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Fertility Status in Arecanut (*Areca catechu* L.) Growing Soils of Malnad Region, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

A survey was taken up in the year 2022 in arecanut gardens of three selected taluks of Malnad region *viz*. Koppa, Sringeri and Thirthahalli. The soil samples were collected at surface (0-30 cm) and sub-surface depths (30-60 cm) and were characterized for chemical properties (pH, EC, OC, CEC and BS) and available nutrients. The pH of surface samples varied from slightly acidic to very strongly acidic and showed minor decline with depth. In all the three taluks, surface samples consistently exhibited a low soluble salt concentration. In Koppa taluk, 56.67 per cent of surface layer samples exhibited a medium available nitrogen status whereas, Sringeri taluk had 46.67 percent in the medium to high range and Thirthahalli showed 90 per cent at a medium status level. Regarding available phosphorus content, Koppa taluk had 60 per cent in the low range, Sringeri taluk had 56.67 per cent in the medium range and Thirthahalli had 56.67 per cent in the low range. Meanwhile, the majority of soil samples from all three taluks displayed medium to high available potassium levels. The study is significant for the scientific community as it provides comprehensive baseline data on soil fertility parameters in arecanut-growing regions of Malnad area, addressing a critical gap in understanding nutrient dynamics in high-rainfall, acidic soils that influence perennial crop productivity. By detailing variations in pH, electrical conductivity, organic carbon, cation exchange capacity, base saturation and available NPK across three taluks, it offers valuable insight into soil health constraints like leaching and nutrient imbalances, which can inform targeted agronomic interventions to enhance yield and sustainability.

Keywords: Arecanut gardens; Malnad region; pH; EC; OC CEC; BS; N; P_2O_5 and K_2O.

1. Introduction

Arecanut is one of the profitable commercial plantation crops grown in Karnataka. Karnataka is India's leading arecanut producer, with cultivation area estimates varying slightly by year, but generally around 2.15 to 6.8 lakh hectares, with recent figures suggesting around 6.8 lakh hectares for the year 2023-24 (Bhat *et al.,* 2024), a significant increase from figures in the year 2017-18 (around 2.79 lakh ha) and 2020-21 (around 5.49 lakh ha), as farmers expand plantations for better returns. The state has got two distinct tracts *viz.,* the malnad tract and maidan tract. Malnad tract is said to be the traditional belt wherein the crop has been grown with considerable past history. Tracts essentially consist of coastal plains of Dakshina and Uttara Kannada, Udupi, parts of Shivamogga and hilly terrains of Chikkmagaluru districts. It is characterized by heavy rainfall, variation in altitude, temperature fluctuations *etc*. These factors play a dominant role in determining the soil fertility and productivity. As such crop like Arecanut is perennial in nature and their productivity is affected by many reasons, out of which soil nutrient imbalance is one of the important productivity constraints (Jayaprakash et al., 2024; Acharya et al., 2015; Sujatha & Bhat, 2016). The status of soil fertility determines the level of crop productivity(Paramesh et al., 2025). In the present study an effort is made to determine the physico-chemical properties and their fertility status of the selected malnad taluks that would focus on adopting appropriate cultural and nutritional management to keep the plants healthy and productive (Kumbar et al., 2025).

2. Material and Methods

Koppa, Sringeri and Thirthahalli taluks of Malnad region was selected as study areas located in Hilly zone (Koppa and Sringeri belong to Chikkamagalur district and Thirthahalli belongs to Shivamogga district) of Karnataka between 13° 53' North latitude and 75° 36' East longitude (Koppa), 13° 25' North latitude and 75° 15' East longitude (Sringeri) and 13° 68' North latitude and 75° 24' East longitude (Thirthahalli), covering an area of about 56600 ha, 44400 ha and 125400 ha respectively. Soil sampling in arecanut growing soils was carried out in three taluks of Malnadregion, where sampling of surface and sub-surface soil was done in 2 depths at 0-30 cm and 30-60 cm in selected healthy and unhealthy arecanut gardens and were brought to the laboratory for analysis.In the laboratory, soil samples were dried under shade, ground using wooden pestle and mortar, passed through 2 mm sieve and stored for analysis.Air dried 2 mm sieved soil samples were further ground and passed through 0.2 mm sieve for organic carbon analysis. After processing, soil samples were analysed for chemical and available nutrients status by following standard methods.

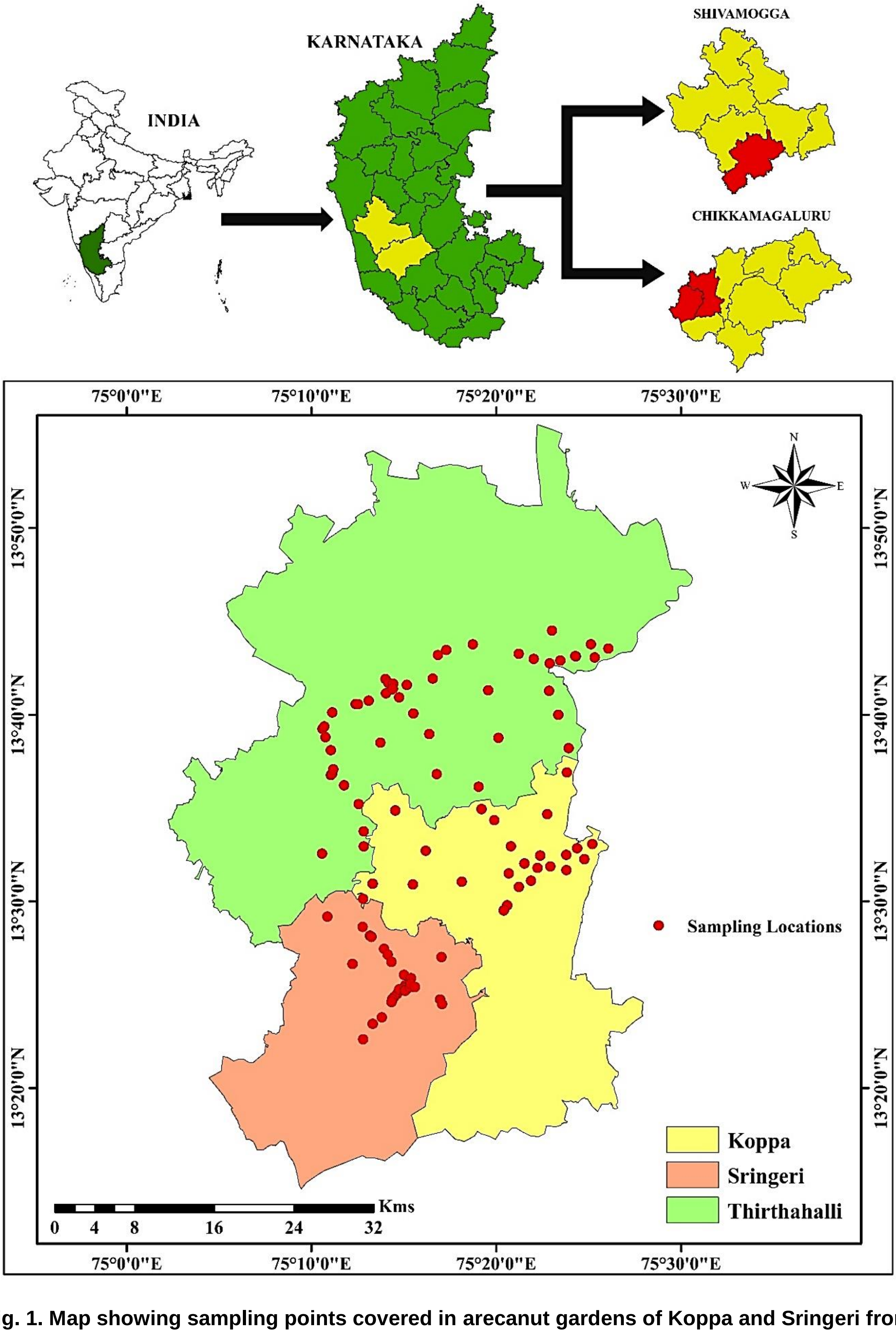

Fig. 1. Map showing sampling points covered in arecanut gardens of Koppa and Sringeri from Chikkamagalur district and Thirthahalli from Shivamogga district

2.1 Soil pH

Soil pH was determined in 1: 2.5 soil to water suspension by dipping the combined electrode (glass electrode plus calomel electrode) of a digital pH meter as described by Jackson, (1973).

2.2 Electrical Conductivity (EC)

Electrical conductivity (EC) of soil was determined in 1: 2 soil to water extract using a conductivity bridge (Conductometry) and the results were expressed in dSm^{-1} at 25 ºC (Jackson, 1973).

2.3 Organic Carbon (OC)

Organic carbon (OC) of soils was determined by following Walkley and Black's method (1934) in which 0.5 g of soil was treated with a known excess of chromic acid, after the reaction, the un-reacted potassium dichromate was back titrated against standard ferrous ammonium sulfate using a diphenylamine indicator and expressed as $g\ kg^{-1}$.

2.4 Cation Exchange Capacity (CEC)

The CEC of the soil was estimated by sodium acetate method as described by Jackson,(1973). The soil sample was mixed with an excess of sodium acetate solution buffered at 8.2 pH. An ammonium acetate solution was then added and the concentration of displaced sodium was then determined by emission spectrophotometer and expressed as $cmol(p^+)\ kg^{-1}$.

2.5 Base Saturation (BS)

The percentage of the exchange complex of a soil occupied by basic cations is termed as per cent base saturation (% BS). It is expressed as a per cent of the total cation exchange capacity. The basic cations considered are Ca, Mg, K and Na ions and is calculated using the below mentioned formula (Jackson, 1973).

$$\%\ \text{Base saturation} = [\text{Exch. } (Ca + Mg + K + Na) / CEC] \times 100$$

where, Ca, Mg, K, Na and CEC are expressed in $cmol(p^+)\ kg^{-1}$.

2.6 Available Nitrogen

Available nitrogen was determined by the alkaline potassium permanganate method as described by Subbiah&Asija, (1956).

2.7 Available Phosphorus

Available phosphorus was extracted from soil using Bray's No.1 (0.03 *N* NH_4F + 0.025 *N* HCl) extractant and concentration of phosphorus in the extract was determined by colorimetric method as described by Jackson, (1973).

2.8 Available Potassium

Available potassium was extracted from the soils using neutral *N* ammonium acetate and the concentration of potassium present in the extract was determined by the flame photometric method (Jackson, 1973).

3. Results and Discussion

3.1 Chemical properties (pH, EC, OC, CEC and BS)

The chemical properties of soils in the arecanut-growing regions of the Malnad region encompass a range of key indicators like soil reaction (pH), electrical conductivity (EC), organic carbon (OC), cation exchange capacity (CEC) and base saturation (BS) that collectively influence soil fertility and plant health which are presented in Tables 1 to 3.

3.1.1 pH (1:2.5)

Soil reaction is the important property which reflects nature of parent material and climate which determine soil composition, nutrients availability and activity of microorganisms and controls physical and chemical properties of soil.Typically, soil in the Malnad region where arecanut palms are cultivated exhibit pH values within a moderately acidic to slightly acidic range, providing an environment conducive to essential nutrient uptake and is presented in Tables 1, 2 and 3.

The range in pH values varies from 4.16 to 6.33 in 0 to 30 cm depth and 4.01 to 6.07 in 30 to 60 cm depth of Koppa taluk and we can notice a slight decrease in pH values with depth (Table 1). Within the pH categories, 50 per cent of samples from surface depth show moderately acidic condition (4.5 to 5.4) and 46.67 per cent samples show slightly acidic condition (5.5 to 6.4) as represented in Fig. 2a and 2b.

The pH values in the studied area of Sringeri taluk display a range from 4.45 to 6.25 within the 0 to 30 cm depth and from 4.32 to 6.10 within the

30 to 60 cm depth. This reveals a slight reduction in pH values with increasing depth (Table 2). Among these pH categories, approximately 53.33 per cent of samples from the surface layer exhibit a moderately acidic condition (pH 4.5 to 5.4), while 43.33 per cent of the samples show a slightly acidic condition (pH 5.5 to 6.4), as illustrated in Fig. 2a and 2b.

The pH values exhibit a range of 4.32 to 6.38 at the 0 to 30 cm depth, and 4.11 to 6.10 at the 30 to 60 cm depth within Thirthahalli taluk's soils. A subtle decline in pH values is discernible with increasing depth (Tables 1 to 3). Among these pH categories, 60 per cent of samples from the surface layer indicate a slightly acidic condition (pH 5.5 to 6.4), while 46.67 per cent of samples demonstrate a moderately acidic condition (pH 4.5 to 5.4), as illustrated in Fig. 2a and 2b.

The pH status across Koppa, Sringeri and Thirthahalli taluks reveals distinct variations in soil acidity. Koppa taluk's soils display slightly a lower range compared to Sringeri and Thirthahalli taluks, with a minor decline in pH with depth. As these soils are derivatives of granite and granite gneiss usually lack basic minerals due to sufficient rainfall with proper distribution and found to possess acidic pH (Shetty *et al.,* 2009). The comparison highlights variations in soil pH among the taluks, which can influence nutrient availability and plant growth across these regions.

Soil pH is primarily shaped by factors such as the parent material and climatic conditions, with rainfall being a particularly influential factor. In the case of traditional arecanut-growing soils, these soils are predominantly derived from acidic parent materials, such as granite, as noted by Ananthanarayana *et al.* (1986) and Veerabhadra, (1992). Consequently, soils formed from granite tend to exhibit an acidic nature. Additionally, when comparing Koppa taluk to Sringeri and Thirthahalli taluks, it's evident that Koppa experiences more evenly distributed annual rainfall over an extended period. This prolonged and heavy rainfall contributes to the leaching of essential basic cations such as K^+, Ca^{2+}, Mg^{2+}, and Na^+, consequently elevating the concentrations of H^+, Al^{3+}, and Mn^{2+}, which leads to soil acidity. Similarly, Vasundhara *et al.* (2021) have also documented slightly acidic soil pH in areas where arecanut and coconut are cultivated in Karnataka, attributing it to the influence of heavy rainfall.

3.1.2 EC (1:2) (dS m^{-1} at 25 °C)

Electrical Conductivity (EC) is another significant chemical parameter that reflects the soil's salinity and can indicate the presence of excess dissolved salts, potentially impacting plant growth. The related information is displayed in the Tables 1, 2 and 3.

The electrical conductivity (EC) levels in Koppa, Sringeri and Thirthahalli taluks demonstrate distinct variations. In Koppa taluk, the EC values range from 0.032 to 0.274 dS m^{-1} at the 0 to 30 cm depth and 0.021 to 0.224 dS m^{-1} at the 30 to 60 cm depth and exhibit a decline in values with depth (Table 1). Sringeri taluk's soils exhibit EC values ranging from 0.028 to 0.196 dS m^{-1} at the 0 to 30 cm depth and 0.011 to 0.144 dS m^{-1} at the 30 to 60 cm depth, following a similar pattern (Table 2). Conversely, Thirthahalli taluk's soils showcase EC values ranging from 0.018 to 0.140 dS m^{-1} at the 0 to 30 cm depth and 0.011 to 0.126 dS m^{-1} at the 30 to 60 cm depth (Table 3). This comparison underscores the EC variations among these taluks, which can have implications for soil salinity and overall plant growth conditions.

In all three taluks, the samples consistently exhibit a low soluble salt concentration within the surface layer (0-30 cm), measuring below 0.8 dS m^{-1}, as clearly depicted in Fig. 3a and 3b. These taluks experience substantial annual rainfall spanning from May to September. This extended and heavy rainfall pattern facilitates the leaching of basic cations from the soil, preventing the accumulation of salts within the soil profile and thereby maintaining a low electrical conductivity (EC). This phenomenon aligns with findings from Teena *et al.* (2023), who also observed similarly low EC levels (ranging from 0.01 to 0.12) in traditional arecanut-growing soils in Karnataka, attributing this outcome to the leaching of soluble salts due to well-distributed rainfall.

3.1.3 Organic Carbon (g kg^{-1})

Organic carbon (OC) content is a fundamental aspect of soil fertility and structure. In arecanut-growing soils, the organic carbon content can vary, influenced by factors like organic matter inputs and decomposition rates. Adequate organic carbon content enhances soil structure, water retention and nutrient-holding capacity. The data pertaining to organic carbon status is presented in Tables 1, 2 and 3.

The OC values in Koppa taluk range from 2.44 to 16.86 g kg^{-1} at depths of 0 to 30 cm and 0.65 to 3.67 g kg^{-1} at depths of 30 to 60 cm. Notably, there was a gradual decrease in OC values with deeper depths (Table 1). Among the analyzed samples, 56.67 per cent of samples at the surface depth exhibit high status, while 33.33 per cent of samples showed low status, as depicted in Fig. 4a and 4b.

In Sringeri taluk, the OC values vary between 2.99 g kg^{-1} and 11.74 g kg^{-1} at depths of 0 to 30 cm and between 1.23 g kg^{-1} and 9.66 g kg^{-1} at depths of 30 to 60 cm. This also reflects a subtle decline in organic carbon values with increasing depth (Table 2). Within analyzed samples, approximately 40 per cent of samples from the surface layer indicate a low status, while 30 per cent of the samples show medium to high, as depicted in Fig. 4a and 4b.

Regarding Thirthahalli taluk, the organic carbon (OC) content ranges from 1.24 to 8.19 g kg^{-1} at depths of 0 to 30 cm and from 0.67 to 4.42 g kg^{-1} at depths of 30 to 60 cm within the soil profile. There is a gradual decline in OC values as you move deeper into the soil layers (Table 3). Among the samples collected, 46.67 per cent of those from the surface layer are classified as having a low OC status, while 43.33 per cent of samples exhibit a medium OC status, as visually represented in Fig. 4a and 4b.

Among the three taluks, Koppa exhibits notably elevated organic carbon (OC) levels compared to Sringeri and Thirthahalli taluks. This discrepancy can be attributed to its status as a forested region, where a substantial amount of organic matter continually contributes to the higher OC content. Conversely, the variances observed in Sringeri and Thirthahalli taluks may arise from factors such as routine organic matter applications, seasonal temperature fluctuations and other management practices. Similar observations were reported by Medirattaet *al.*(1985).

3.1.4 Cation exchange capacity [cmol(p^+) kg^{-1}]

Cation Exchange Capacity (CEC) is a measure of the soil's ability to retain and exchange positively charged ions like calcium, magnesium and potassium, which are vital for plant nutrition. The information concerning CEC status can be found in Tables 1, 2 and 3.

In Koppa taluk, the CEC values exhibit significant variability, ranging from 8.60 to 15.89 cmol(p^+) kg^{-1} in the 0 to 30 cm depth and 7.75 to 14.93 cmol(p^+) kg^{-1} in the 30 to 60 cm depth, as outlined in Table 1. Interestingly, there is a noticeable pattern of CEC values showing a slight uptick with increasing soil depth.

Within the Sringeri taluk research area, CEC values showcase a broad spectrum, ranging between 8.11 to 15.70 cmol(p^+) kg^{-1} at depths of 0 to 30 cm and 8.02 to 15.24 cmol(p^+) kg^{-1} at depths of 30 to 60 cm, as detailed in Table 2. It's noteworthy that there is a subtle rise in CEC values as we delve deeper into the soil, a trend commonly associated with acid soils and the leaching process.

In Thirthahalli taluk soils, CEC values present a wide range, oscillating from 7.93 to 15.69 cmol(p^+) kg^{-1} at depths of 0 to 30 cm and 7.54 to 15.34 cmol(p^+) kg^{-1} at depths of 30 to 60 cm, as depicted in Table 3. Similar to Sringeri taluk, there appears to be a gradual increase in CEC values with greater soil depth, attributed to the leaching process and the potential accumulation of base cations at specific depths. This observation aligns with the findings elucidated by Jayaprakash *et al.* (2012).

Among the exchangeable bases, calcium and magnesium were dominant cations followed by sodium and potassium. As such surface soils found to possess low cation exchange capacity. This is in accordance with the findings of Waliaand Chamua(1990), Sahu*et al.*(1990) and Alur (1994). However, among the different taluks studied cationexchange capacity was higher in Koppa and Sringeri taluks followed by Thirthahalli.

3.1.5 Base Saturation (%)

Base saturation (BS) reflects the proportion of the CEC that is occupied by basic cations (calcium, magnesium, potassium and sodium). Proper base saturation is crucial for maintaining optimal nutrient balance and pH levels in the soil.

In Koppa taluk, there is a notable range in base saturation (BS) values, spanning from 2.58 to 19.95 per cent within the 0 to 30 cm depth and 3.08 to 25.64 per cent within the 30 to 60 cm depth, as delineated in Table 1.

Within the Sringeri taluk study area, base saturation (BS) values display a wide spectrum, with per centages ranging from 5.83 to 23.51 per cent at depths of 0 to 30 cm and 7.13 to 22.20 per cent at depths of 30 to 60 cm, as elaborated in Table 2.

In the soils of Thirthahalli taluk, the base saturation (BS) values exhibit a diverse range, fluctuating between 3.50 and 21.28 per cent at depths of 0 to 30 cm and 4.09 to 23.57 per cent at depths of 30 to 60 cm, as illustrated in Table 3.

All the three taluks (Koppa, Sringeri, and Thirthahalli) display a similar trend of increasing CEC values with greater soil depth. However, the specific CEC value ranges differ among the taluks, suggesting variations in the base saturation status. To make a more detailed comparison, we need to analyse the actual base saturation per centages or concentrations of base cations like calcium, magnesium and potassium in these soils, as CEC values alone do not provide a direct measure of base saturation (Shetty *et al.,* 2009). Further, per cent base saturation was low and varied and highest was in Sringeri taluk and that of lowest was in Koppa taluk (0.2-7.9). This can be attributed to textural variations and difference in the status of organic matter (Veerabhadra, 1992). Ananthanarayana *et al.* (1986) further observed in their studies that the soils of Malnad area are low in cation exchange capacity.

Overall, a holistic understanding of these chemical properties in the arecanut-growing soils of the Malnad region aids in formulating appropriate soil management strategies, ensuring optimal nutrient availability, pH levels and overall soil health for successful arecanut cultivation.

Table 1. Chemical properties of surface and sub-surface soils in the arecanut gardens of Koppa taluk of Malnad region

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
K1	0-30	6.33	0.122	5.73	15.89	5.35
	30-60	6.07	0.099	1.21	14.54	9.53
K2	0-30	5.42	0.069	8.77	13.30	2.58
	30-60	5.09	0.055	2.16	12.29	3.08
K3	0-30	5.10	0.093	9.61	13.39	4.44
	30-60	4.44	0.084	2.77	8.36	7.66
K4	0-30	5.06	0.093	12.34	10.06	7.84
	30-60	4.87	0.089	0.98	8.41	10.14
K5	0-30	5.75	0.260	9.69	12.91	7.12
	30-60	4.74	0.224	1.53	8.10	12.12
K6	0-30	5.80	0.070	15.36	13.66	9.24
	30-60	4.30	0.057	2.44	9.80	14.31
K7	0-30	5.91	0.069	3.38	10.24	19.95
	30-60	4.17	0.056	1.25	8.11	18.21
K8	0-30	4.82	0.087	5.72	9.07	14.19
	30-60	5.69	0.063	1.29	13.21	13.02
K9	0-30	5.23	0.069	16.86	12.26	8.35
	30-60	4.34	0.077	3.63	9.92	10.12
K10	0-30	4.16	0.067	9.67	9.05	10.72
	30-60	4.01	0.066	1.54	7.75	11.34
K11	0-30	5.52	0.057	13.21	10.95	10.88
	30-60	5.10	0.048	1.81	12.98	9.09
K12	0-30	5.54	0.095	3.94	13.39	13.86
	30-60	5.14	0.089	2.77	12.79	12.02
K13	0-30	5.47	0.061	3.02	13.12	13.45
	30-60	5.28	0.043	0.65	12.54	15.20
K14	0-30	5.59	0.044	4.88	13.25	17.59
	30-60	5.43	0.034	1.23	13.35	18.80
K15	0-30	5.54	0.057	3.36	13.72	8.79
	30-60	5.38	0.048	0.99	11.39	17.20
K16	0-30	5.33	0.039	15.97	11.32	11.37

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
	30-60	5.21	0.033	3.64	10.72	11.57
K17	0-30	4.83	0.036	9.65	9.86	8.35
	30-60	4.56	0.030	2.48	9.22	10.23
K18	0-30	5.26	0.109	16.22	11.87	8.37
	30-60	5.10	0.095	3.33	11.48	14.63
K19	0-30	5.23	0.122	3.67	12.99	13.52
	30-60	5.11	0.099	0.91	11.66	25.64
K20	0-30	6.10	0.274	13.29	15.74	6.02
	30-60	5.48	0.189	2.45	14.93	11.32
K21	0-30	4.78	0.140	5.76	8.60	11.19
	30-60	4.10	0.068	1.24	7.84	13.37
K22	0-30	5.78	0.067	8.78	13.28	4.85
	30-60	5.43	0.058	2.17	13.34	3.75
K23	0-30	5.69	0.138	12.63	14.24	11.76
	30-60	5.12	0.085	2.79	13.22	15.30
K24	0-30	4.98	0.094	9.64	11.66	17.99
	30-60	4.57	0.067	1.87	10.69	12.44
K25	0-30	5.12	0.086	2.44	12.33	6.32
	30-60	4.97	0.069	0.66	9.02	7.37
K26	0-30	5.82	0.133	4.57	13.69	10.43
	30-60	5.24	0.095	2.78	12.44	10.87
K27	0-30	5.76	0.127	4.29	13.14	12.43
	30-60	5.21	0.084	2.15	12.01	16.05
K28	0-30	5.39	0.084	12.32	13.10	6.02
	30-60	5.11	0.074	3.33	12.45	6.21
K29	0-30	4.80	0.032	15.31	8.66	10.76
	30-60	4.66	0.021	3.67	8.42	8.55
K30	0-30	6.10	0.125	3.90	14.20	8.09
	30-60	5.87	0.110	2.41	13.70	9.14
Range	0-30	4.16 - 6.33	0.032 - 0.274	2.44 - 16.86	8.60 - 15.89	2.58 - 19.95
	30-60	4.01 - 6.07	0.021 - 0.224	0.65 - 3.67	7.75 - 14.93	3.08 - 25.64
Mean	0-30	5.41 ± 0.47	0.10 ± 0.06	8.80 ± 4.65	12.30 ± 1.97	11.26 ± 4.43
	30-60	4.99 ± 0.52	0.08 ± 0.06	2.07 ± 4.65	11.16 ± 2.20	14.36 ± 5.26

Table 2. Chemical properties of surface and sub-surface soils in the arecanut gardens of Sringeri taluk of Malnad region

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
S1	0-30	5.25	0.041	10.21	12.04	17.02
	30-60	5.14	0.026	3.37	11.51	19.10
S2	0-30	6.12	0.104	5.44	14.54	13.66
	30-60	5.89	0.098	2.73	13.36	15.30
S3	0-30	4.45	0.044	8.45	9.32	10.71
	30-60	4.32	0.020	3.08	9.30	15.37
S4	0-30	5.57	0.065	10.59	10.67	13.58
	30-60	5.32	0.048	5.78	10.66	13.49
S5	0-30	5.69	0.031	4.17	11.59	14.81
	30-60	5.41	0.022	3.36	11.74	19.40
S6	0-30	6.12	0.178	9.95	14.77	15.01
	30-60	5.98	0.106	9.34	13.53	16.94
S7	0-30	5.01	0.068	6.33	12.73	6.71
	30-60	4.96	0.056	5.42	9.33	9.10

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
S8	0-30	4.99	0.039	5.77	9.49	10.26
	30-60	4.86	0.027	4.23	9.53	8.94
S9	0-30	5.63	0.037	4.69	13.62	17.78
	30-60	5.11	0.029	3.91	12.63	16.73
S10	0-30	6.07	0.123	5.43	14.09	6.67
	30-60	5.97	0.095	2.77	13.36	7.53
S11	0-30	5.69	0.037	3.58	12.59	14.88
	30-60	5.48	0.022	2.11	12.18	15.93
S12	0-30	5.42	0.037	2.99	13.65	12.75
	30-60	5.38	0.029	1.23	13.45	17.26
S13	0-30	5.11	0.039	10.30	14.50	12.56
	30-60	4.78	0.028	9.66	8.02	9.71
S14	0-30	4.89	0.043	9.07	8.11	8.79
	30-60	4.77	0.037	8.42	8.07	9.94
S15	0-30	5.11	0.033	8.11	13.50	6.13
	30-60	5.09	0.031	7.89	13.02	7.74
S16	0-30	5.66	0.096	7.59	14.82	15.78
	30-60	5.48	0.043	4.05	14.71	14.23
S17	0-30	5.32	0.044	7.68	13.83	19.35
	30-60	5.14	0.030	3.92	13.76	19.21
S18	0-30	5.09	0.057	3.35	12.90	18.61
	30-60	4.99	0.048	1.86	9.86	18.26
S19	0-30	6.11	0.147	8.34	15.63	12.50
	30-60	5.74	0.088	5.47	13.14	15.37
S20	0-30	6.25	0.176	6.10	15.70	17.23
	30-60	6.10	0.122	3.77	15.16	22.20
S21	0-30	5.89	0.065	11.74	14.23	11.55
	30-60	5.66	0.058	4.58	14.03	15.31
S22	0-30	5.23	0.069	10.22	13.90	15.11
	30-60	5.09	0.063	8.43	12.72	10.32
S23	0-30	5.56	0.028	5.41	13.93	11.85
	30-60	5.18	0.011	2.14	13.11	17.35
S24	0-30	6.11	0.153	2.99	15.65	10.98
	30-60	5.22	0.144	2.77	12.90	14.01
S25	0-30	4.67	0.086	6.30	8.96	23.51
	30-60	4.55	0.077	6.04	8.80	17.29
S26	0-30	4.98	0.069	6.02	9.13	9.82
	30-60	4.87	0.052	2.45	9.02	10.67
S27	0-30	5.89	0.074	3.77	13.13	13.82
	30-60	5.46	0.037	2.38	12.07	21.51
S28	0-30	6.12	0.196	5.99	15.50	6.07
	30-60	6.07	0.042	2.76	15.24	7.13
S29	0-30	5.09	0.055	7.02	13.72	5.83
	30-60	4.82	0.037	3.33	9.97	8.20
S30	0-30	5.68	0.127	3.60	13.64	19.91
	30-60	5.41	0.091	2.16	13.39	14.65
Range	0-30	4.45 - 6.25	0.028 - 0.196	2.99 - 11.74	8.11 - 15.70	5.83 - 23.51
	30-60	4.32 - 6.10	0.011 - 0.144	1.23 - 9.66	8.02 - 15.24	7.13 - 22.20
Mean	0-30	5.49 ± 0.49	0.08 ± 0.05	6.71 ± 2.55	13.00 ± 2.16	14.67 ± 4.43
	30-60	5.27 ± 0.46	0.05 ± 0.03	4.33 ± 2.33	11.92 ± 2.13	14.66 ± 5.02

Table 3. Chemical properties of surface and sub-surface soils in the arecanut gardens of Thirthahalli taluk of Malnad region

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
T1	0-30	4.52	0.018	6.07	8.28	14.65
	30-60	4.41	0.011	3.42	8.12	18.28
T2	0-30	4.32	0.068	7.55	7.93	9.72
	30-60	4.11	0.055	4.36	7.54	11.51
T3	0-30	5.62	0.098	5.49	13.33	5.80
	30-60	5.22	0.078	2.14	12.27	7.46
T4	0-30	4.89	0.059	5.71	9.51	13.12
	30-60	4.56	0.042	2.43	8.14	15.25
T5	0-30	5.22	0.037	8.11	13.71	17.16
	30-60	5.10	0.029	3.04	13.20	18.22
T6	0-30	5.66	0.034	6.36	14.82	5.02
	30-60	5.47	0.026	2.45	13.29	7.00
T7	0-30	5.77	0.034	7.28	13.48	5.36
	30-60	5.36	0.028	2.77	13.46	5.79
T8	0-30	5.75	0.043	5.49	14.92	6.17
	30-60	5.65	0.031	3.62	14.25	7.41
T9	0-30	5.89	0.033	6.85	14.73	9.60
	30-60	5.71	0.011	3.97	14.61	14.62
T10	0-30	5.66	0.028	6.68	14.55	17.66
	30-60	5.47	0.022	3.89	13.70	18.99
T11	0-30	6.23	0.140	7.28	15.28	16.46
	30-60	6.09	0.126	2.15	15.11	17.74
T12	0-30	5.99	0.123	1.24	14.35	8.57
	30-60	5.84	0.110	0.67	14.19	4.77
T13	0-30	5.52	0.042	3.39	13.52	13.06
	30-60	5.13	0.029	2.47	13.16	20.70
T14	0-30	5.48	0.044	2.78	13.88	19.05
	30-60	5.22	0.020	0.93	12.24	23.57
T15	0-30	5.56	0.065	6.01	13.87	15.92
	30-60	5.42	0.048	2.35	13.56	13.93
T16	0-30	5.23	0.035	7.21	12.88	5.00
	30-60	5.11	0.022	3.32	13.34	5.02
T17	0-30	6.38	0.119	5.70	15.55	20.01
	30-60	6.10	0.105	2.13	15.34	19.87
T18	0-30	5.79	0.056	4.22	14.63	21.28
	30-60	5.66	0.044	2.91	14.43	16.30
T19	0-30	5.46	0.096	2.75	14.28	9.42
	30-60	5.37	0.084	0.91	14.14	12.39
T20	0-30	5.33	0.077	2.17	14.26	14.64
	30-60	5.21	0.052	1.38	13.82	8.66
T21	0-30	5.63	0.069	8.19	13.97	4.51
	30-60	5.59	0.058	3.97	13.53	4.55
T22	0-30	6.11	0.108	5.45	15.27	10.07
	30-60	6.08	0.098	2.82	15.19	5.91
T23	0-30	5.06	0.022	4.21	12.81	19.78
	30-60	4.89	0.018	2.95	9.39	12.79
T24	0-30	5.21	0.044	5.46	13.96	3.50
	30-60	5.07	0.039	2.14	13.72	4.09
T25	0-30	6.11	0.112	3.32	15.57	14.99
	30-60	5.74	0.104	1.84	14.39	19.72
T26	0-30	5.28	0.042	7.32	13.49	6.32
	30-60	5.07	0.038	3.31	13.10	7.20

Sl. No.	Depth (cm)	pH	EC (1:2) (dS m^{-1})	OC (g kg^{-1})	CEC [cmol(p^+) kg^{-1}]	BS (%)
T27	0-30	5.69	0.035	7.83	14.28	10.97
	30-60	5.03	0.030	4.42	14.01	16.94
T28	0-30	5.55	0.067	6.36	14.57	11.81
	30-60	5.47	0.054	3.33	14.37	19.36
T29	0-30	6.11	0.120	2.71	15.69	6.47
	30-60	6.08	0.111	1.11	15.15	7.39
T30	0-30	5.29	0.048	6.38	13.97	17.56
	30-60	5.07	0.032	2.47	13.50	14.74
Range	0-30	4.32 - 6.38	0.018 - 0.140	1.24 - 8.19	7.93 - 15.69	3.50 - 21.28
	30-60	4.11 - 6.10	0.011 - 0.126	0.67 - 4.42	7.54 - 15.34	4.09 - 23.57
Mean	0-30	5.54 ± 0.47	0.06 ± 0.03	5.52 ± 1.92	13.71 ± 1.91	12.39 ± 5.64
	30-60	5.34 ± 0.48	0.05 ± 0.03	2.66 ± 1.02	13.14 ± 2.09	13.83 ± 6.21

3.2 Available NPK Status in Soils

The nutrient status of soil is a critical factor in determining the success of crop cultivation and it plays a pivotal role in the growth and productivity of plants. Malnad region which is known for its extensive arecanut cultivation, understanding the available nutrient status in the soil is of utmost importance. The availability of different nutrients is presented in Tables 4, 5 and 6.

3.2.1 Available Nitrogen (kg ha^{-1})

Nitrogen holds significant importance in arecanut growing soils as it is indispensablefor robust plant growth and essential for the synthesis of chlorophyll. In these soils, nitrogen is predominantly found in organic forms, primarily within organic matter. This organic nitrogen undergoes a transformation, facilitated by microorganisms, to become accessible to plants in forms like ammonium and nitrate. Thus, maintaining an adequate supply of nitrogen, often bound within organic matter, is vital to ensure healthyarecanut crops with efficient photosynthesis, leading to enhanced growth and productivity.

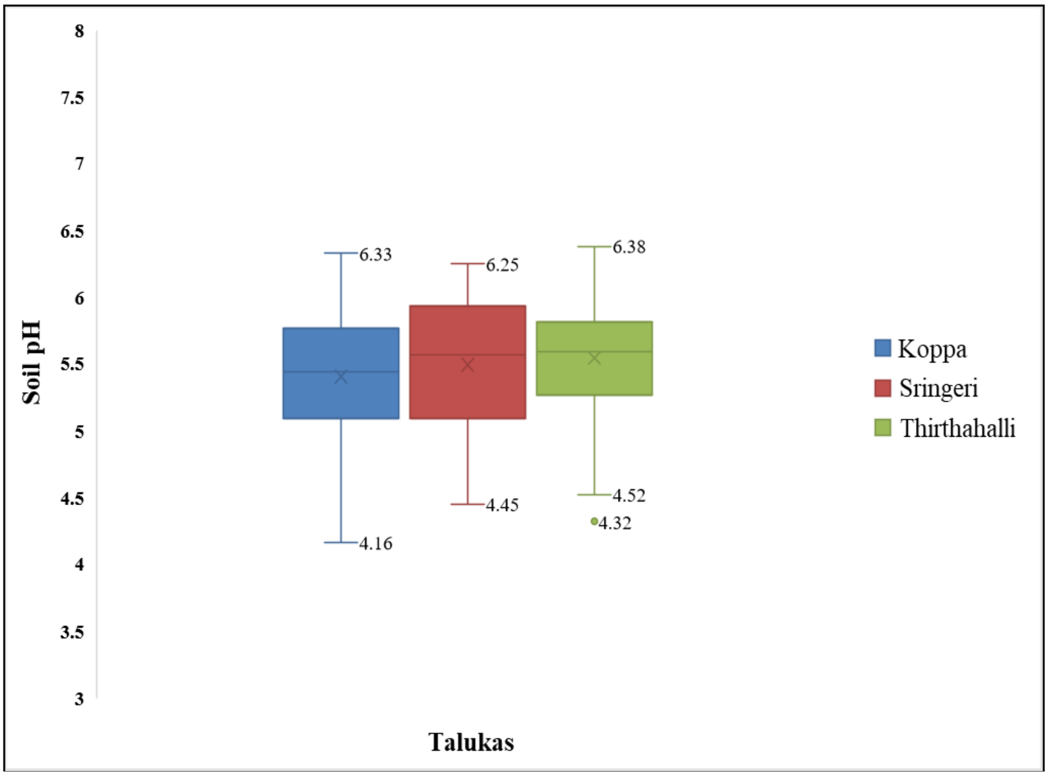

Fig. 2a. Soil reaction (pH) of surface soils in the arecanut gardens of selected taluks of Malnad region

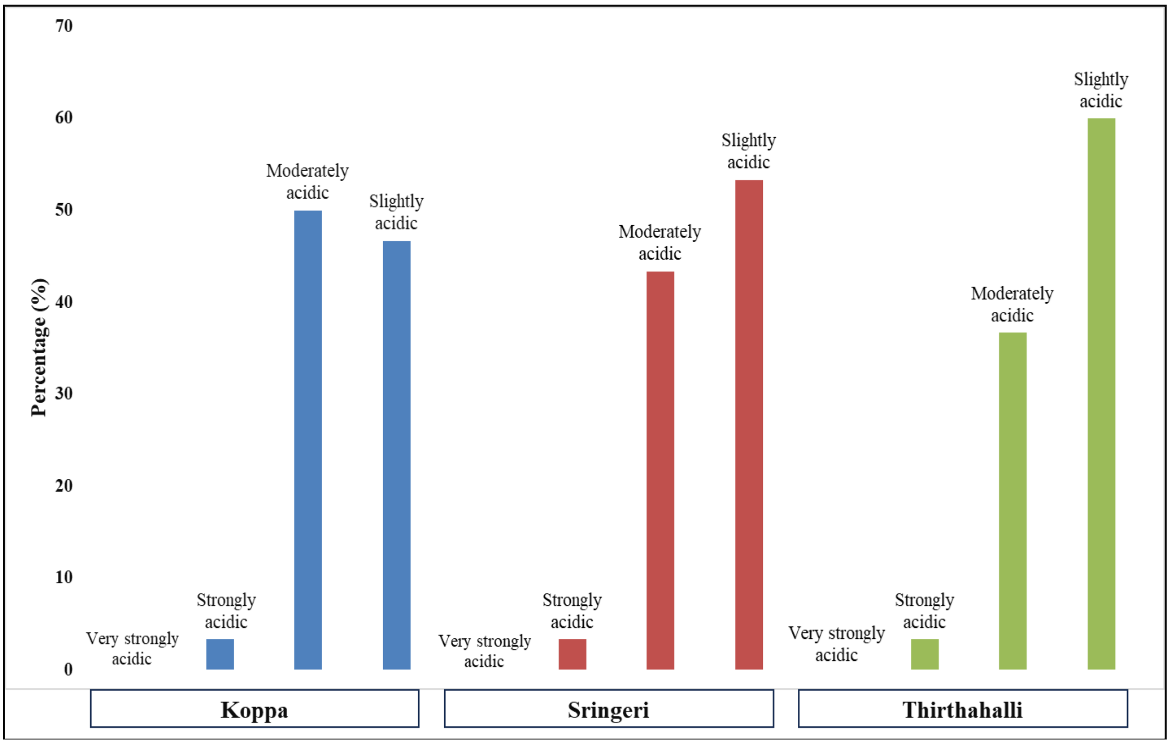

Fig. 2b. Per cent distribution of soil pH classes of surface soils in the arecanut gardens of selected taluks of Malnadregion

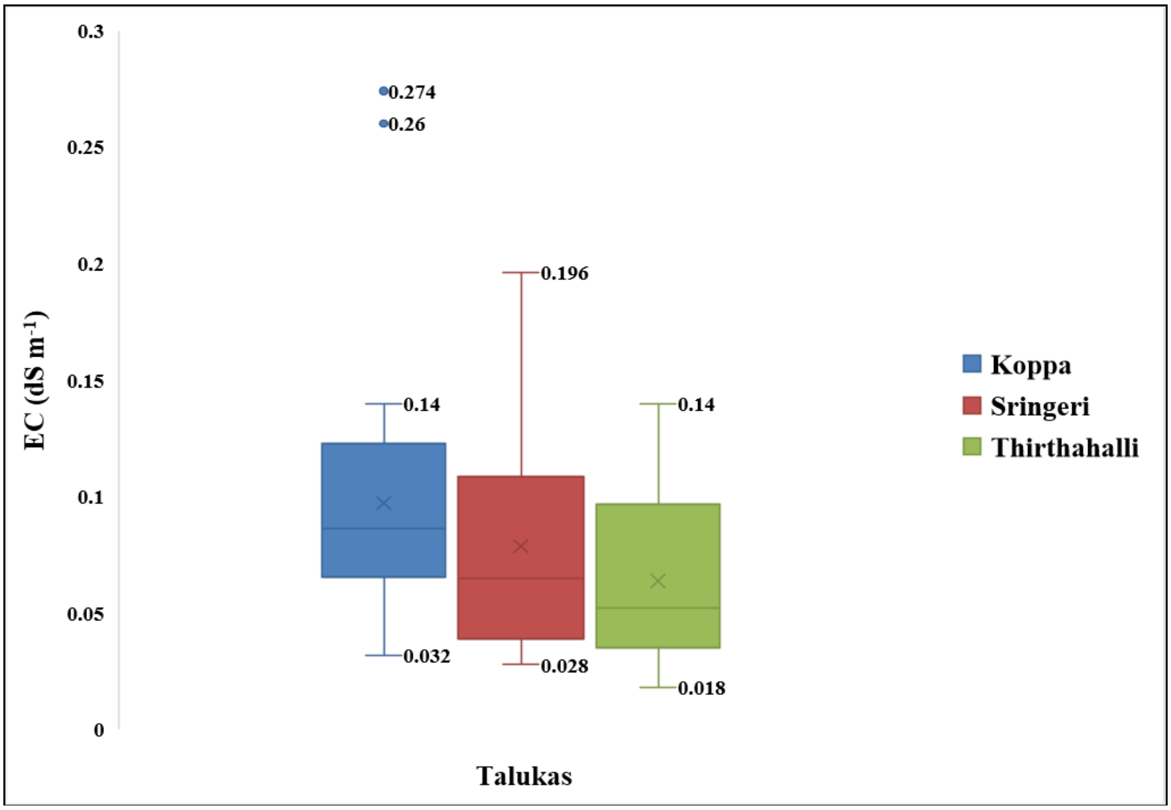

Fig. 3a. Soluble salt content of surface soils in the arecanut gardens of selected taluks of Malnad region

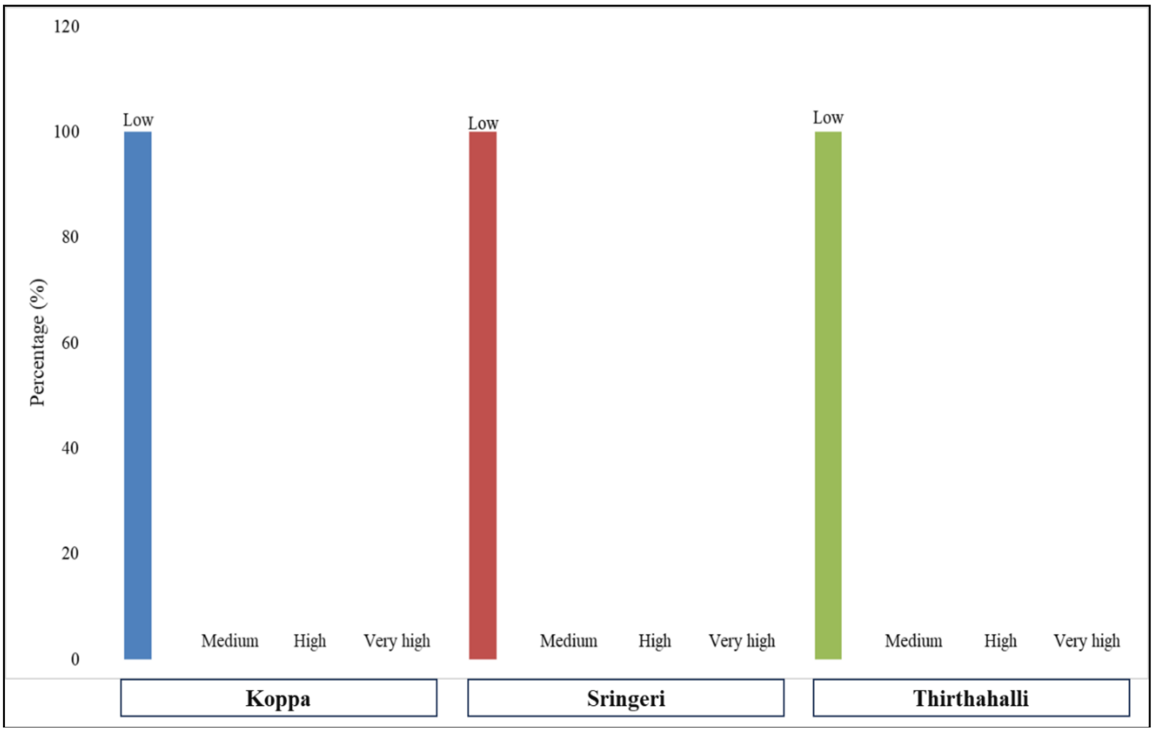

Fig. 3b. Percent distribution of EC classes of surface soils in the arecanut gardens of selected taluks of Malnad region

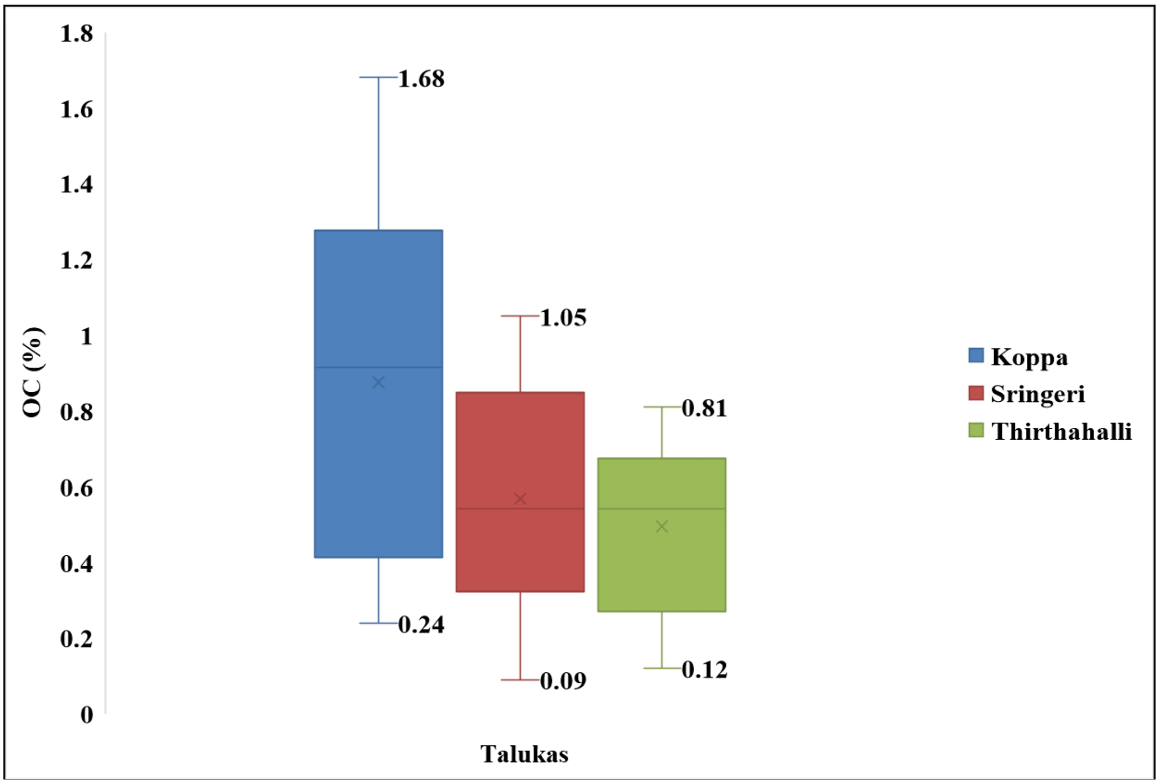

Fig. 4a. Soil organic carbon status of surface soils in the arecanut gardens of selected taluks of Malnad region

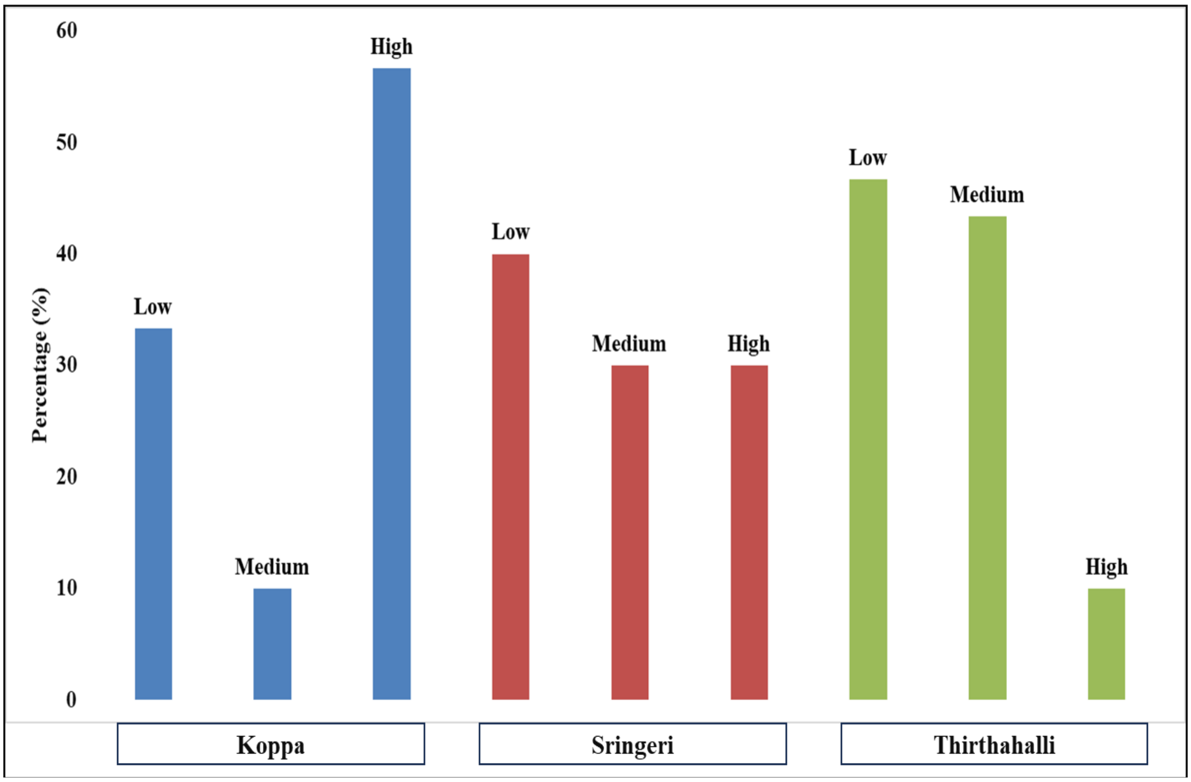

Fig. 4b. Percent distribution of soil organic carbon classes of surface soils in the arecanut gardens of selected taluks of Malnad region

Nitrogen values within the arecanut gardens of the Koppa taluk exhibit a notable range, spanning from 263.42 to 777.72 kg ha^{-1}at a depth of 0 to 30 cm, and from 137.98 to 326.14 kg ha^{-1} at a depth of 30 to 60 cm (refer toTable 4). In this taluk, nitrogen values in the top 30 cm of soil display a wide range, indicating potential variability in soil fertility. The presence of 56.67 per cent of samples in the medium status range and 40 per cent in the high-status range suggests that a considerable portion of the arecanut gardens in this region has access to sufficient nitrogen for optimal plant growth (Fig. 5a and 5b). The gradual decrease in nitrogen content with depth is typical and can be attributed to the fact that nitrogen is often concentrated in the upper soil layers due to organic matter decomposition and nutrient cycling. The high nitrogen values in this taluk might be influenced by specific agricultural practices or soil types.

In the Sringeri taluk, nitrogen values within the study area range from 175.61 to 777.72 kg ha^{-1} at a depth of 0 to 30 cm, and from 112.89 to 351.23 kg ha^{-1} at a depth of 30 to 60 cm, as outlined in Table 5. Here, a similar trend of decreasing nitrogen values with increasing depth is observed, reflecting a common pattern in soil nutrient distribution. Approximately 46.67 per cent of samples from the surface layer fall within the medium to high status range, indicating favourable conditions for arecanut cultivation as visually depicted in Fig. 5a and 5b. This region's moderate to high nitrogen levels in the surface layers may be attributed to both natural factors and agricultural practices, including the use of nitrogen-containing fertilizers.

In Thirthahalli taluk, the nitrogen values encompass a range of 100.35 to 526.84 kg ha^{-1} at the 0 to 30 cm depth and 62.72 to 338.68 kg ha^{-1} at the 30 to 60 cm depth, as detailed in Table 6. While nitrogen values in the top 30 cm are within a comparable range to the other taluks, a remarkable 90 per cent of samples from the surface layer indicate a medium status (Fig. 5a and 5b). This suggests a consistent and relatively uniform level of nitrogen availability, potentially influenced by the prevalent soil types or local agricultural practices. The gradual decline in nitrogen values with depth remains consistent with the natural nutrient distribution pattern.

In summary, the variations in nitrogen values among the three taluks can be attributed to a combination of factors, including soil types, agricultural practices and local environmental conditions. Understanding these differences is crucial for tailoring nutrient management strategies in each region to ensure optimal arecanut cultivation and sustainable agricultural practices.

In general, soil organic carbon content is commonly used as an indicator of available nitrogen content. Despite the high levels of soil organic carbon in the study area, the availability of nitrogen in the soil is relatively low. This phenomenon may be attributed to the leaching of nitrate nitrogen, primarily caused by heavy rainfall and the region's undulating terrain, resulting in the loss of accessible nitrogen. Additionally, nitrogen availability is affected by crop uptake and other losses. Notably, many arecanut farmers in the Malnad region rely on inorganic nitrogen fertilizers, with urea being a preferred source due to its high nitrogen content. However, it's worth noting that urea is also susceptible to volatilization losses, as observed by Teena *et al.* (2023). The arecanut crop's substantial nitrogen removal, estimated at 236 kg per hectare, is a consequence of high crop demand, limited mineralization, and overall low availability of nitrogen in the soil within the Malnad region (Bhat and Sujatha, 2012).

3.2.2 Available Phosphorous (kg ha^{-1})

Phosphorus plays a pivotal role in arecanut growing soils of the Malnad region, serving as a crucial nutrient involved in various vital plant processes, including energy transfer, root development, flowering and fruiting. The availability of phosphorus is paramount for ensuring robust arecanut yields. Adequate phosphorus levels promote healthier root systems, which are particularly crucial for anchoring the tall arecanut palms in the region's hilly terrain.

In Koppa taluk, phosphorus values exhibit a range from 8.02 to 37.63 kg ha^{-1} at a depth of 0 to 30 cm, and from 5.26 to 18.06 kg ha^{-1} at a depth of 30 to 60 cm (Table 4). This suggests that phosphorus content generally declines with increasing soil depth, a trend consistent with nutrient distribution patterns. Notably, 60 per cent of samples taken from the surface layer indicate a low status, while 40 per cent fall within the medium range (Fig. 6a and 6b). This disparity may be attributed to factors such as soil types and historical agricultural practices, impacting the availability of phosphorus in Koppa's arecanut gardens.

In Sringeri taluk, phosphorus values range from 10.03 to 46.41 kg ha^{-1} at a depth of 0 to 30 cm, and from 6.39 to 20.07 kg ha^{-1} at a depth of 30 to 60 cm (Table 5). Approximately 56.67 per cent of samples from the surface layer fall within the medium range, while 43.33 per cent exhibit a low status (Fig. 6a and 6b). This variation can be influenced by factors like soil types, topography, and fertilization practices specific to Sringeri.

Thirthahalli taluk presents similar trends, with phosphorus values ranging from 8.02 to 39.13 kg ha^{-1} at the 0 to 30 cm depth and from 5.14 to 18.43 kg ha^{-1} at the 30 to 60 cm depth (Table 6). A majority, 56.67 per cent, of samples from the surface layer indicate a low phosphorus status, while 43.33 per cent display a medium status (Fig. 6a and 6b). These differences in phosphorus values may be attributed to inherent soil characteristics and agricultural management practices in Thirthahalli.

In conclusion, the diversity in phosphorus values across the three taluks reflects distinct soil characteristics, varying approaches to nutrient management and the influence of historical agricultural practices in each locale. Recognizing and comprehending these disparities are imperative for customizing phosphorus management techniques tailored to the specific needs of arecanut cultivation in Koppa, Sringeri and Thirthahalli taluks.

The study area's soil, with a pH ranging from slightly acidic to moderately acidic range, promotes favourable phosphorus availability compared to acidic or alkaline soils. Many arecanut growing soils in the region exhibit a medium range of phosphorus content, closely linked to the soil's pH (0.59). This favourable phosphorus availability is attributed to the use of rock phosphate as a P fertilizer, which, combined with the soil's acidity, converts it into water-soluble P accessible to plants. The substantial application of organic manures like FYM and sheep manure by farmers further enhances P availability. Despite phosphorus's essential role in plant growth, the arecanut's nutrient uptake hierarchy reveals a lower P requirement compared to N and K. With only 20 kg of phosphorus removal per hectare, in contrast to 236 kg of nitrogen and 90 kg of potassium (Bhat and Sujatha, 2012), along with regular use of organic and inorganic fertilizers, the soil consistently maintains a medium to high level of available phosphorus. Notably, Kumar&Ullasa(2017) noted variations in phosphorus levels in arecanut gardens across Karnataka due to diverse phosphorus sources.

3.2.3 Available Potassium (kg ha^{-1})

The potassium status in arecanut growing soils is a pivotal determinant of crop health and yield. Adequate potassium levels are essential as this nutrient plays a fundamental role in maintaining proper plant functions, including regulating water uptake, strengthening disease resistance and optimizing photosynthesis. An imbalance or deficiency in potassium can lead to reduced water efficiency, increased susceptibility to diseases and overall plant vigor, ultimately impacting arecanut production. Therefore, closely monitoring and managing potassium levels in arecanut soils is imperative to ensure robust and productive arecanut crops.

The potassium values in the three taluks, Koppa, Sringeri and Thirthahalli, exhibit variations in their respective arecanut gardens. In Koppa taluk, the potassium content gradually decreases with depth, ranging from 108 to 424.32 kg ha^{-1} at 0 to 30 cm and from 61.20 to 301.56 kg ha^{-1} at 30 to 60 cm (Table 4). The majority of samples (43.33 %) in the surface layer indicate a medium status, while 40 per cent display a high status (Fig. 7a and 7b).

In Sringeri taluk, the potassium values vary from 182.88 to 494.64 kg ha^{-1} at 0 to 30 cm and from 87.12 to 265.44 kg ha^{-1} at 30 to 60 cm (Table 5). Approximately 60 per cent of samples from the surface layer fall within the medium range, while 40 per cent show a high status (Fig. 7a and 7b).

In Thirthahalli taluk, the potassium values range from 114.12 to 434.76 kg ha^{-1} at 0 to 30 cm and from 62.64 to 301.56 kg ha^{-1} at 30 to 60 cm (Table 6). Similar to Koppa, a significant 46.67 per cent of surface layer samples indicate a medium status, while 30 per cent display a high status (Fig. 7a and 7b).

Table 4. Available primary nutrient status of surface and sub-surface soils in the arecanut gardens of Koppa taluk of Malnad region

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
K1	0-30	564.48	31.48	226.44
	30-60	225.79	14.42	69.12
K2	0-30	388.86	37.63	108.00
	30-60	213.24	18.06	61.20
K3	0-30	677.37	12.04	421.44
	30-60	188.16	6.52	301.56
K4	0-30	777.72	15.30	122.76
	30-60	313.60	9.65	103.56
K5	0-30	702.46	26.71	146.76
	30-60	238.33	12.41	86.40
K6	0-30	677.37	24.96	424.32
	30-60	163.07	7.90	219.12
K7	0-30	263.42	14.04	323.16
	30-60	238.33	7.77	183.36
K8	0-30	326.14	12.29	375.36
	30-60	213.24	7.02	240.60
K9	0-30	388.86	13.92	352.32
	30-60	313.60	6.39	174.24
K10	0-30	426.49	8.02	363.36
	30-60	150.52	5.26	155.52
K11	0-30	765.18	30.23	377.76
	30-60	326.14	11.91	189.48
K12	0-30	388.86	14.80	141.96
	30-60	137.98	12.41	93.00
K13	0-30	526.84	8.65	115.44
	30-60	250.88	6.52	62.76

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
K14	0-30	514.30	17.18	204.72
	30-60	263.42	5.64	102.72
K15	0-30	363.77	19.69	302.64
	30-60	188.16	8.52	168.00
K16	0-30	451.58	19.56	315.84
	30-60	250.88	6.27	154.08
K17	0-30	413.95	32.73	384.60
	30-60	263.42	12.04	132.24
K18	0-30	338.68	14.04	339.12
	30-60	213.24	8.65	184.92
K19	0-30	464.12	31.36	136.32
	30-60	301.05	15.05	90.24
K20	0-30	677.37	22.07	216.24
	30-60	225.79	10.28	90.00
K21	0-30	652.28	19.19	235.56
	30-60	200.70	6.52	122.76
K22	0-30	715.00	22.83	300.00
	30-60	225.79	11.16	194.76
K23	0-30	413.95	9.28	386.64
	30-60	238.33	5.64	252.48
K24	0-30	451.58	33.36	384.84
	30-60	213.24	8.40	301.32
K25	0-30	351.23	34.37	241.80
	30-60	137.98	11.28	94.68
K26	0-30	589.56	26.71	122.76
	30-60	200.70	8.02	91.56
K27	0-30	489.21	15.30	325.44
	30-60	150.52	6.77	209.52
K28	0-30	577.02	21.82	394.08
	30-60	150.52	9.40	150.72
K29	0-30	664.83	24.20	398.40
	30-60	263.42	10.28	144.60
K30	0-30	413.95	13.92	325.68
	30-60	137.98	6.77	122.76
Range	0-30	263.42 - 777.72	8.02 - 37.63	108.00 - 424.32
	30-60	137.98 - 326.14	5.26 - 18.06	61.20 - 301.56
Mean	0-30	513.88 ± 145.78	20.92 ± 8.47	283.79 ± 105.52
	30-60	219.93 ± 54.10	9.23 ± 3.16	151.58 ± 66.66

Table 5. Available primary nutrient status of surface and sub-surface soils in the arecanut gardens of Sringeri taluk of Malnad region

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
S1	0-30	175.61	37.63	198.48
	30-60	112.89	17.56	89.40
S2	0-30	326.14	42.27	481.44
	30-60	137.98	20.07	210.60
S3	0-30	564.48	46.41	435.12
	30-60	263.42	9.40	182.76
S4	0-30	765.18	33.86	306.48
	30-60	351.23	8.65	134.64
S5	0-30	740.09	14.42	222.72
	30-60	263.42	8.15	134.88
S6	0-30	313.60	10.03	385.80

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
	30-60	213.24	7.02	170.04
S7	0-30	639.74	27.22	354.72
	30-60	263.42	10.53	158.64
S8	0-30	301.05	32.11	305.28
	30-60	250.88	6.89	137.76
S9	0-30	338.68	11.91	375.00
	30-60	175.61	6.89	221.40
S10	0-30	288.51	15.42	258.96
	30-60	263.42	11.91	122.76
S11	0-30	313.60	21.19	270.72
	30-60	213.24	12.04	171.24
S12	0-30	413.95	32.36	390.72
	30-60	163.07	9.40	209.40
S13	0-30	602.11	39.13	325.32
	30-60	238.33	17.56	136.32
S14	0-30	539.39	46.28	341.40
	30-60	213.24	12.04	195.12
S15	0-30	652.28	12.04	182.88
	30-60	263.42	6.52	87.12
S16	0-30	740.09	33.74	296.88
	30-60	288.51	10.66	148.32
S17	0-30	313.60	39.01	318.48
	30-60	238.33	14.04	205.32
S18	0-30	702.46	11.79	386.04
	30-60	150.52	7.90	264.12
S19	0-30	765.18	19.56	254.64
	30-60	301.05	11.66	176.88
S20	0-30	639.74	21.07	399.00
	30-60	150.52	14.04	182.52
S21	0-30	677.37	39.76	231.12
	30-60	137.98	15.30	102.84
S22	0-30	351.23	46.28	261.24
	30-60	163.07	15.05	110.76
S23	0-30	777.72	11.91	225.24
	30-60	288.51	6.77	102.72
S24	0-30	351.23	18.56	329.40
	30-60	313.60	8.52	161.88
S25	0-30	413.95	21.19	478.20
	30-60	263.42	9.53	265.44
S26	0-30	238.33	33.24	494.64
	30-60	125.44	14.30	252.84
S27	0-30	288.51	45.40	222.12
	30-60	137.98	19.81	97.08
S28	0-30	702.46	40.39	318.48
	30-60	238.33	12.16	185.04
S29	0-30	652.28	11.03	206.76
	30-60	263.42	6.39	129.24
S30	0-30	413.95	40.26	398.64
	30-60	150.52	12.41	149.40
Range	0-30	175.61 - 777.72	10.03 - 46.41	182.88 - 494.64
	30-60	112.89 - 351.23	6.39 - 20.07	87.12 - 265.44
Mean	0-30	500.08 ± 192.78	28.52 ± 12.74	321.86 ± 87.65
	30-60	219.93 ± 64.53	11.44 ± 3.97	163.22 ± 50.05

Table 6. Available primary nutrient status of surface and sub-surface soils in the arecanut gardens of Thirthahalli taluk of Malnad region

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
T1	0-30	100.35	30.23	194.76
	30-60	75.26	14.30	111.00
T2	0-30	288.51	39.13	258.24
	30-60	87.80	17.31	206.88
T3	0-30	413.95	10.78	267.60
	30-60	137.98	5.26	174.72
T4	0-30	514.30	27.22	396.00
	30-60	288.51	11.03	257.64
T5	0-30	100.35	21.57	229.80
	30-60	62.72	12.29	98.76
T6	0-30	489.21	8.02	134.76
	30-60	163.07	5.26	101.40
T7	0-30	464.12	33.36	349.44
	30-60	188.16	7.40	221.52
T8	0-30	288.51	31.23	399.00
	30-60	137.98	11.28	180.00
T9	0-30	451.58	30.23	397.32
	30-60	288.51	11.91	144.48
T10	0-30	526.84	27.34	182.76
	30-60	137.98	12.41	111.00
T11	0-30	489.21	9.90	380.88
	30-60	313.60	5.14	158.88
T12	0-30	413.95	16.93	129.84
	30-60	213.24	8.65	87.00
T13	0-30	526.84	24.83	114.12
	30-60	326.14	7.02	73.68
T14	0-30	413.95	19.81	216.84
	30-60	175.61	8.78	114.48
T15	0-30	213.24	16.68	271.44
	30-60	87.80	8.40	208.80
T16	0-30	338.68	26.84	434.76
	30-60	112.89	10.53	154.08
T17	0-30	451.58	24.83	423.00
	30-60	163.07	9.03	184.92
T18	0-30	351.23	16.68	124.20
	30-60	137.98	8.65	85.68
T19	0-30	363.77	18.31	232.32
	30-60	112.89	10.16	101.28
T20	0-30	326.14	19.69	247.56
	30-60	263.42	7.77	134.76
T21	0-30	338.68	22.95	233.40
	30-60	163.07	10.53	62.64
T22	0-30	401.40	9.53	122.76
	30-60	225.79	6.52	74.76
T23	0-30	451.58	32.99	421.44
	30-60	250.8	8.27	301.56
T24	0-30	501.7	29.35	135.24
	30-60	338.68	10.03	103.56
T25	0-30	388.86	26.84	266.76
	30-60	112.89	13.79	101.28
T26	0-30	401.40	32.73	244.32
	30-60	125.44	13.17	111.96
T27	0-30	363.77	37.63	209.40

Sl. No.	Depth(cm)	N(kg ha^{-1})	P_2O_5(kg ha^{-1})	K_2O(kg ha^{-1})
	30-60	137.98	18.43	74.76
T28	0-30	514.30	11.91	421.44
	30-60	200.70	7.15	301.56
T29	0-30	476.67	14.04	122.76
	30-60	188.16	9.28	103.56
T30	0-30	451.58	27.97	146.76
	30-60	125.44	10.53	86.40
Range	0-30	100.35 - 526.84	8.02 - 39.13	114.12 - 434.76
	30-60	62.72 - 338.68	5.14 - 18.43	62.64 - 301.56
Mean	0-30	393.88 ± 111.74	23.32 ± 8.66	256.96 ± 108.96
	30-60	178.12 ± 77.56	10.01 ± 3.25	141.10 ± 66.12

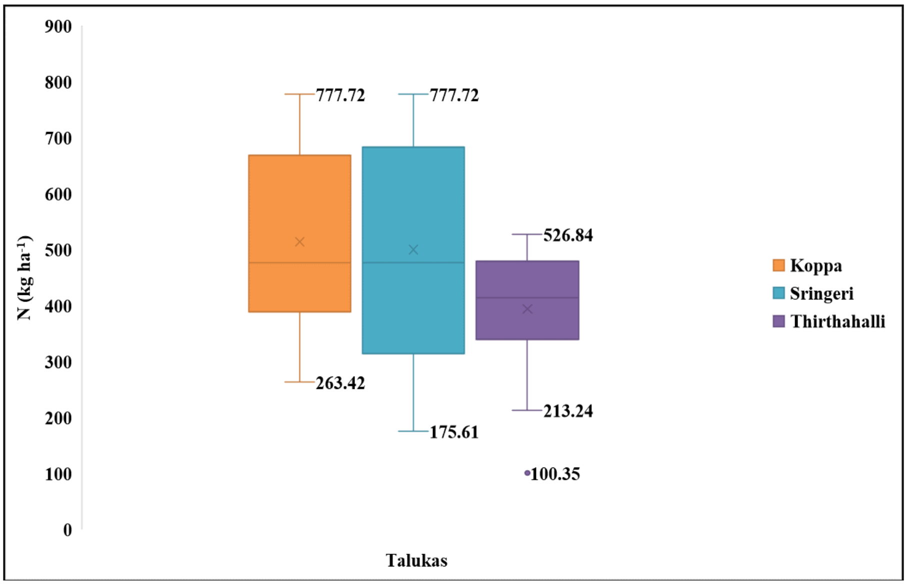

Fig. 5a. Available nitrogen status of surface soils in the arecanut gardens of selected taluks of Malnad region

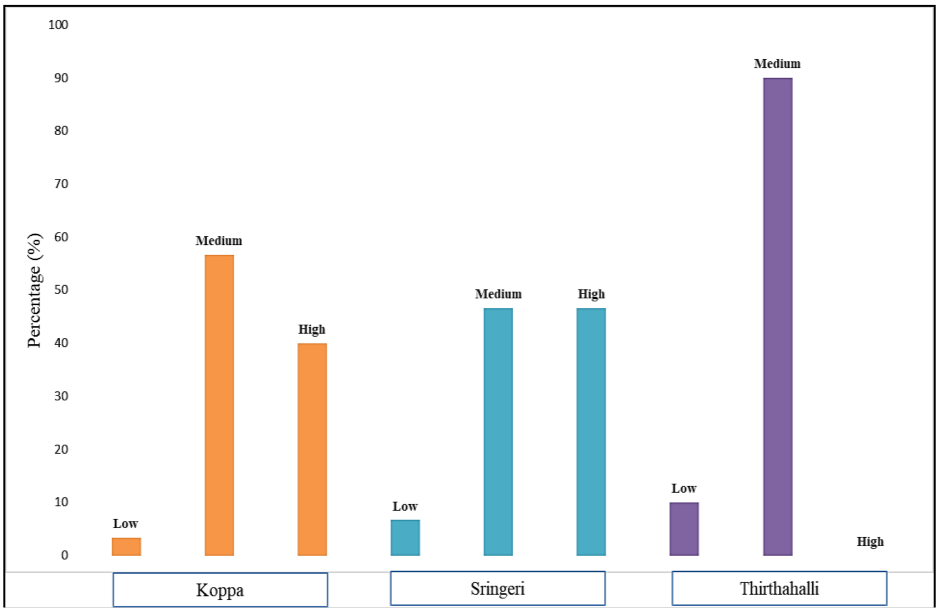

Fig. 5b. Percent distribution of available nitrogen classes of surface soils in the arecanut gardens of selected taluks of Malnad region

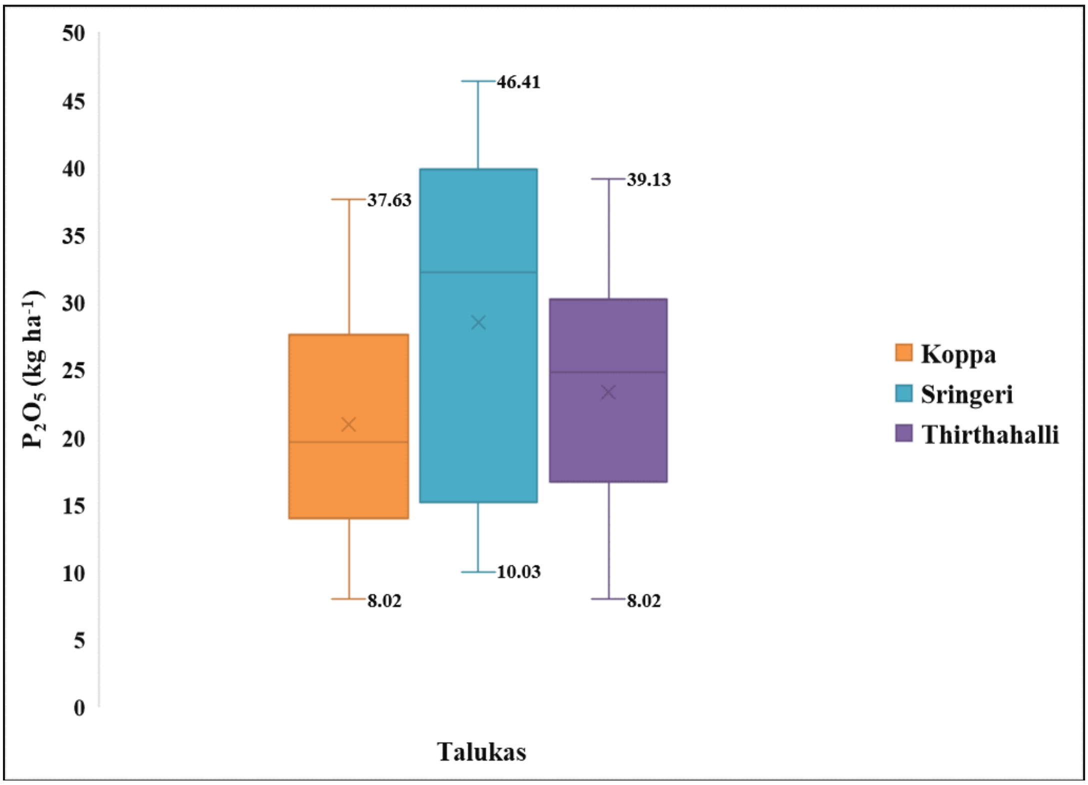

Fig. 6a. Available phosphorous status of surface soils in the arecanut gardens of selected taluks of Malnad region

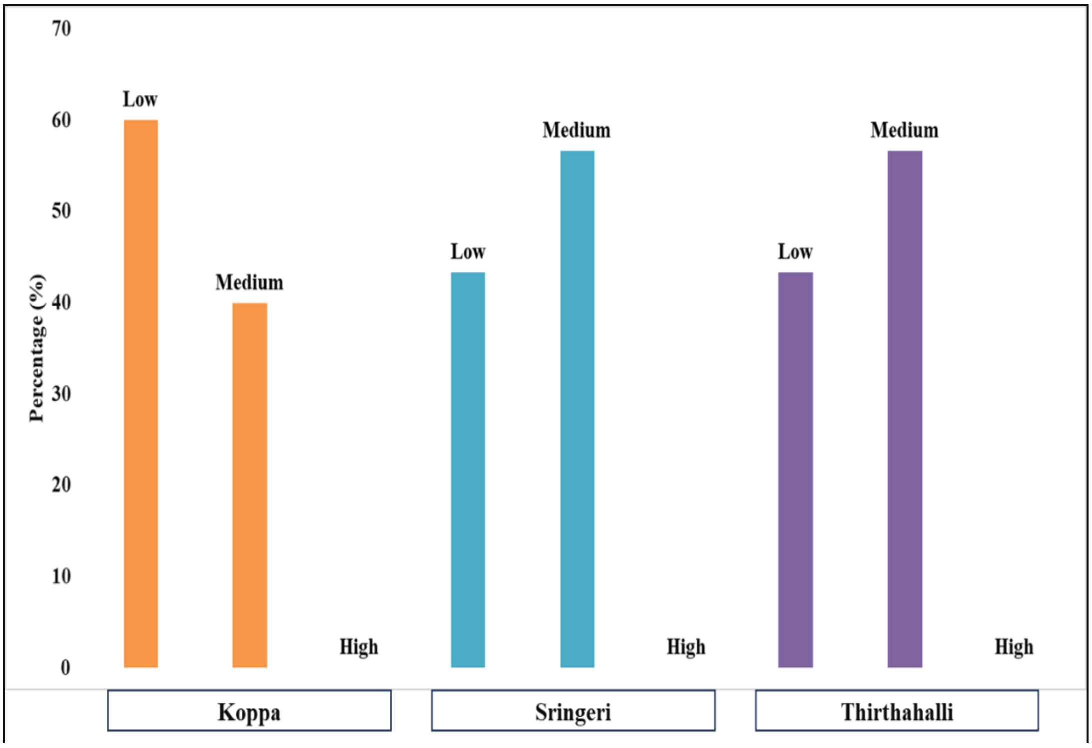

Fig. 6b. Percent distribution of available phosphorous classes of surface soils in the arecanut gardens of selected taluks of Malnad region

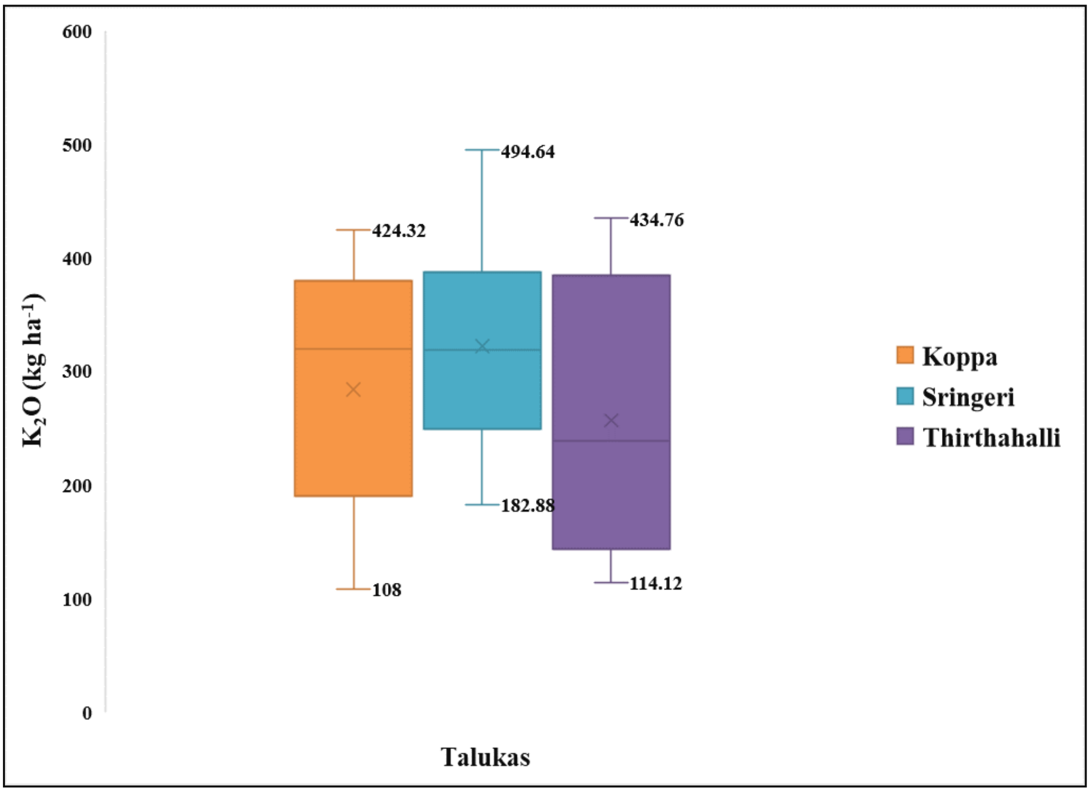

Fig. 7a. Available potassium status of surface soils in the arecanut gardens of selected taluks of Malnad region

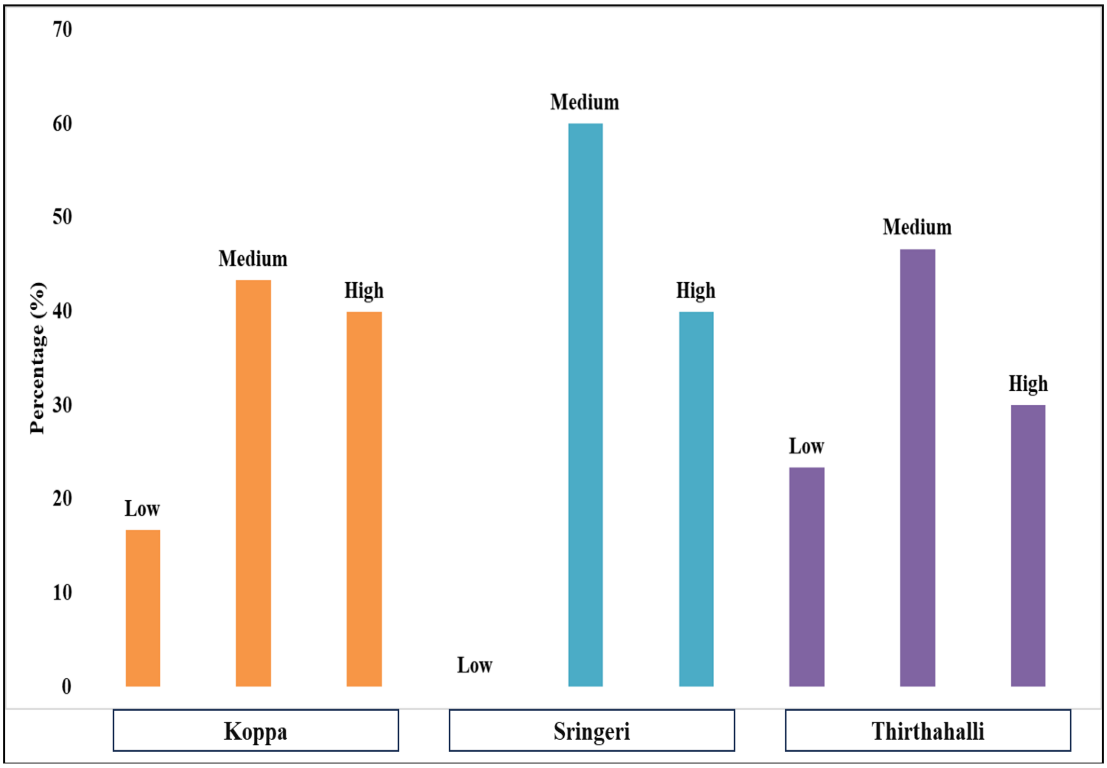

Fig. 7b. Percent distribution of available potassium classes of surface soils in the arecanut gardens of selected taluks of Malnad region

The inherent fertility of soils in each taluk, in conjunction with historical land utilization practices, can be a driving factor in potassium variations. Potassium availability is closely intertwined with weathering processes and the specific clay mineral composition within the soil. Within the Malnad region, farmers consistently employ potassium-based fertilizers and incorporate organic amendments like FYM and vermicompost into their agricultural practices. Moreover, the predominant clay mineral in arecanut-growing soils in the Malnad region is the 1:1 type Kaolinite, which exhibits a lower capacity for potassium fixation. Considering the substantial potassium demands of arecanut cultivation (up to 90 kg ha^{-1}, as documented by Bhat and Sujatha in (2012), the cumulative effect is a medium-range potassium availability status.

4. Conclusion

- The results from the analysis of survey samples of the three taluks of Malnad region *viz.* Koppa, Sringeri and Thirthahalli indicated that particle size analysis of soil samples exhibited a range of textural classes from sandy loam to sandy clay loam. The pH varied from slightly acidic to very strongly acidic and all samples from all the three taluks showed low status for soluble salt concentration.
- Among the exchangeable bases, calcium and magnesium were dominant cations followed by sodium and potassium. As such surface soils found to possess low cation exchange capacity. All the three taluks display a similar trend of increasing CEC values with greater soil depth. However, the specific CEC value ranges differ among the taluks, suggesting variations in the base saturation status. Further, per cent base saturation was low and varied which can be attributed to textural variations and differences in the status of organic matter.
- The analysis of the samples revealed a medium status regarding the availability of primary nutrients such as N, P and K.
- The study is significant for the scientific community as it provides comprehensive baseline data on soil fertility parameters in arecanut-growing regions of Malnad area, addressing a critical gap in understanding nutrient dynamics in high-rainfall, acidic soils that influence perennial crop productivity. By detailing variations in pH, electrical conductivity, organic carbon, cation exchange capacity, base saturation and available NPK across three taluks, it offers valuable insights into soil health constraints like leaching and nutrient imbalances, which can inform targeted agronomic interventions to enhance yield and sustainability. Furthermore, the study emphasizes on regional-specific factors such as heavy rainfall and parent material influences which contributes to broader knowledge in tropical soil science, aiding researchers in developing climate-resilient farming strategies and supporting policy decisions for plantation crop management in similar agro-ecological zones.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Acharya, G. C., Paul, S. C., Chakrabarty, R., & Ray, A. K. (2015). Effect of organic and inorganic sources of nutrients on soil fertility status of arecanut (*Areca catechu*) in north-east India. *Indian Journal of Agricultural Sciences*, *85*(10), 1335-41.https://doi.org/10.56093/ijas.v85i10.52299

Alur, A.S. (1994). *Properties of Red Soils of Agroclimatic Zone-3 (Region II) of North Karnataka* (Doctoral dissertation, University of Agricultural Sciences). https://krishikosh.egranth.ac.in/server/api/core/bitstreams/de005e34-dc93-43ee-b875-6b147d3f4888/content

Ananthanarayana, R., Reddy, M. N., Mithyantha, M. S. &Perur, N. G. (1986). Status of available secondary nutrients in acid soils of Karnataka. *Journal of the Indian Society of Soil Science,*34(3), 614-616.

Bhat, R. & Sujatha, S. (2012). Influence of biomass partitioning and nutrient uptake on yield of arecanut grown on a laterite soil. *Communications in Soil Science and Plant Analysis,* 43(13), 1757-1767. https://doi.org/10.1080/00103624.2012.684823

Bhat, R., Sujatha, S., Bhavishya, Priya, U. K., Gupta, A. &Uchoi, A. (2024). Arecanut (*Areca catechu* L.). In *Soil Health Management for Plantation Crops: Recent Advances and New Paradigms* (pp. 177-206), Singapore: Springer Nature Singapore. https://doi.org/10.1007/978-981-97-0092-9_4

Jackson, M. L. (1973). Soil Chemical Analysis. *Prentice Hall of India, Pvt. Ltd.* http://krishikosh.egranth.ac.in/handle/1/5810135824

Jayaprakash, R., Arun Malage&S, Jyothikiran. (2024). Assessment of Soil Nutrient Status for Arecanut Cultivation in Karnataka, India. *International Journal of Environment and Climate Change*, 14(7), 435–442. https://doi.org/10.9734/ijecc/2024/v14i74283

Jayaprakash, R., Shetty, Y. V., Punitha, B. C. &Shilpashree, V. M. (2012). Physico-chemical properties of surface soils in arecanut growing region of Southern Karnataka (Non-traditional), 7(2), 324-326. http://www.researchjournal.co.in/online/AJSS.htm

Kumar, M. D., &Ullasa, M. Y. (2017). Spatial distribution of organic carbon in selected arecanut gardens of Karnataka. *International Journal of Farm Sciences*, 7(3), 28-33. https://www.sadhnahp.com/article-overview/spatial-distribution-of-organic-carbon-in-selected-arecanut-gardens-of-karnataka

Kumbar, V. K., Shivakumar, K. M., Manukumar, H. R., Nagaraja, M. S., Satagond, R. M., Yogeeshappa, H., &Meti, S. (2025). Impact of different nutrient management practices on soil fertility status in arecanut and black pepper cropping system of Uttara Kannada district, Karnataka, India. *International Journal of Research in Agronomy, 8*(6), 450–455. https://doi.org/10.33545/2618060X.2025.v8.i6f.3058

Mediratta, J. C., Bansal, K. N. & Gupta, G. P. (1985). Characterisation of Some Salt-Affected Soils of Harsi Command Area of Madhya Pradesh. *Journal of the Indian Society of Soil Science,* 33(1), 214-217.

Paramesh, V., Kumar, P., Kumar, R. M., Jinger, D., Chillarge, S., Bhattacharjee, S., &Sannagoudar, M. S. (2025). Soil quality enhancement in arecanut (*Areca catechu*)-based agroforestry system: Insights from organic farming and integrated nutrient management. *The Indian Journal of Agricultural Sciences*, *95*(3), 331-335. https://doi.org/10.56093/ijas.v95i3.162261

Sahu, G. C., Patnaik, S. N. & Das, P. K. (1990). Morphology, genesis, mineralogy and classification of soils of northern plateau zone of Orissa. *Journal of the Indian Society of Soil Science,* 38, 116-121. https://www.cabidigitallibrary.org/doi/full/10.5555/19901949183

Shetty, Y. V., Narayanaswamy, C., Dhananjaya, B. C., &Shesagiri, K. S. (2009). Available micronutrient status in the traditional arecanut growing soils of Karnataka. *Mysore Journal of Agricultural Sciences*, 43(3), 579-582. https://www.cabidigitallibrary.org/doi/10.1079/PA20090000

Subbiah, B. V., &Asija, G. L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science*, 25, 259-260. https://www.cabidigitallibrary.org/doi/full/10.5555/19571900070

Sujatha, S., & Bhat, R. (2016). Impact of organic and inorganic nutrition on soil–plant nutrient balance in arecanut (Areca catechu L.) on a laterite soil. *Journal of Plant Nutrition*, *39*(5), 714-726. https://doi.org/10.1080/01904167.2015.1087561

Teena, R., Meti, S., Nagaraj, M. S., Yogeeshapa, H., Hadimani, H. P., &Shreepad, V. (2023). Soil fertility mapping of arecanut growing areas in SirsiHobli of Uttara Kannada district, Karnataka. *The Pharma Innovation Journal,* 12(3), 1234-1238. https://www.thepharmajournal.com/archives/2023/vol12issue3/PartK/12-2-112-450.pdf

Vasundhara, R., Prakash, N. B., Anil Kumar, K. S., Hegde, R., &Dharumarajan, S. (2021). Soil fertility status of coconut and arecanut growing soils. *Journal of Plantation Crops*, 49(2), 83-89.

https://doi.org/10.25081/jpc.2021.v49.i2.7254

Veerabhadra, R. K. (1992). *Dynamics of aluminium in base unsaturated soils of Karnataka* (Doctoral dissertation, University of Agricultural Sciences; Bangalore). https://krishikosh.egranth.ac.in/items/3c0c0eba-181c-4548-bdb5-540006b12b79

Walia, C. S. &Chamua, G. S. (1990). Characteristics, classification and suitability for land use planning of foothill soils. *Journal of the Indian Society of Soil Science,*38(2): 286-292.

Walkley, A. J., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modificationof the chromic acid titration method. *Soil Science,* 37(1), 29-38. https://doi.org/10.1097/00010694-193401000-00003

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