughout the year. Hence, adequate water and nutrients should be maintained during the entire period. Soil physical and chemical properties regulates the water economy and nutrient availability of the plant and so is indispensable for the rational utilization of limited water supplies for the production of the highest possible yields (Patil and Basavaraja, 2015). The pH is master variable in soil, knowledge regarding pH helps in management of plant nutrients and their dynamics. Particle size distribution is a very important soil property influencing soil structure stability, nutrient availability, soil pH and reaction to fertilizers and other ameliorants (Yadav *et al.*, 2011). The availability of essential nutrients is the governing factor in obtaining higher coconut yields.

The assessment of soil fertility is generally carried through estimation of soil reaction (pH), electrical conductivity of soil solution and plant available macro, secondary and micronutrients. There is a paucity of information on the status of soil physico-chemical properties in central and southern dry zone of coconut growing areas of Hassan district of Karnataka. This study helps to gain knowledge about surface and sub-surface characteristics of coconut growing soil since the palm health and yield are affected by the chemical environment and fertility of the soil. With this view, a study was conducted to know the 'Soil physico-chemical properties in central and southern dry zones of coconut growing areas of Hassan district of Karnataka'.

Material and Methods

Study Area

Hassan district is situated in the Karnataka state between latitude of 12°33' and 13°33' N, longitude of 75°33' and 76°38' East with altitude of 943.05 m and rainfall of 718-1200 mm (Anonymous., 2021). Administratively the district is divided into eight taluks and comes under four agro-climatic zones namely, central dry zone, southern dry zone, southern transitional zone and hilly zone. Arasikere taluk comes under Central dry zone, Channarayapatna taluk comes under southern dry zone, Holenarsipur, Arkalgud, Alur and Belur comes under southern transitional zone where as Sakleshpur taluk comes under hilly zone. Hassan has the second largest coconut growing area in the State with land area of 66637 ha with production of 6204 MT (Anonymous, 2020). Of the eight Taluks in Hassan, Arisekere which comes under central dry zone and Channarayapatna which comes under southern dry zone contributes maximum towards the coconut production in the district (almost 81 per cent) (Anonymous, 2020). Henceforth, the study area was selected under these two agro climatic zones (Fig. 1).

Soil Sampling and Analysis

Fifty random sampling location were selected from each taluk *i.e.,* Arasikere and Channarayapatna at both surface (0-30 cm) and sub surface (30-60 cm) depths at three meters away from the bole of palm based on yield (low, medium and high) of coconut palm. One hundred soil samples, 50 each from surface and sub surface soils were collected from coconut gardens in each agro climatic zone. Details of soil samples collected from central dry zone (Arasikere taluk) and southern dry zone (Channarayapatna taluk) of coconut growing areas of Hassan district, Karnataka are given in Table 1.

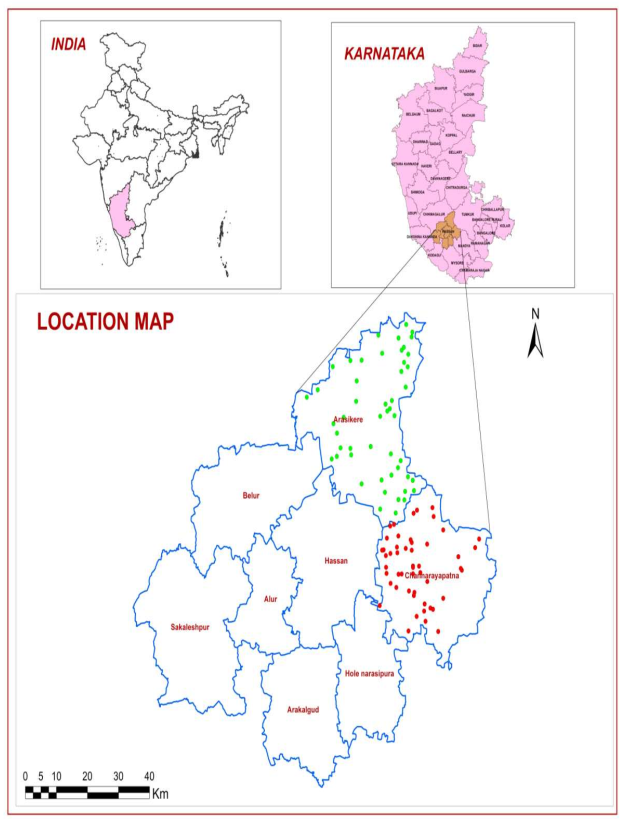


Fig. 1 : Location map showing study area of Hassan district

TABLE 1

Location details of soil samples collected from central dry zone (Arasikere taluk) and southern dry zone (Channarayapatna taluk) of coconut growing areas of Hassan district, Karnataka

Central dry zone	Southern dry zone
Thimlapura	Annenahalli gate
Uttaradevanahalli	Katrighatta
Nagarahallikatta	Doddmatthagatta
Lingapura	Settyhalli
Aaldahalli	K. Hosur
Aaldahalli	Boodhikere
B. K Hosuru	Akkanahalli
Somashettihalli	Lakshmipura
Chandanahalli	Narihalli
Mullikere	Annenahalli
S Diggenahalli	Badalpura
Gandasi	Doddakaradevu
Bachenahalli	Doddakaradevu
Giddegowdanakopplu	Agrahara
Yedunahalli	Vaaranahalli
Gollarahalli	Ankenahalli
Gundha	Yeliyurukopplu
Dummenahalli	Madaba
Rudranahalli	Gulasindha
Borahalli	Chikkanayakanahalli
Bhageshwara	Koordalli
Nagatthalli	M. shura
Gollarahatti	Kembalu
G. Shankaranahalli	Kembalubaaguru
G. Shankaranahalli	Kembalu
Shayanagiri	Doddakaradevu
Padavanahalli	Kundur
Tudikenahalli	Madanahalli
J. C. Pura	Bagur
Rampura	Nellur
Holelkere	Kuruvanka
Chikkametikurike	Shravaneri
Doddametikurike	Byaladakere
Megalagollarahatti	Malekopplu
Yerehallikopplu	Sathenalli
K. Shankarahalli	Navile

Continued

Table 1 Continued

Central dry zone	Southern dry zone
Konanakatte	Didaga
Hosakalyadi	Dasarigatta
Gundavanahalli	Byrapura
Kanakanchenahalli	Bindiganavile
Thimmanahalli	Tagadur
Odeyarhalli	Gowdgere
Singhanahalli	Gollarahosahalli
Singhanahalli	Vaddarahalli
Byrambudhi	Sorekaipura
Bendekere	Santhebachanahalli
Kuruvangavalli	Jogipura
Nagasamudra	Bediganahalli
Sappnalli	Janivara
Kadakatte	Kantharajpura

Physico-Chemical Analysis of the Soils

Air-dried soil samples were used for analysis of texture, pH, electrical conductivity (EC), organic C, available N, P_2O_5, K_2O, exchangeable cations *i.e.* Ca and Mg, available S and micronutrients. Soil texture was estimated by International Pipette Method as described by Piper (1966). Soil pH and electrical conductivity in soil samples were measured in 1:2.5 soil: water suspension as outlined by Jackson (1973). Organic C was estimated by Walkley and Black (1934) rapid titration method. The alkaline potassium permanganate method was adopted to analyse the available nitrogen content in soils (Subbaiah and Asija, 1956). The available phosphorus in the soil samples was determined by Bray's No.1 method (Jackson, 1973). The available sulphur was determined as described by Black (1965). Available potassium was extracted with 1 M ammonium acetate at pH 7 and measured using a flame photometer (Jackson, 1973). Exchangeable calcium and magnesium were estimated by titrating suitable aliquot of ammonium acetate extract of soil against standard EDTA solution as described by Jackson (1973) and the micro nutrients such as Zn, Cu, Mn and Fe were extracted by using DTPA (Diethylene tri amine penta acetic acid) and measured by using AAS (Lindsay and Norwell, 1978).

Results and Discussion

Physico-Chemical Properties of Soils

Soil Reaction (pH) : The results on pH of soils of central dry zone varied from 6.38 to 7.60 in surface and 6.40 to 7.65 in sub-surface. The lowest (6.38) and highest (7.60) pH were recorded in Kuruvangavalli and Bhageshwara, respectively in surface soils, likewise the lowest (6.40) pH values were recorded in Kuruvangavalli and highest (7.65) pH values were recorded in Bhageshwara in sub-surface soils.

The average pH of soils of central dry zone in surface was 6.99 and in sub-surface was 7.02 (Table 2).

Table 2

Soil reaction, EC and organic carbon in surface (0-30 cm) and sub-surface (30-60 cm) soil samples collected from central dry zone (Arasikere taluk) of coconut growing areas of Hassan district, Karnataka

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ ($dS\ m^{-1}$)		OC (%)	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
1	6.83	6.91	0.12	0.14	0.72	0.66
2	6.53	6.61	0.11	0.13	0.63	0.57
3	7.3	7.32	0.14	0.15	0.6	0.54
4	6.66	6.7	0.15	0.16	0.75	0.66
5	6.83	6.91	0.17	0.18	0.72	0.63
6	6.68	6.74	0.04	0.07	0.69	0.6
7	6.58	6.66	0.05	0.07	0.72	0.63
8	7.4	7.35	0.03	0.04	0.66	0.6
9	7.34	7.38	0.06	0.05	0.69	0.57
10	6.48	6.51	0.23	0.27	0.75	0.63
11	7.12	7.14	0.09	0.1	0.66	0.57
12	6.88	6.84	0.13	0.17	0.6	0.48
13	6.8	6.74	0.16	0.17	0.87	0.72
14	7.12	7.13	0.15	0.16	0.75	0.63
15	6.57	6.6	0.09	0.1	0.87	0.66
16	7.44	7.36	0.21	0.24	0.6	0.51
17	6.95	6.97	0.17	0.19	0.84	0.69
18	7.11	7.14	0.23	0.27	0.6	0.45
19	6.88	6.98	0.15	0.18	0.87	0.63
20	7.41	7.48	0.14	0.16	0.75	0.66
21	7.5	7.52	0.12	0.16	0.72	0.6
22	6.92	6.97	0.09	0.11	0.81	0.63
23	7.07	7.1	0.17	0.19	0.87	0.63
24	6.65	6.67	0.13	0.15	0.66	0.48
25	6.82	6.84	0.08	0.09	0.60	0.42
26	7.29	7.32	0.14	0.17	0.78	0.6
27	7.16	7.17	0.17	0.2	0.72	0.57

Continued

Table 2 Continued

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ (dS m^{-1})		OC (%)	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
28	7.1	7.12	0.19	0.21	0.66	0.54
29	7.41	7.47	0.24	0.27	0.72	0.57
30	6.95	6.98	0.18	0.19	0.6	0.48
31	7.22	7.38	0.12	0.15	0.57	0.45
32	7.08	7.11	0.21	0.24	0.51	0.36
33	6.81	6.87	0.16	0.19	0.54	0.39
34	6.61	6.67	0.13	0.17	0.6	0.54
35	6.69	6.7	0.22	0.27	0.66	0.57
36	7.28	7.3	0.09	0.11	0.69	0.6
37	7.14	7.17	0.07	0.08	0.63	0.6
38	6.7	6.71	0.17	0.19	0.6	0.66
39	7.34	7.3	0.23	0.25	0.54	0.36
40	6.99	7.01	0.16	0.17	0.57	0.48
41	7.12	7.17	0.18	0.2	0.66	0.54
42	6.46	6.5	0.11	0.14	0.78	0.63
43	6.74	6.78	0.14	0.17	0.72	0.6
44	7.22	7.24	0.12	0.14	0.66	0.51
45	6.8	6.81	0.09	0.1	1.20	0.75
46	6.88	6.89	0.19	0.2	0.720	0.6
47	6.38	6.4	0.14	0.15	0.69	0.54
48	7.46	7.48	0.23	0.24	0.9	0.69
49	7.41	7.48	0.17	0.18	0.84	0.66
50	7.34	7.39	0.13	0.15	0.78	0.63
Range	6.38-7.50	6.4-7.52	0.03-0.24	0.04-0.27	0.51-1.20	0.36-0.75
Mean	6.99	7.02	0.14	0.16	0.71	0.58
S.D.	0.309	0.305	0.052	0.057	0.120	0.089
C.V.	4.42	4.34	36.42	34.79	17.02	15.43

The experimental data related to pH of the southern dry zone soils varied from 6.36 to 7.50 in surface and 6.22 to 7.52 in sub-surface. The lowest (6.36) and highest (7.50) pH values were recorded in Boodhikere and Kuruvanka for surface soils, respectively. The sub-surface lowest (6.22) and highest (7.52) pH was obtained in Santhebachanahalli and Kuruvanka soils, respectively. Southern dry zone soils recorded average pH of 6.97 in surface and 7.00 in sub-surface. The pH values indicated that the soils of central and southern dry zone are slightly acidic to neutral in reaction (Table 3).

The slightly acidic reaction in some samples might be due to granite, gneiss which is considered as acidic parent material. Iron hydroxide species might have contributed for higher H^+ concentration which might have led to lower soil reaction. The good amount of basic cations and good amount of organic carbon may be the reason for neutral pH in majority of soil

TABLE 3

Soil reaction, EC and organic carbon in surface (0-30 cm) and sub-surface (30-60 cm) soil samples collected from southern dry zone (Channarayapatna taluk) of coconut growing areas of Hassan district, Karnataka

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ (dS m^{-1})		OC (%)	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
1	7.28	7.3	0.13	0.15	0.75	0.66
2	7.47	7.49	0.14	0.17	0.66	0.57
3	7.39	7.45	0.05	0.06	0.51	0.42
4	7.45	7.31	0.07	0.08	0.72	0.6
5	6.98	7.02	0.08	0.09	0.66	0.54
6	6.36	6.32	0.14	0.16	0.33	0.27
7	6.41	6.45	0.09	0.13	0.3	0.21
8	7.41	7.48	0.1	0.13	0.36	0.27
9	7.04	7.11	0.04	0.06	0.51	0.39
10	7.49	7.52	0.03	0.05	0.54	0.42
11	6.38	6.42	0.11	0.12	0.66	0.6
12	7.39	7.51	0.12	0.14	0.51	0.39
13	6.4	6.34	0.08	0.07	0.69	0.6
14	6.37	6.4	0.13	0.15	0.57	0.48
15	6.43	6.48	0.12	0.14	0.51	0.39
16	6.9	7.03	0.1	0.12	0.39	0.33
17	6.46	6.5	0.07	0.05	0.51	0.42
18	7.12	7.13	0.17	0.18	0.54	0.45
19	7.4	7.51	0.15	0.16	0.54	0.39
20	6.44	6.46	0.11	0.12	0.6	0.48
21	7.33	7.25	0.08	0.09	0.45	0.33
22	7.27	7.33	0.06	0.09	0.51	0.42
23	7.42	7.45	0.14	0.16	0.54	0.45
24	7.31	7.32	0.09	0.11	0.6	0.66
25	6.49	6.51	0.11	0.14	0.54	0.48
26	6.53	6.59	0.17	0.18	0.57	0.54
27	6.75	6.77	0.21	0.23	0.66	0.75
28	6.5	6.55	0.2	0.18	0.57	0.51
29	6.7	6.74	0.04	0.05	0.51	0.48
30	6.66	6.67	0.03	0.04	0.63	0.51
31	7.5	7.52	0.25	0.27	0.6	0.66
32	6.68	6.7	0.03	0.05	0.51	0.39
33	6.5	6.53	0.05	0.06	0.48	0.33
34	6.75	6.79	0.04	0.05	0.6	0.51
35	7.36	7.45	0.19	0.21	0.66	0.57

Continued

Table 3 Continued

Sample No.	$pH_{1:2.5}$		$EC_{1:2.5}$ (dS m^{-1})		OC (%)	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
36	7.3	7.32	0.18	0.19	0.63	0.57
37	7.4	7.43	0.18	0.2	0.54	0.42
38	7.41	7.45	0.09	0.12	0.57	0.48
39	6.68	6.82	0.11	0.14	0.54	0.45
40	7.24	7.33	0.22	0.23	0.48	0.6
41	6.55	7	0.06	0.09	0.3	0.18
42	6.48	6.41	0.07	0.08	0.66	0.57
43	7.08	7.1	0.06	0.08	1.32	0.81
44	7	7.05	0.05	0.06	0.75	0.72
45	7.46	7.5	0.09	0.11	0.69	0.6
46	7.36	6.22	0.06	0.08	0.57	0.48
47	6.97	6.93	0.13	0.14	0.51	0.42
48	7.12	7.31	0.08	0.11	0.63	0.6
49	7.36	7.44	0.08	0.11	0.66	0.57
50	6.88	7.11	0.1	0.12	0.48	0.36
Range	6.36-7.50	6.22-7.52	0.03-0.25	0.04-0.27	0.3-1.32	0.18-0.81
Mean	6.97	7.00	0.11	0.12	0.57	0.49
S.D.	0.404	0.421	0.054	0.055	0.150	0.133
C.V.	5.79	6.02	51.31	44.77	26.26	27.41

samples. Similar findings were observed by Dasog and Patil (2011). The increased pH with depth might be attributed to the process of illuviation, where leaching down of bases takes place and is deposited in the sub surface layer (Pinki *et al.*, 2017).

Electrical Conductivity (dS m^{-1}) : The electrical conductivity values of surface soil of coconut growing areas of central dry zone varied from 0.01 to 0.21dS m^{-1} and in sub-surface soils varied from 0.02 to 0.29dS m^{-1}. The lowest (0.01dS m^{-1}) and highest (0.21dS m^{-1}) EC values were recorded in Somashettihalli and J.C Pura in surface soils, respectively. The lowest (0.02dS m^{-1}) EC was obtained in Somashettihalli and highest (0.29dS m^{-1}) EC was obtained in J.C Pura for sub-surface soils, respectively (Table 2).

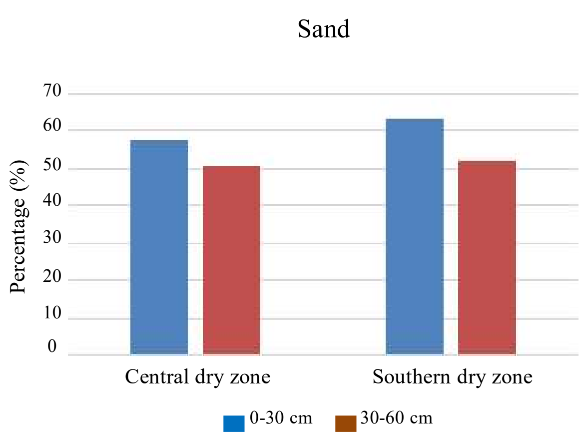
The electrical conductivity values of surface soil of coconut growing areas of southern dry zone varied from 0.03 to 0.25 dS m^{-1} and in subsurface soils varied 0.04 to 0.27 dS m^{-1}. The lowest (0.03 dS m^{-1}) EC was obtained in Annenahalli, Nellur and Shravaneri and highest (0.25 dS m^{-1}) EC was obtained in Kuruvanka for surface soils, respectively. Where as, soils of Nellur and Kuruvanka recorded lowest (0.04 dS m^{-1}) and highest (0.27 dS m^{-1}) EC for sub-surface soils, respectively. EC values were normal in both surface and sub-surface soils of coconut growing areas of central and southern dry zone (Table 3).

The EC of the soil water suspension (1:2.5) of all the samples of coconut growing areas of central and southern dry zone were found low (<0.8 dS m^{-1}) which might be attributed to the removal of released bases by the free drainage conditions and percolating drainage water (Pramod and Patil, 2015), which resulted in non-salinity in the soils.

Organic Carbon (%) : Organic carbon values of surface soil of coconut growing areas of central dry zone varied from 0.51 to 1.20 per cent and in sub-surface soils varied from 0.36 to 0.75 per cent. Organic carbon content of the central dry zone soils showed highest (1.20 per cent) in Byrambudhi and lowest (0.51 per cent) in Chikkametikurike in surface soils, where as the sub-surface soils the content was highest (0.75 per cent) in Byrambudhi and the lowest (0.36 per cent) in Chikkametikurike and Gundavanahalli, respectively (Table 2).

Organic carbon values of surface soil of coconut growing areas of southern dry zone varied from 0.3 to 1.32 per centand in sub-surface soils varied from 0.18 to 0.81 per cent. Organic carbon content of the southern dry zone showed highest (1.32 per cent) in Gollarahosahalli and lowest (0.3 per cent) in Akkanahalli and Tagadur in surface soils, whereas the sub-surface soils the content was highest (0.81 per cent) in Gollarahosahalli and the lowest (0.18 per cent) in Tagadur, respectively. In general, most of the surface soils were higher in organic carbon content compared to sub-surface soils (Table 3).

The organic carbon content was higher in surface soils as compared to sub-surface soils in most of the soil samples (Srinivasa and Chikkaramappa., 2019). It was obviously due to the addition of plant residues, litter and farmyard manure to surface horizons and very less opportunity to move down the depth due to rapid decomposition at a higher temperature and inadequate pedoturbation (Singh and Rathore, 2015).



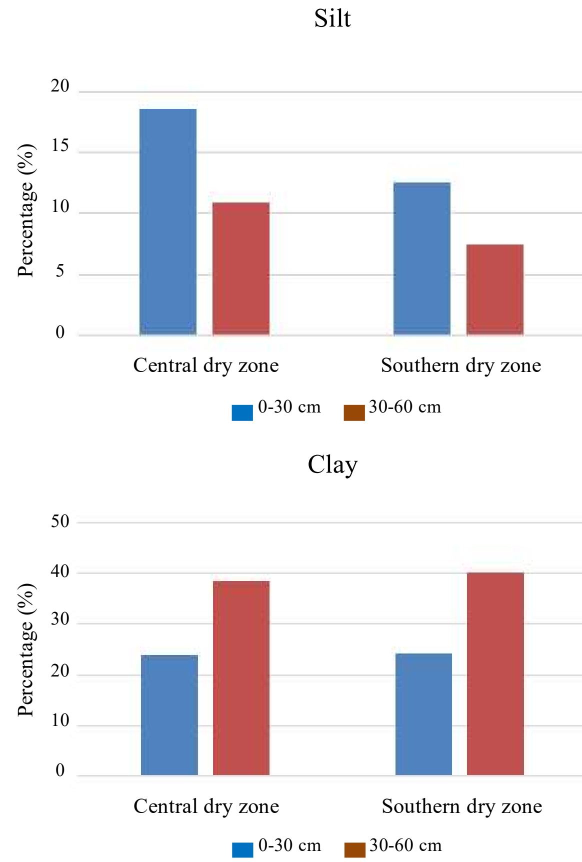


Fig. 2 : Sand, silt and clay content (%) under central and southern dry zone of coconut growing areas of Hassan district, Karnataka

Particle Size Distribution : The experimental data on particle size distribution of coconut growing soils of central dry zone revealed that mean values of sand, silt and clay were 57.50, 18.46 and 24.03 per cent, respectively in surface layer. Where as, mean contents of sand, silt and clay were 50.55, 10.76 and 38.70 per cent in sub-surface samples, respectively. The texture of soil varied from sandy clay loam to sandy loam in surface soils and sandy clay in sub-surface depths (Fig. 2).

The data on particle size distribution of coconut growing soils of southern dry zone revealed that the mean contents of sand, silt and clay were 63.12, 12.55 and 24.33 per cent in surface layer, respectively. Where as, mean values of sand, silt and clay were 52.10, 7.36 and 40.54 per cent in sub-surface samples, respectively. The surface samples were sandy clay loam to sandy loam in texture. The sub-surface samples were sandy clay in texture (Fig. 2).

The sand content was higher in soils of central and southern dry zone of coconut growing areas of Hassan district which could be attributed to the parent material from which they have derived such as granite, genesis. The accumulation of clay and silt was observed in the sub-surface soil with decrease in sand content which might be due to the eluviation of clay under the influence of rainfall from surface layers and its accumulation in sub-surface layers (Amara *et al.*, 2015).

Available Nutrient Status

Available Nitrogen (*kg ha^{-1}*) : The available nitrogen in the surface and sub-surface soil samples of coconut growing areas of central dry zone (Table 4) rangedfrom 197.57 to 376.32 kg ha^{-1} and 125.44 to 275.97 kgha^{-1}, respectively. The lowest (197.57 kg ha^{-1}) and highest (376.32 kg ha^{-1}) available nitrogen were recorded in Kanakanchenahalli and Giddegowdana kopplu, respectively in surface soils, like wise the lowest (125.44 kg ha^{-1}) available nitrogen values were recorded in Kanakanchenahalli and highest (275.97 kg ha^{-1}) available nitrogen values were recorded in Kadakatte in sub-surface soils. The mean available nitrogen in surface soil was 283.87 kg ha^{-1} and in sub-surface soil was 230.06 kg ha^{-1}, respectively.

The experimental data related to available nitrogen of the southern dry zone soils (Table 5) varied from 222.66 to 376.32 kg ha^{-1} in surface and 156.80 to

TABLE 4

Available macro nutrients status in soil samples collected from central dry zone (Arasikere taluk) of coconut growing areas of Hassan district, Karnataka

Sample No.	Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
1	291.65	250.88	53.35	27.70	268.92	218.64
2	285.38	244.61	50.78	21.54	276.12	236.76
3	307.33	257.15	51.81	22.57	281.4	251.28
4	310.46	260.29	55.40	26.67	274.44	225.24
5	294.78	235.20	56.94	29.24	263.76	194.04
6	313.60	263.42	41.04	19.49	274.08	217.8
7	344.96	269.70	30.78	14.36	288.24	242.16
8	275.97	219.52	47.19	24.11	283.8	235.68
9	348.10	250.88	37.45	15.90	240.6	204.96
10	250.88	222.66	54.37	29.75	385.92	341.16
11	282.24	244.61	35.91	17.95	303.72	263.28
12	285.38	260.29	46.17	23.60	326.28	295.32
13	344.96	241.47	55.40	30.26	361.44	332.64
14	376.32	247.74	51.81	28.21	430.32	381.72
15	282.24	235.20	57.45	28.73	423.24	367.56
16	254.02	216.38	27.19	11.80	365.88	329.16
17	301.06	247.74	26.16	10.77	401.76	349.68
18	291.65	254.02	37.96	17.44	435.84	331.32

Continued

Table 4 Continued

Sample No.	Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
19	310.46	260.29	45.14	24.11	424.08	372.84
20	285.38	247.74	54.89	26.57	408.36	339.96
21	288.51	241.47	41.04	20.52	396.72	347.04
22	297.92	232.06	51.81	25.14	256.2	220.44
23	301.06	222.66	50.78	19.49	363.96	319.32
24	250.88	213.25	45.65	21.03	326.76	288.36
25	263.42	219.52	37.45	14.36	302.64	256.08
26	235.20	191.30	29.75	25.08	395.28	338.16
27	316.74	266.56	33.34	13.85	363	326.88
28	238.34	175.62	25.14	10.77	459	374.28
29	285.38	244.61	25.65	7.18	315.72	261
30	279.10	222.66	41.55	21.54	339.72	304.08
31	304.19	254.02	32.83	19.70	398.16	361.32
32	225.79	181.89	55.91	26.16	362.16	334.56
33	235.20	188.16	47.71	24.42	385.8	341.52
34	260.29	219.52	38.98	15.13	373.8	331.44
35	254.02	194.43	50.78	21.90	352.44	301.44
36	228.93	197.57	52.83	27.03	336	315.24
37	294.78	250.88	26.67	8.21	344.64	307.68
38	244.61	172.48	55.91	27.55	348	292.44
39	269.70	219.52	51.30	21.90	306.84	273
40	197.57	125.44	25.14	10.26	250.56	197.52
41	225.79	172.48	55.40	31.29	361.44	320.52
42	332.42	269.70	40.01	13.39	375.36	330.24
43	282.24	238.34	54.37	27.55	374.76	345
44	266.56	216.38	38.47	12.31	410.52	360.6
45	241.47	194.43	52.83	21.34	303.12	259.32
46	310.46	250.88	53.86	16.93	344.04	288.96
47	301.06	244.61	48.73	23.08	292.08	254.88
48	297.92	225.79	51.81	23.60	263.28	223.32
49	282.24	250.88	45.14	22.06	244.44	207.36
50	344.96	275.97	36.42	19.49	315.84	274.08
Range	197.57	125.44	25.14	7.18	240.60	194.04
	-376.32	-275.97	-57.45	-31.29	-459.00	-381.72
Mean	283.87	230.06	44.29	20.86	339.61	293.75
S.D.	36.66	31.185	10.19	6.29	57.438	54.049
C.V.	12.91	13.56	23.01	30.14	16.91	18.40

TABLE 5
Available macro nutrients status in soil samples collected from southern dry zone (Channarayapatna taluk) of coconut growing areas of Hassan district, Karnataka

Sample No.	Available N ($kg\ ha^{-1}$)		Available P_2O_5 ($kg\ ha^{-1}$)		Available K_2O ($kg\ ha^{-1}$)	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
1	282.24	191.30	51.30	26.73	291.84	241.8
2	250.88	188.16	55.91	29.08	269.52	220.08
3	294.78	222.66	53.86	27.24	446.28	398.28
4	275.97	194.43	51.81	28.42	273.72	217.32
5	313.60	232.06	57.45	27.55	352.08	307.68
6	285.38	188.16	55.40	24.88	340.92	289.8
7	326.14	247.74	45.14	21.08	314.16	273
8	272.83	203.84	46.68	20.57	254.76	204.48
9	288.51	197.57	40.01	16.11	364.92	310.08
10	225.79	194.43	56.43	32.88	303.36	257.52
11	263.42	191.30	41.55	20.42	290.16	230.04
12	260.29	172.48	42.58	16.00	329.88	301.92
13	250.88	194.43	56.43	30.83	398.16	349.68
14	235.20	181.89	50.78	31.39	373.8	325.92
15	313.60	244.61	45.65	19.70	423	375
16	285.38	206.98	55.40	32.37	434.52	389.76
17	260.29	175.62	51.30	25.60	430.08	382.08
18	228.93	178.75	48.22	22.78	409.44	349.68
19	247.74	172.48	51.81	26.37	402.72	353.52
20	291.65	200.70	52.83	29.08	373.8	321
21	285.38	213.25	30.78	13.13	363.36	317.76
22	323.01	247.74	54.89	27.55	384.48	341.52
23	329.28	228.93	31.29	15.95	350.64	311.28
24	241.47	188.16	46.68	22.11	435.72	373.68
25	310.46	247.74	43.09	21.39	398.16	305.52
26	282.24	225.79	31.80	14.72	372	317.4
27	294.78	232.06	33.09	18.72	352.44	309
28	263.42	206.98	27.75	10.82	401.88	355.68
29	294.78	219.52	42.11	28.21	413.16	365.76
30	291.65	228.93	53.86	21.13	341.16	288.48
31	297.92	222.66	31.29	12.26	377.52	317.52
32	241.47	172.48	23.08	9.59	285	233.64
33	254.02	188.16	29.24	12.36	276	229.8
34	344.96	244.61	23.60	10.82	313.68	271.68
35	341.82	250.88	48.22	22.78	389.52	325.8

Continued

Table 5 Continued

Sample No.	Available N (kg ha^{-1})		Available P_2O_5 (kg ha^{-1})		Available K_2O (kg ha^{-1})	
	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)	Surface (0-30 cm)	Sub-surface (30-60 cm)
36	332.42	254.02	52.32	21.95	349.8	292.56
37	351.23	279.10	56.94	23.96	317.16	272.04
38	247.74	191.30	51.81	31.34	377.28	328.2
39	348.10	275.97	52.32	30.11	389.76	325.32
40	376.32	294.78	51.30	25.08	397.68	352.44
41	254.02	203.84	23.60	12.52	374.16	330.6
42	282.24	219.52	15.90	5.85	377.04	317.52
43	238.34	203.84	24.98	10.82	384	343.32
44	228.93	197.57	33.34	16.98	349.8	301.92
45	222.66	194.43	55.40	26.78	349.8	304.44
46	263.42	219.52	50.27	21.24	360	304.08
47	326.14	263.42	45.14	19.54	353.76	310.92
48	319.87	247.74	39.50	16.93	375.36	317.64
49	244.61	181.89	37.45	19.49	385.8	325.32
50	247.74	156.80	32.83	14.47	425.4	361.8
Range	222.66 -376.32	156.80 -294.78	15.90 -57.45	5.85 -32.88	254.76 -446.28	204.48 -398.28
Mean	282.68	213.62	43.69	21.35	361.97	311.03
S.D.	38.17	31.30	11.24	6.91	47.542	46.531
C.V.	13.50	14.65	25.74	32.38	13.13	14.96

294.78 kg ha^{-1} in sub-surface. The lowest (222.66 kg ha^{-1}) and highest (376.32 kg ha^{-1}) available nitrogen were recorded in Vaddarahalli and Bindiganavile for surface soils, respectively. The sub-surface lowest (156.80 kg ha^{-1}) and highest (294.78 kg ha^{-1}) available nitrogen was obtained in Kantharajpura and Bindiganavile soils, respectively. The mean values of available nitrogen were 282.68 and 213.62 kg ha^{-1} in surface and sub-surface soils, respectively.

Available N content was found to be maximum in surface soils and decreased with sub-surface depths, which might possibly be due to the accumulation of plant residues, debris and rhizosphere (Srinivasan *et al,* 2013). The relatively higher available N could be associated with the continuous addition of fertilizers and relatively higher organic carbon which in turn resulted from plant and root biomass as well as residues being returned to the soil system (Pulakeshi *et al,* 2014).

Available Phosphorus (*kg ha^{-1}*) : The available phosphorus in soils of central dry zone varied from 25.14 to 57.45 kg ha^{-1} in surface soil and in sub-surface soil ranged from 7.18 to 31.29 kg ha^{-1}. The highest (57.45 kg ha^{-1}) and lowest (25.14 kg ha^{-1}) available phosphorus in surface soil was recorded in Yedunahalli and Tudikenahalli, respectively. The sub-surface lowest (7.18 kgha^{-1}) and highest (31.29 kgha^{-1}) available phosphorus was obtained in J. C. Pura and Thimmanahalli soils, respectively. The mean available phosphorus in surface soil was 44.29 kg ha^{-1} and in sub-surface soil was 20.86 kg ha^{-1}, respectively (Table 4).

The available phosphorus in soils of southern dry zone varied from 15.90 to 57.45 kg ha^{-1} in surface soil and 5.85 to 32.88 kg ha^{-1} in sub-surface soil. The lowest (15.90 & 5.85 kg ha^{-1}) available phosphorus for both surface and sub-surface soils was obtained in Gowdgere and highest (57.45 & 32.88 kg ha^{-1}) available phosphorus in surface and sub-surface soils was recorded in K. Hosur and Annenahalli, respectively. The mean values of available phosphorus were 43.69 and 21.35 kg ha^{-1} in surface and sub-surface soils, respectively (Table 5).

The available phosphorus decreased with depth which was possibly due to the restriction of crop cultivation to the rhizosphere and supplementing the depleted phosphorous through fertilizers. The lower available phosphorus content in the sub-surface layers might be related to phosphorus fixation (Sekhar *et al.*, 2017). The available phosphorus status in soils of the study area was medium to high which might be due to the inherent high-P status of the parent material, good drainage and application of diammonium phosphate (DAP) as a source of nutrients in adequate quantity (Moges *et al.*, 2013).

Available Potassium (*kg ha^{-1}*) : The available potassium in soils of central dry zone varied from 240.60 to 459.00 kg ha^{-1} in surface layer and sub-surface layer ranged from 194.04 to 381.72 kg ha^{-1}. The highest (459.00 kg ha^{-1}) available potassium in surface layer was recorded in Tudikenahalli soil and that of lowest (240.60 kg ha^{-1}) in Chandanahalli soil, respectively. Similarly, the sub-surface highest (381.72 kg ha^{-1}) and lowest (194.04 kg ha^{-1}) available potassium was obtained in Giddegowdanakopplu and Aaldahalli soils, respectively. The mean available potassium in surface was 339.61 kg ha^{-1} and that of sub-surface layer was 293.75 kg ha^{-1} (Table 4).

The available potassium in soils of southern dry zone varied from 254.76 to 446.28 kg ha^{-1} in surface layer and 204.48 to 398.28 kg ha^{-1} in sub-surface layer. The highest (446.28 & 398.28 kg ha^{-1}, respectively) available potassium for both surface and sub-surface soils was obtained in Doddamatthagatta and corresponding lowest value (254.76 & 204.48 kg ha^{-1}, respectively) in Lakshmipura soil (Table 5). The mean values of available potassium were 361.97 and 311.03 kg ha^{-1} in surface and sub-surface layers, respectively.

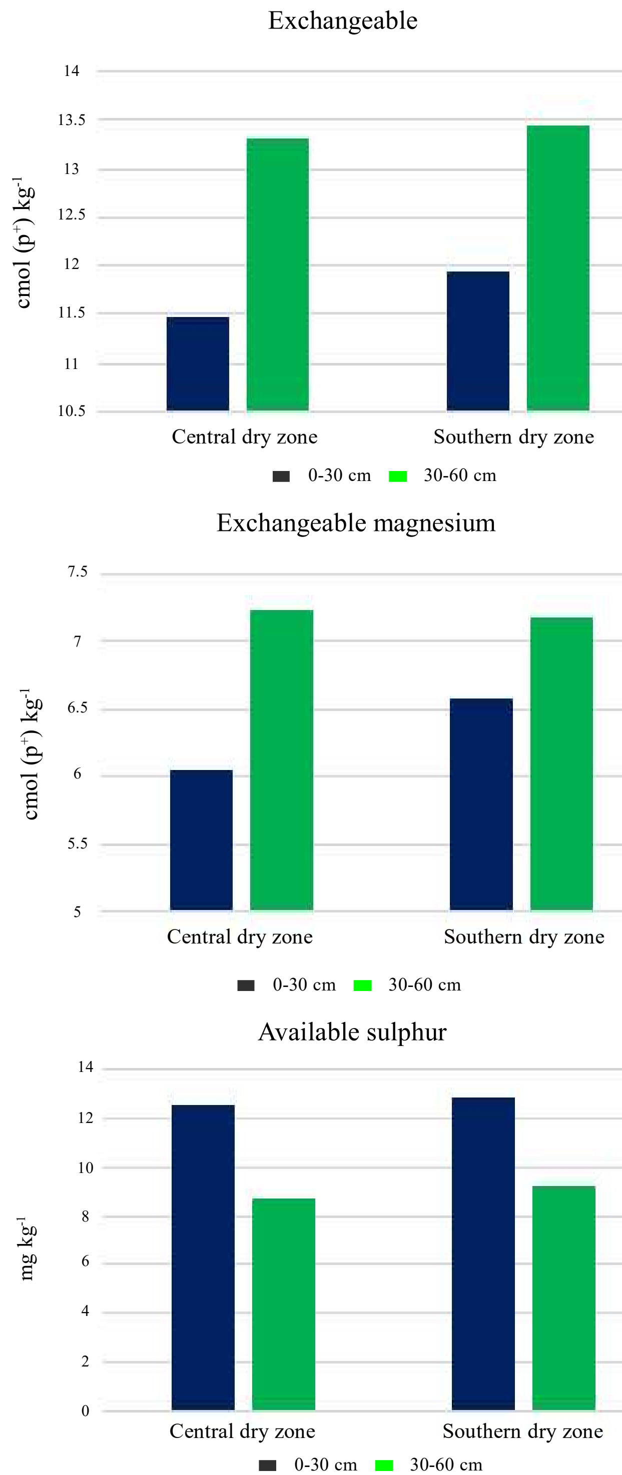


Fig. 3 : Soil exchangeable calcium, exchangeable magnesium and available sulphur status under central and southern dry zone of coconut growing areas of Hassan district, Karnataka

The surface available potassium in soils was more compared to sub-surface which could be attributed to more intensive weathering, release of labile K from organic residues and application of sufficient quantities of potash fertilizers (Harsha and Jagadeesh., 2017). Adequate level of available K in soils of the study area might be due to the prevalence of K-rich clay minerals like illite and secondary clay minerals like smectite in the surface soils (Anjali, 2017).

Exchangeable Calcium (*C mol* (p^+) kg^{-1}) : The mean exchangeable calcium in surface soils of central dry zone was 11.49 cmol (p^+) kg^{-1} and that of sub-surface layer was 13.30 cmol (p^+) kg^{-1}, respectively. Where as, the mean values of exchangeable calcium of southern dry zone were 11.95 and 13.44 cmol (p^+) kg^{-1} in surface and sub-surface layers, respectively (Fig. 3).

Exchangeable Magnesium (*C mol* (p^+) kg^{-1}) : The mean exchangeable magnesium in surface soils of central dry zone was 6.05 cmol (p^+) kg^{-1} and that of sub-surface layer was 7.24 cmol (p^+) kg^{-1}, respectively. Where as, the mean values of exchangeable magnesium was 6.59 and 7.19 cmol (p^+) kg^{-1} in surface and sub-surface layers of southern dry zone, respectively (Fig. 3). In all the study area of central and southern dry zone of coconut growing regions of Hassan district, exchangeable calcium and magnesium was maximum in sub-surface layers compared to surface layers. The variation in exchangeable Ca and Mg are attributed to the type and amount of clay present in these soils (Avinash, 2019).

Available Sulphur (*mg* kg^{-1}) : The mean available sulphur in the surface and sub-surface soil samples of coconut growing areas of central dry zone was 12.63 mg kg^{-1} and 8.74 mg kg^{-1}, respectively. Where as, the mean values of available sulphur of the southern dry zone soils were 12.85 and 9.26 mg kg^{-1} in surface and sub-surface soils, respectively (Fig. 3).

Adequate levels of sulphur were found in majority of areas. This might be due to the application of sulphur containing fertilizers (Srinivasan *et al.,* 2013). The high sulphur content in surface layer may be

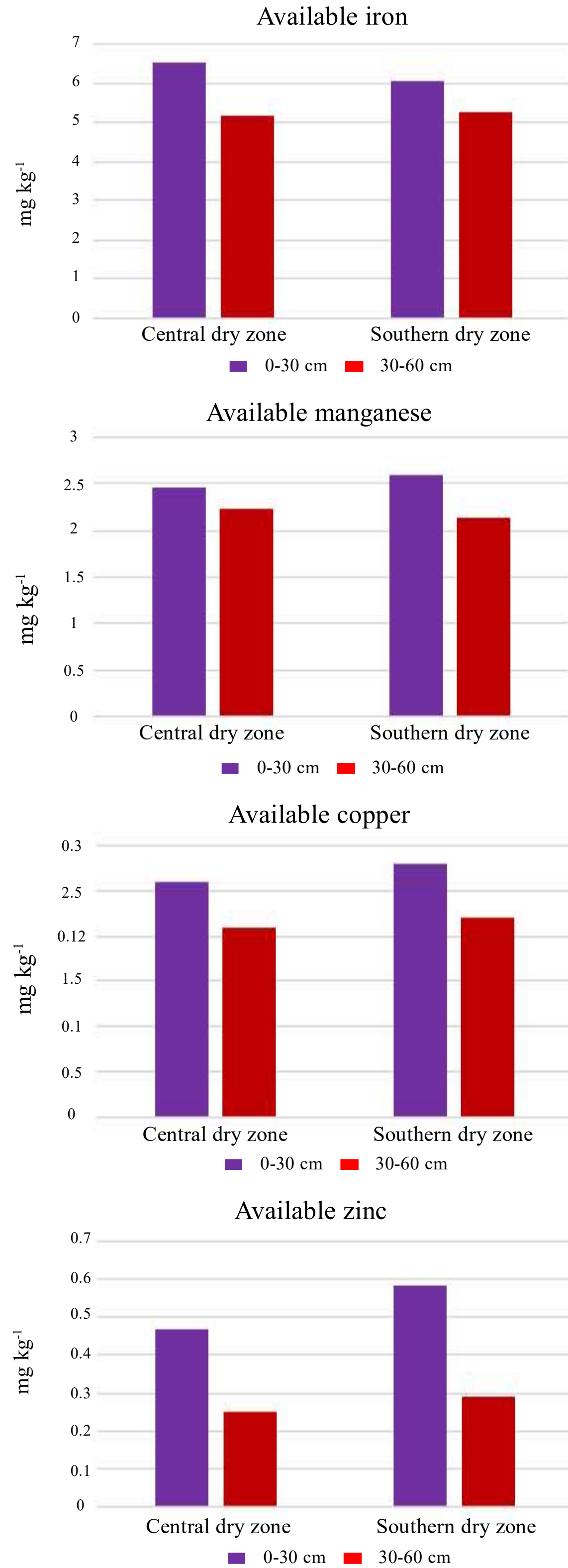


Fig. 4 : Soil available micronutrient status under central and southern dry zone of coconut growing areas of Hassan district, Karnataka

TABLE 6

Distribution of nutrients and nutrient index (NI) of soil samples collected from central (Arasikere taluk) and southern dry zone (Channarayapatna taluk) of coconut growing areas of Hassan district, Karnataka

Parameters	Central dry zone								Southern dry zone							
	Surface (0-30 cm)				Sub-surface (30-60 cm)				Surface (0-30 cm)				Sub-surface (30-60 cm)			
	L	M	H	NI value	L	M	H	NI value	L	M	H	NI value	L	M	H	NI value
pH (1:2.5)	3	47	0	1.94	2	48	0	1.96	12	38	0	1.76	10	36	4	1.88
EC (1:2.5)	50	0	0	1.00	50	0	0	1.00	50	0	0	1.00	50	0	0	1.00
OC (%)	0	38	12	2.24	10	40	0	1.80	9	40	1	1.84	28	20	2	1.48
Available N (kg ha^{-1})	19	31	0	1.62	50	0	0	1.00	23	27	0	1.54	49	1	0	1.02
Available P_2O_5 (kg ha^{-1})	0	48	2	2.04	29	21	0	1.42	1	45	4	2.06	30	20	0	1.40
Available K_2O (kg ha^{-1})	0	23	27	2.54	0	37	13	2.26	0	12	38	2.76	0	36	14	2.28
Available S (mg kg^{-1})	13	35	2	1.78	32	18	0	1.36	11	39	0	1.78	29	21	0	1.42
Available Fe (mg kg^{-1})	1	13	36	2.70	7	17	26	2.38	0	11	39	2.78	2	15	33	2.62
Available Mn (mg kg^{-1})	2	9	39	2.74	4	14	32	2.56	3	10	37	2.68	6	16	28	2.44
Available Cu (mg kg^{-1})	1	20	29	2.56	5	21	24	2.38	0	9	41	2.82	3	16	31	2.56
Available Zn (mg kg^{-1})	36	14	0	1.28	50	0	0	1.00	29	18	3	1.48	49	1	0	1.02
		Deficient		Sufficient		Deficient		Sufficient		Deficient		Sufficient		Deficient		Sufficient
Exchangeable Ca (meq $100g^{-1}$)		0		100		0		100		0		100		0		100
Exchangeable Mg (meq $100g^{-1}$)		0		100		0		100		0		100		0		100

attributed to higher organic matter and lower in sub-surface layers due to the weathering intensity of sulphate minerals in soils (Rehman *et al*., 2017).

Micronutrients

The mean available iron, manganese, copper and zinc in the surface soil samples of coconut growing areas of central dry zone was 6.55, 2.47, 0.26 and 0.47 mg kg^{-1} and in sub-surface soil was 5.17, 2.24, 0.21 and 0.25 mg kg^{-1}, respectively. Where as, the mean available iron, manganese, copper and zinc in the surface soil samples of coconut growing areas of the southern dry zone soils was 6.06, 2.60, 0.28 and 0.58 mg kg^{-1} and in sub-surface soil was 5.28, 2.14, 0.22 and 0.29 mg kg^{-1}, respectively (Fig. 4).

The available Cu was found insufficient in entire study area, which may be due to nature of the parent material as reported by Prasad and Sahi (1989); Raghupathi (1989). Sufficient content of manganese was due to high organic matter content (Yeresheemi *et al*., 1997 and Vijayshekar *et al.,* 2000). Despite the variation observed at different depths, available Zn was at an insufficient level for plant growth under coconut growing areas of both agro-climatic zones where the pH was found to be neutral because all the micronutrients are available under low pH except for boron which increases with increased pH. The available micronutrients like iron, copper, manganese and zinc in the surface horizons was found high compared to subsurface horizons because of lower pH.

Nutrient Index

To evaluate the soil fertility status along the coconut growing soils of central and southern dry zone of Hassan district, the most convenient and suitable index like 'Nutrient Index' (NI) was calculated based on the specific rating chart and comprehensive nutrients status of for all nutrients is presented in Table 6.

Soil nutrient index among the coconut growing soils of central and southern dry zone of Hassan district differs with each other. In central dry zone soil, nutrient index value of EC, available nitrogen and Zn were found low in surface (1.00, 1.62 and 1.28, respectively) and sub-surface soils (1.00, 1.00 and 1.00, respectively) medium in case of pH (1.94 and 1.96, respectively), OC (2.24 and 1.80, respectively). Available Fe, Mn and Cu recorded high nutrient indexvalue in both surface (2.70, 2.74 and 2.56, respectively) and sub-surface (2.38, 2.56 and 2.38, respectively) soils. The available P_2O_5 recorded medium NI value in surface (2.04) and low NI value in case of sub-surface soils (1.42). Whereas, the available K_2O recorded high NI values in surface (2.54) and medium NI values in sub-surface soils (2.26).

Soil electrical conductivity, available N and Zn in coconut growing soils of southern dry zone have low nutrient index value in surface (1.00, 1.54 and 1.48) and sub-surface depths (1.00, 1.02 and 1.02, respectively), where as, pH was found to be medium in both surface (1.76) and sub-surface depths (1.88). Organic carbon, available P_2O_5, S was observed to be medium in surface soils (1.84, 2.06 and 1.78, respectively) and low in sub-surface depths (1.48, 1.40 and 1.42, respectively). Available Fe, Mn and Cu recorded high nutrient index value in both surface (2.78, 2.68 and 2.82, respectively) and sub-surface (2.62, 2.44 and 2.56, respectively) soils. Results confirm with the findings of Ravikumar and Somashekar (2014), who noticed that NPK status of Karnataka was L-L-H but Uttar Pradesh NPK status was L-MM (Kumar *et al*., 2013).

The results showed a distinct variation in soil physico-chemical properties of the coconut growing areas of central and southern dry zone of Hassan district, Karnataka. The study area has low bulk density in surface which is indicating the higher soil organic matter content in surface. The soil pH was slightly acidic to neutral and increased with depth due to leaching down of bases and deposition in lower layer, further resulting in higher electrical conductivity when compared to surface soil. The medium to higher soil organic carbon was recorded in both agro-climatic zones and showed a decreasing trend with soil depth. The available N and P_2O_5 content was low to medium in surface and sub-surface soil and decreased with depth. The K_2O contents were medium to high and decreased with depth in both the agro-climatic zones. Even higher concentration of secondary nutrients were recorded in soils of coconut growing areas of central and southern dry zone. The soils varied appreciably in their physico-chemical properties. The study revealed that variation in physico-chemical properties was due to various facts such as cultural practices, application of fertilizers, organic manures and other inputs. These results in further can be used by planners to plan fertilizer recommendation for a region based the soil type thatis dominated.

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