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Soil fertility status of coconut and arecanut growing soils

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Abstract

The present study was undertaken to assess the soil fertility status of major coconut and arecanut growing soils in different agro-climatic conditions of Karnataka state, India. Based on the agro-climate variability, 30 typical soil pedons representing five different agro-climatic zones (ACZs) of Karnataka, namely, eastern dry zone (EDZ), southern dry zone (SDZ), southern transitional zone (STZ), hilly zone (HZ), and coastal zone (CZ), were studied for their physicochemical properties. The study revealed that soils of semi-arid (EDZ and SDZ) and sub-humid (STZ) zones have near neutral to moderately alkaline reaction and humid region soils (coastal and hilly zones) have high acidity. The soils are non-saline with low cation exchange capacity. Greater soil organic carbon was recorded in arecanut soils than coconut under all ACZs except the coastal zone. The major nutrients status of the soil samples indicated that the available nitrogen is low in all the pedons; the pooled data of available nitrogen content was higher in arecanut (166.3 kg ha^{-1}) than coconut (152.6 kg ha^{-1}), and hilly zone soils recorded higher available nitrogen. A wide range of available P_2O_5 was noticed in coconut and arecanut soils, ranging from 1.0 to 64.2 kg ha^{-1}. The coconut soils (11.5 kg ha^{-1}) recorded higher available P_2O_5 than arecanut soils (9.62 kg ha^{-1}) when data were pooled. The soils were low to medium in available potassium, and a higher available K_2O content was recorded in arecanut soils (151.7 kg ha^{-1}) compared to coconut (110.1 kg ha^{-1}). The available K_2O ranged from 66.8 to 511.7 kg ha^{-1} in the surface and 37.6 to 461.2 kg ha^{-1} in sub-surface soils.

***Keywords*:** Arecanut, agro-climatic zone, coconut, major nutrients, pedons, soil fertility

Introduction

Arecanut (*Areca catechu* L.) and coconut (*Cocos nucifera* L.) are predominant perennial plantation crops in south India. Cultivation of these palms in India also has a rich diversity and varied history, with each crop having its own distinct historical and economic context of development. Karnataka is one of the major producers of plantation crops. Coconut and arecanut are cultivated in different agro-climatic regions in Karnataka (Singh *et al.,* 2013) under diverse climatic conditions and soil types. Due to variation in environmental conditions and management, the productivity of these crops also varies under different agro-climatic zones (ACZs). Soil fertility is one factor that limits the productivity of these crops, mainly influenced by the inherent capacity of the soil. The factors which influence soil fertility are mineral composition, soil pH, soil texture, organic matter and cation exchange capacity (CEC). To understand palm productivity in a particular region or climate, an understanding of soil fertility status is essential. Maintaining soil fertility is highly important to sustain the yield of arecanut (Bhat and Sujatha, 2014).

Knowing the inherent capacity of soils to provide nutrients is an important crop nutrient prerequisite to decide the extent of organic residues required, *i.e.,* the manures and fertilizers to be applied per palm to obtain a better yield. Hence, the present study was undertaken to understand the fertility levels of soils in arecanut and coconut growing areas under different agro-climatic conditions of Karnataka to deliver soil quality information to achieve sustainable yields. This information will also guide the balanced use of

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fertilizer and implementation of cropping pattern as a component crop in plantation-based systems under varied climatic conditions.

Materials and methods

Soil profiles were excavated in coconut and arecanut plantations covering five different agro-climatic zones (ACZs), with varying rainfall, topography, soil type and climatic characteristics, including cropping patterns. The study location represents five ACZs, covering major production centres of arecanut and coconut plantations of Karnataka. Three profiles from each of these five ACZs were selected by recording GPS points (Fig. 1) for the study, and the location details are mentioned in Table 1. The soil profiles were dug to a depth of 120 cm. The site for sampling was representative of the area. The soil profiles were examined by demarcating different horizons based on colour, texture and structure. The details such as depth, colour, texture and structure were recorded in standard proforma for soil profile description. The list of profile samples collected from different ACZs and the details are presented in Table 1.

One hundred seventy-six soil samples representing 30 soil profiles were drawn at different depths depending upon horizon distribution. A portion of each of the soil samples was air-dried, ground in a wooden pestle with mortar and passed through a 2 mm stainless steel sieve for determining various soil properties. Electrical conductivity and pH were determined by standard methods (Jackson, 1973). Easily oxidizable organic carbon was estimated according to the wet oxidation method (Walkley and Black, 1934). Available nitrogen was estimated by the alkaline permanganate method (Subbiah and Asija, 1956). The soil samples were both in the acidic and alkaline range. Hence both Olsen's reagent (for neutral and alkaline soils) and Bray's reagent (for acid soils) were used for extraction. The phosphorus content in the soil extract was determined by blue colour formed by the ascorbic acid-molybdate complex, and the colour intensity was read at 660 nm using a spectrophotometer (Jackson, 1973). The exchangeable potassium was extracted with neutral normal ammonium acetate from a known quantity of soil. The filtered extract was fed to a flame photometer for measuring available potassium content (Page *et al*., 1982).

Site description

In Karnataka, these plantation crops are grown in the eastern dry zone (EDZ), southern dry zone (SDZ), southern transitional zone (STZ), hilly zone (HZ), and coastal zone (CZ). EDZ and SDZ experience hot moist, semi-arid climate, recording average annual rainfall of 750 mm to 850 mm,

Table 1. Details of soil profile samples collected from arecanut and coconut plantations representing different agro-climatic zones of Karnataka

	Location (Coconut)	Location (Arecanut)
Eastern dry zone	Gubbi	Hebbur, Tumkur
	Kanakuppe, Tumkur	Borogowdana Palya, Kunigal
	Hottigana Hosahali Channapattana	Hesaraghatta
Southern dry zone	Thamadahalli, Chamarajanagar	T. Narasipura
	Kadaballi Nelamangala	Cholanahalli Channarayapattana
	V.C Farm, Mandya	Channegowdana Doddi, Maddur
Southern transitional zone	Bhadravathi	Tarikere
	Gurupura Hunusur	H D Kote
	Muddanahalli Village, Hassan	Hosur Alur Hassan
Hilly zone	Mavinakere, Kalasa	Sukkamatti, Sringeri
	Manase, Sringeri	Bidharahalli, Mudigere
	ARS Mudigere	Sirsi
Coastal zone	Udupi	Mudalu, Karkala,
	Mogeru, Belthangady	Pillya, Belthangady
	Bramhavar	Kumata

length of dry period >150 days. STZ has a sub-humid climate receiving 950 mm rainfall, length of dry period-120 days. Hilly and coastal zone have hot, humid climate receiving an annual average rainfall of >1500 mm and 4500 mm, respectively, with 90 days of dry period. The soil temperature regime is isohyperthermic for all the studied soils as they have a difference of less than 5 °C between mean summer temperature and mean winter temperatures at a depth of 50 cm and a mean annual soil temperature of 22 °C or higher.

Results and discussion

Soil reaction and electrical conductivity

Soil nutrient availability was directly influenced by soil pH. Results of soil pH revealed that the soil pH was higher in all the agroclimatic zones except in HZ and CZ of the study area. (Table 2 and Fig. 2).

Soil pH ranged from 5.13-8.34 in coconut to 4.99-8.32 in arecanut soils. The pH of EDZ, SDZ, STZ, HZ and CZ varied from 7.46-7.79, 8.05-8.34, 6.79-7.58, 5.15-6.12 and 5.13-5.25, respectively, in coconut soils, whereas in arecanut, the soil pH varied from 7.55-7.91, 8.12- 8.32, 7.72-7.85, 4.99-5.34 and 5.43-5.65, respectively.

Irrespective of crop, a very low pH range was recorded in HZ and CZ soil pedons, while high pH was observed in SDZ soil pedons (Fig. 2a & b). Electrical conductivity in EDZ, SDZ, STZ, HZ and CZ ranged from 0.155-0.212, 0.115-0.18, 0.135-0.15, 0.043-0.05, and 0.03-0.232 dS m^{-1} in coconut soils. In arecanut soils, EC ranged from 0.185-0.253, 0.151-0.207, 0.155-0.251, 0.03-0.0.52 and 0.022-0.031 dS m^{-1}, respectively.

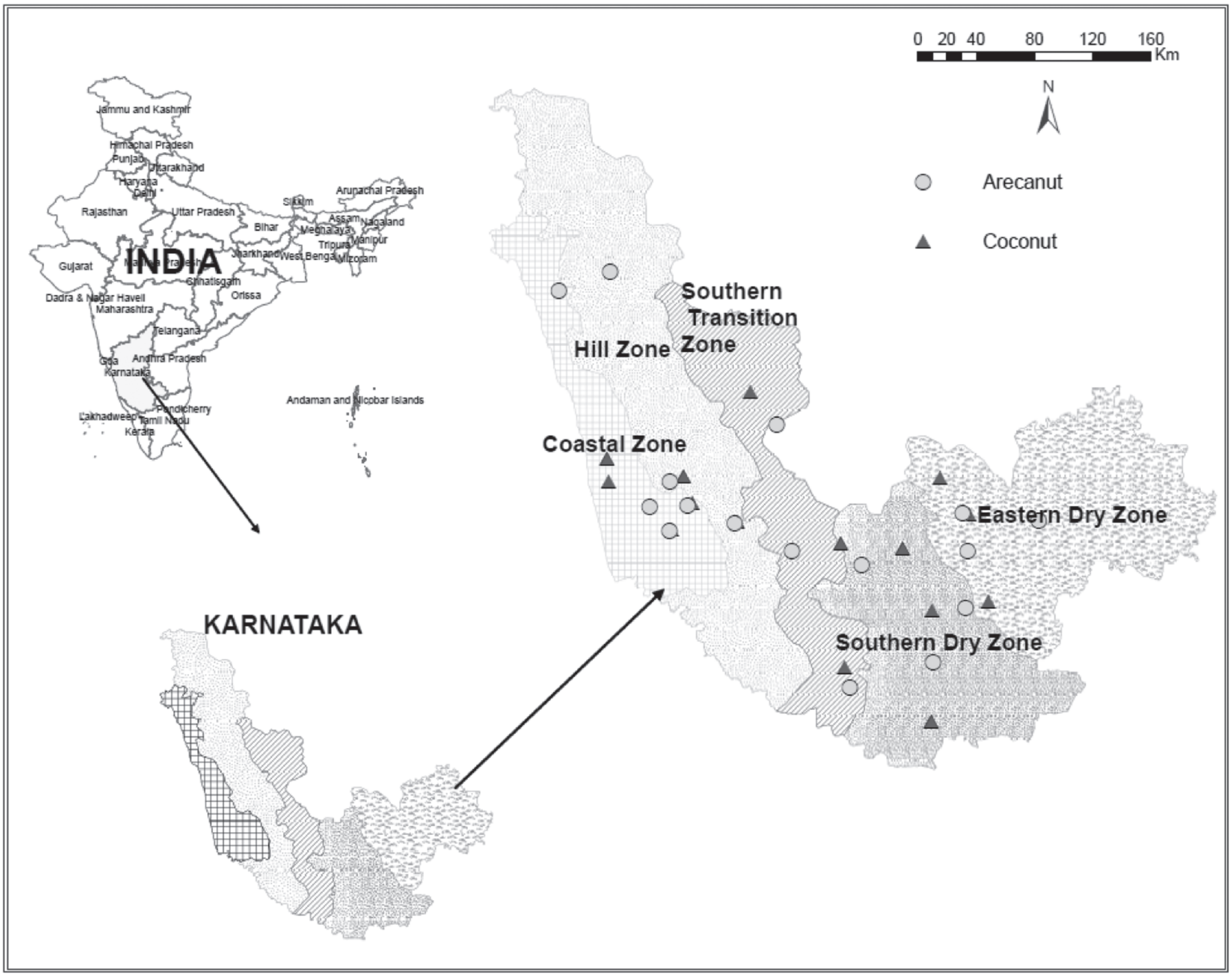

Fig. 1. Location map of the study area

Analysis of coconut and arecanut soils representing different agro-climatic zones of Karnataka revealed that EDZ, SDZ, and STZ soils were slight to moderately alkaline, HZ and CZ were acidic, and STZ were neutral in pH (Fig. 2 a and b). Electrical conductivity values indicated the non-saline nature of the soils of the study area.

Moderate to slightly acidic soil reaction in HZ and CZ soils are mainly due to the heavy rainfall, which causes leaching of bases, thereby reducing the soil pH. Badrinath *et al.* (1995) reported that southern parts (CZ and HZ) of Karnataka were distributed with acidic soil, affecting crop yields. Slightly to moderately alkaline soil reaction in other areas was due to accumulation of basic salts from the weathered parent material.

Soil organic carbon and cation exchange capacity (CEC)

Soils of arecanut plantations recorded higher organic carbon content compared to coconut. An increase in organic carbon content noticed in arecanut soils may be due to well managed mixed farming system, which produces higher recyclable biomass from component crops, and higher biomass turnover in arecanut enhances the carbon in soil compared to coconut. Arecanut has a higher recycling potential of organic wastes (Sujatha *et al.*, 2015). Arecanut also equally contributes greater

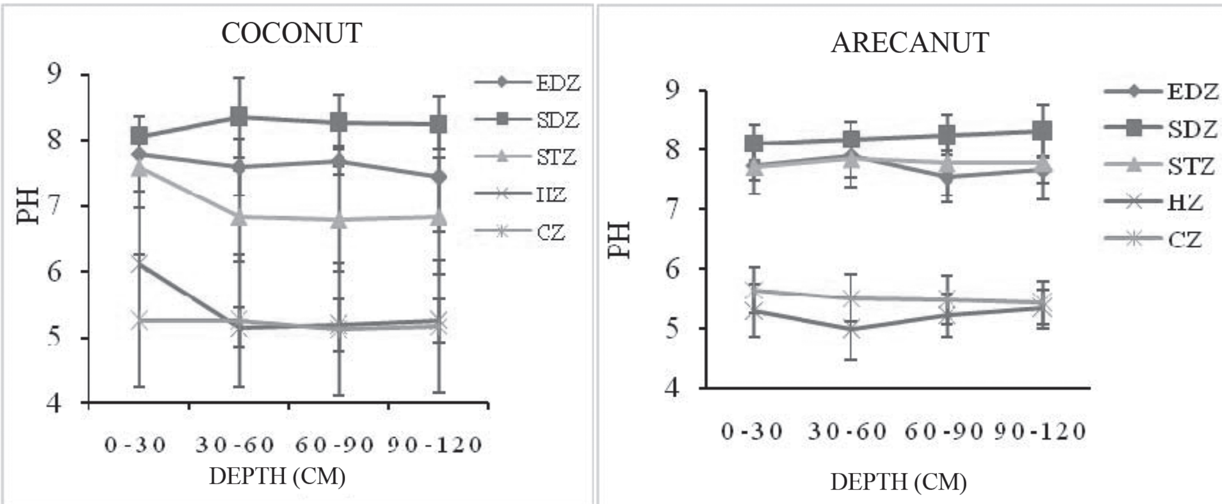

Fig. 2. Soil reaction-in different depths of coconut and arecanut plantations across different agro-climatic zones

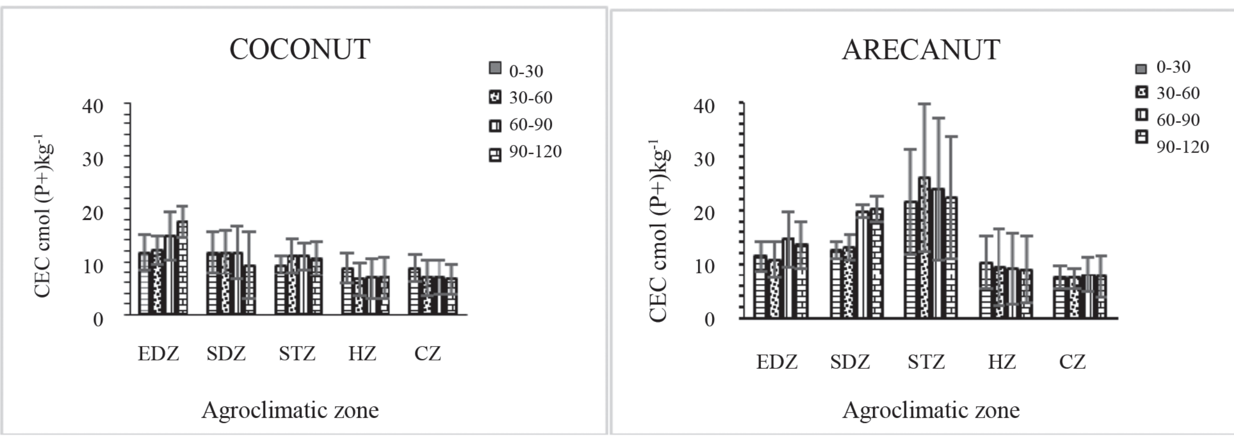

Fig. 3. CEC in different depths of coconut and arecanut plantations across different agro-climatic zones

Table 2. Per cent clay, pH, EC and CEC of soil pedons of coconut and arecanut plantations across different agro-climatic zones (ACZ) of Karnataka

ACZ	Depth (cm)	Coconut Clay (%)	Coconut pH	Coconut EC (dS m^{-1})	Coconut CEC cmol (p+) kg^{-1}	Arecanut Clay (%)	Arecanut pH	Arecanut EC (dS m^{-1})	Arecanut CEC cmol (p+) kg^{-1}
Eastern dry zone	0-30	31.2(±10.8)	7.8(±0.6)	0.2 (±0.2)	11.7(±3.2)	28.1(±12.8)	7.7(±0.24)	0.253(±0.09)	11.39(±2.71)
	30-60	32.4(±9.2)	7.6(±0.4)	0.2 (±0.1)	12.1(±2.6)	33.9(±9.4)	7.9(±0.36)	0.187(±0.05)	10.71(±3.22)
	60-90	39.9(±3.1)	7.7(±0.2)	0.2(±0.2)	14.8(±4.6)	44.5(±3.1)	7.6(±0.43)	0.194(±0.01)	14.58(±5.22)
	90-120	41.1(±4.8)	7.5(±0.9)	0.2(±0.3)	17.5(±3.0)	43.6(±3.4)	7.7(±0.22)	0.185(±0.03)	13.58(±4.41)
Southern dry zone	0-30	27.4(±12.3)	8.05(±0.3)	0.12(±0.06)	11.69(±3.88)	32.4(±5.6)	8.12(±0.3)	0.207(±0.08)	12.56(±1.56)
	30-60	37.3(±9.9)	8.34(±0.61)	0.116(±0.06)	11.7(±3.96)	38.7(±4.2)	8.19(±0.28)	0.151(±0.04)	12.97(±2.35)
	60-90	38.1(±3.6)	8.26(±0.41)	0.115(±0.09)	11.69(±4.95)	43.1(±4.8)	8.25(±0.34)	0.165(±0.07)	19.81(±1.09)
	90-120	27.2(±7.7)	8.25(±0.4)	0.182(±0.04)	9.28(±6.21)	44.4(±3.3)	8.32(±0.44)	0.18(±0.07)	20.32(±2.31)
Southern transitional zone	0-30	25.6(±3.1)	7.58(±0.61)	0.15(±0.05)	9.32(±1.71)	38.1(±10.1)	7.72(±0.46)	0.223(±0.03)	21.62(±9.78)
	30-60	37.5(±7)	6.84(±0.7)	0.142(±0.07)	11.02(±3.12)	43.3(±7.4)	7.85(±0.46)	0.251(±0.12)	26.0(±13.84)
	60-90	36.8(±6.4)	6.79(±0.8)	0.135(±0.08)	10.99(±2.5)	42.6(±5)	7.78(±0.54)	0.199(±0.14)	23.95(±13.24)
	90-120	36.5(±7.6)	6.84(±0.88)	0.135(±0.08)	10.44(±3.13)	46.2(±2.5)	7.78(±0.6)	0.155(±0.11)	22.28(±11.36)
Hilly zone	0-30	28.8(±8.8)	6.12(±1.87)	0.05(±0.0)	8.70(±2.88)	45.4(±3.6)	5.31(±0.44)	0.05(±0.04)	10.08(±4.88)
	30-60	29.5(±7.5)	5.15(±0.31)	0.05(±0.0)	6.61(±3.17)	47.2(±6)	4.99(±0.52)	0.052(±0.05)	9.31(±7.09)
	60-90	34.6(±10.2)	5.18(±0.4)	0.043(±0.01)	6.77(±3.74)	46.5(±6.8)	5.24(±0.36)	0.037(±0.03)	9.13(±6.55)
	90-120	33.3(±13.4)	5.25(±0.32)	0.043(±0.01)	6.87(±3.82)	45.1(±7.7)	5.34(±0.33)	0.03(±0.02)	8.85(±6.15)
Coastal zone	0-30	30.3(±2.8)	5.25(±0.38)	0.232(±0.24)	8.70(±2.49)	32.4(±4.5)	5.65(±0.39)	0.031(±0.01)	7.45(±2.11)
	30-60	34.2(±6.4)	5.25(±0.27)	0.035(±0.02)	6.9(±3.37)	39.3(±6.7)	5.52(±0.39)	0.023(±0.01)	7.29(±1.98)
	60-90	33.7(±5.3)	5.13(±0.24)	0.03(±0.02)	6.97(±3.21)	40.5(±5)	5.48(±0.41)	0.025(±0.02)	8.0(±3.14)
	90-120	33.3(±4.9)	5.17(±0.28)	0.036(±0.02)	6.51(±2.85)	39.6(±5.4)	5.43(±0.36)	0.022(±0.01)	7.66(±3.82)

Table 3. Available nitrogen (kg ha^{-1}) of soil pedons of coconut and arecanut plantations in different agro-climatic zones (ACZ) of Karnataka

Depth (cm)		EDZ	SDZ	STZ	HZ	CZ	Crop × depth mean
Coconut							
0-30		192.9 (±83.4)^{a}	164.5 (±41.2)	134.8 (±15.4)	179.5 (±68.6)	239.7 (±28.4)	182.3
30-60		168.9 (±51.2)^{ab}	179.3 (±110.6)	175.8 (±39.6)	149.1 (±88.2)	213.9 (±51.3)	177.4
60-90		110.9 (±35.1)^{bc}	98.1 (±33.6)	141.5 (±43.7)	123.9 (±119.8)	164.7 (±91.2)	127.8
90-120		102.3 (±62.6)^{c}	100.9 (±92.2)	115 (±50.4)	125.4 (±122.1)	170.0 (±82.5)	122.7
Coconut×zone mean		143.8	135.7	141.8	144.5	197.1	152.6
SEm±		17.2	34.7	17.8	16.6	20.1	
CD at 0.05		59.4	NS	54.0	50.7	61.0	
Arecanut							
0-30		158.4 (±64.4)	236.6 (±70.2)	223.7 (±18)^{a}	263.6 (±38.8)	189.9 (±86.1)	214.4
30-60		160.8 (±28.3)	185.0 (±33)	188.4 (±52.2)^{ab}	235.3 (±135.9)	158.5 (±42.4)	185.6
60-90		141.1 (±68.9)	139.9 (±97)	143.7 (±32.3)^{bc}	207.3 (±112.1)	131.2 (±39.5)	152.7
90-120		116.2 (±24.6)	86.2 (±51.4)	118.8 (±25.8)^{c}	168.6 (±112.2)	73.1 (±50.6)	112.6
Arecanut×zone mean		144.1	161.9	168.7	218.7	138.2	166.3
SEm±		28.4	29.9	16.8	30.0	33.5	
CD at 0.05		NS	90.1	58.2	NS	99.6	
Grand zone mean		143.9	148.8	155.2	181.6	167.6	Depth mean
Interactions	C	Z	D	C×Z	C×D	Z×D	C×Z×D
SEm±	9.1	14.3	12.8	20.2	18.1	28.6	40.5
CD at 0.05	NS	NS	36.1	57.1	NS	NS	NS

The results are shown as the mean (±SD). Values with the same letters within columns (soil depths) are not significantly different at $P<0.05$. C:Crop, Z:Zone, D:Depth, EDZ:eastern dry zone, SDZ:southern dry zone, STZ:southern transition zone, HZ:hilly zone and CZ:coastal zone

biomass (8.5-18 t ha^{-1} depending on the age of arecanut crop) like other palms such as coconut (12-18 t ha^{-1}) and oil palm (14-15 t ha^{-1}) owing to high population density per unit area. Among the ACZs, HZ soils recorded the highest organic carbon content, which might be due to clay mineralogy, clay fraction and biochemical environment of the soil such as pH, higher rainfall, its intensity and distribution in a year, which favours higher production of biomass. It is very much evidenced (Table 4) that the clay content of the hilly zone was higher compared to other ACZ pedons. Higher accumulation of soil organic carbon in hilly and mountain areas can be attributed to favourable soil-climate environment (Fig. 4).

The results revealed that the CEC of 176 soils representing 30 soil pedons ranged from 2.53 to 38.12 cmol (p^{+}) kg^{-1}. Lower CEC was recorded in CZ, while higher CEC was observed in STZ soil pedons (Fig. 3). Soils collected from coconut plantations recorded low CEC, ranging from 6.51 to 17.45 cmol (p^{+}) kg^{-1}. In arecanut soils, CEC ranged from 7.29 to 26.0 cmol (p^{+}) kg^{-1} (Table 2 and Fig. 3).

CEC was higher in STZ ranging from 9.32 to 26.0 cmol (p^{+}) kg^{-1} followed by SDZ (9.28 to 21.32 cmol (p^{+}) kg^{-1}) and EDZ (10.71 to 17.45 cmol (p^{+}) kg^{-1}).

Table 4. Available P_2O_5 (kg ha^{-1}) in soil pedons of coconut and arecanut plantations in different agro-climatic zones (ACZ) of Karnataka

Depth (cm)		EDZ	SDZ	STZ	HZ	CZ	Crop × depth mean
Coconut							
0-30		16.5 (±11.1)	8.3 (±5.3)	64.3 (±35.7)^a	4.1 (±3.6)	15.9 (±20.0)	21.8
30-60		12.1 (±9.4)	7.9 (±4.2)	15.0 (±9.4)^b	1.4 (±0.5)	12.8 (±16.1)	9.8
60-90		9.2 (±10.6)	4.2 (±2.8)	11.9 (±6.6)^b	1.3 (±0.6)	10.4 (±13.6)	7.4
90-120		6.2 (±5.1)	4.7 (±2.8)	11.5 (±5.6)^b	1.0 (±0.0)	10.4 (±13.6)	6.8
Coconut×zone mean		**11.0**	**6.3**	**25.7**	**2.0**	**12.4**	11.5
SEm±		2.3	1.1	8.7	1.0	1.8	
CD at 0.05		**7.1**	**3.4**	**30.2**	**NS**	**NS**	
Arecanut							
0-30		17.4 (±6.87)^a	33.1 (±28.09)	20.9 (±7.75)^a	11.5 (±8.38)	5.9 (±7.5)	17.8
30-60		5.7 (±2.13)^b	19.5 (±16.77)	3.8 (±1.99)^b	8.0 (±9.17)	3.0 (±0.6)	8.0
60-90		7.2 (±4.05)^b	10.9 (±11.31)	3.5 (±2.3)^b	7.5 (±8.29)	3.8 (±0.1)	6.6
90-120		6.1 (±2.52)^b	8.3 (±4.7)	2.8 (±1.65)^b	8.9 (±10.75)	4.6 (±1.2)	6.1
Arecanut×zone mean		**9.1**	**18.0**	**7.8**	**9.0**	**4.3**	**9.6**
SEm±		2.1	4.8	2.1	4.2	2.2	
CD at 0.05		7.3	15.2	7.1	NS	NS	
Grand zone mean		**10.1** ^{bc}	**12.1** ^{ab}	**16.7** ^{a}	**5.5** ^{c}	**8.3** ^{b}	**Depth mean**
Interactions	C	Z	D	C×Z	C×D	Z×D	C×Z×D
SEm±	9.1	14.3	12.8	20.2	18.1	28.6	40.5
CD at 0.05	**NS**	**NS**	**36.1**	**57.1**	**NS**	**NS**	**NS**

The results are shown as the mean (±SD). Values with the same letters within columns (soil depths) are not significantly different at P<0.05. C:Crop, Z:Zone,D:Depth, EDZ: eastern dry zone, SDZ: southern dry zone, STZ: southern transition zone, HZ: hilly zone and CZ: coastal zone

Lower CEC was observed in HZ and CZ, ranging from 6.61 to 10.08 cmol (p$^+$) kg^{-1} and 6.51 to 8.7 cmol (p$^+$) kg^{-1}, respectively. Low CEC in HZ and CZ due to the presence of kaolinite minerals. Heavy rainfall in these regions enhanced K leaching, leading to lesser fixation of K in sites. Normally, kaolinite minerals soils hold a lesser amount of available and exchangeable K (Martin and Sparks, 1985). Organic carbon and clay content play a major role in influencing CEC. Organic carbon content decreased with depth in all soils; still, CEC showed an increasing trend indicating the mineralogy of the soils, which probably had a larger role in regulating CEC in these soils than the organic matter. Saikh *et al.* (1998) observed a poor correlation between CEC and organic carbon in ferruginous soils under deciduous forest and attributed this change in CEC to mineralogy.

Available major nutrients status in coconut and arecanut plantations

Available nitrogen

The average content of available nitrogen in coconut and arecanut soils varied from 98.1 to 239.7 kg ha^{-1} and 73.1 to 263.6 kg ha^{-1}, respectively. The mean available nitrogen content was higher in arecanut (166.3 kg ha^{-1}) than coconut (152.6 kg ha^{-1}). In coconut, higher available nitrogen was observed in CZ (197.1 kg ha^{-1}) followed by HZ (144.5 kg ha^{-1}) and in arecanut, maximum available nitrogen was observed in HZ (218.7 kg ha^{-1}) followed by STZ (168.7 kg ha^{-1}), SDZ (161.9 kg ha^{-1}), CZ (138.2 kg ha^{-1}) and EDZ (144.1 kg ha^{-1}). Among the ACZs the available nitrogen content followed the order of HZ (181.6 kg ha^{-1}) >CZ (167.6 kg ha^{-1}) >STZ (155.2 kg ha^{-1})> SDZ (148.8 kg ha^{-1}) >EDZ (143.9 kg ha^{-1}).

The available nitrogen status in coconut and arecanut soils in different ACZs are presented in Figure 4a and Table 3. Higher available nitrogen was noticed in the surface (0-30 cm) and decreased with an increase in depth; a significant difference was noticed at all depths. Higher available nitrogen noticed in 0-60 cm depth might be due to applying chemical fertilizers and FYM, high turnover of crop residues. Bhat and Sujatha (2007) observed significantly higher mineral N in the arecanut+pepper crop-based system (0-30 cm depth) than in cocoa and clove. Organic matter recycling (OMR) was significantly higher in arecanut based cropping systems than other plantations. Higher nitrogen content in HZ might be due to higher biomass returns to soil (Achalu *et al.,* 2012).

Available P_2O_5

The available P_2O_5 status in coconut and arecanut soils varied from 1.0 to 64.2 kg ha^{-1} and 2.9 to 47.8 kg ha^{-1}, respectively. The coconut soils (11.5 kg ha^{-1}) recorded higher available P_2O_5 when compared to arecanut soils (9.62 kg ha^{-1}); however, no significant difference was noticed (Fig. 4b). The low status of available P_2O_5 in arecanut soils is attributed to higher removal than replenishment due to high nutrient demand from the main crop and component crop (Table 4).

In coconut, higher available P_2O_5 was observed in STZ (25.66 kg ha^{-1}) followed by CZ (12.37 kg ha^{-1}), EDZ (11.0 kg ha^{-1}), SDZ (6.27 kg ha^{-1}) and HZ (1.96 kg ha^{-1}). In arecanut growing soil, available P_2O_5 followed the trend SDZ (17.95 kg ha^{-1}) > EDZ (9.1kg ha^{-1}) > HZ (8.97 kg ha^{-1}) ≥ STZ (7.75 kg ha^{-1}) > CZ (4.31kg ha^{-1}).

Table 5. Available K_2O (kg ha^{-1}) in soil pedons of coconut and arecanut plantations in different agro-climatic zones (ACZ) of Karnataka

Depth (cm)		EDZ	SDZ	STZ	HZ	CZ	Crop ×depth mean
Coconut							
0-30		233.6 (±275.0)	105.3 (±75.6)	198.7 (±98.2)	79.4 (±9.8)^a	125.6 (±68.1)^a	148.5
30-60		461.2 (±696.0)	54.2 (±8.2)	115.9 (±44.1)	37.3 (±5.2)^b	75.5 (±37.4)^{ab}	148.8
60-90		126.8 (±105.4)	50.7 (±19.0)	114.3 (±35.6)	40.3 (±3)^b	60.4 (±35.4)^b	78.5
90-120		88.2 (±25.0)	43.7 (±38.4)	101.2 (±35.3)	37.6 (±3.8)^b	51.5 (±34.2)^b	64.4
Coconut×zone mean		**227.4**	**63.5**	**132.5**	**48.7**	**78.3**	**110.1**
SEm±		175.0	17.4	21.4	3.7	15.0	
CD at 0.05		**NS**	**53.4**	**65.4**	**12.9**	**51.7**	
Arecanut							
0-30		119.2 (±62.4)	250.0 (±101.9)^a	511.7 (±533.2)	188.8 (±135.3)	66.4 (±31.7)	227.2
30-60		70.1 (±28.4)	136.7 (±77.4)^c	308.5 (±252.9)	118.3 (±96.7)	56.8 (±32.3)	138.1
60-90		76.9 (±27.3)	177.1 (±91.8)^b	262.7 (±134.5)	69.9 (±49.9)	58.1 (±34.3)	128.9
90-120		66.0 (±20.9)	178.7 (±94.6)^b	212.1 (±85)	48.4 (±32.3)	57.2 (±39.7)	112.5
Arecanut×zone mean		**83.1**	**185.6**	**323.7**	**106.3**	**59.6**	**151.7**
SEm±		24.4	15.0	131.7	30.1	12.2	
CD at 0.05		NS	35.9	NS	91.4	NS	
Grand zone mean		**155.3** ^{ab}	**124.5** ^{b}	**228.1** ^{a}	**77.5** ^{b}	**69.0** ^{b}	**Depth mean**
Interactions	C	Z	D	C×Z	C×D	Z×D	C×Z×D
SEm±	20.9	3.1	29.6	46.8	41.9	66.2	93.6
CD at 0.05	**NS**	**90.6**	**81.1**	**128.2**	**NS**	**NS**	**NS**

The results are shown as the mean (±SD). Values with the same letters within columns (soil depths) are not significantly different at P<0.05. C:Crop, Z:Zone,D:Depth, EDZ:eastern dry zone, SDZ:southern dry zone, STZ:southern transition zone, HZ:hilly zone and CZ:coastal zone

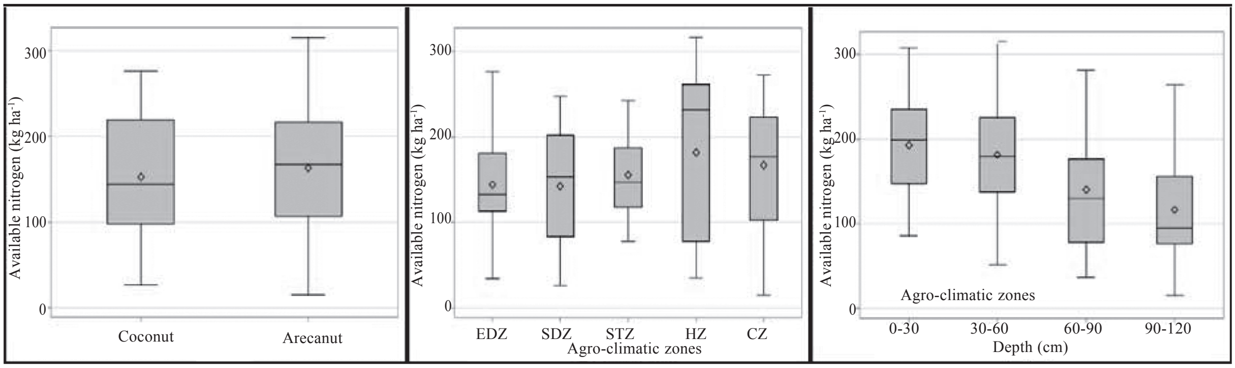

Fig. 4a. Distribution of available nitrogen (kg ha^{-1}) in (a) coconut and arecanut plantations (b) different agro-climatic zones (c) different depths of soil pedons

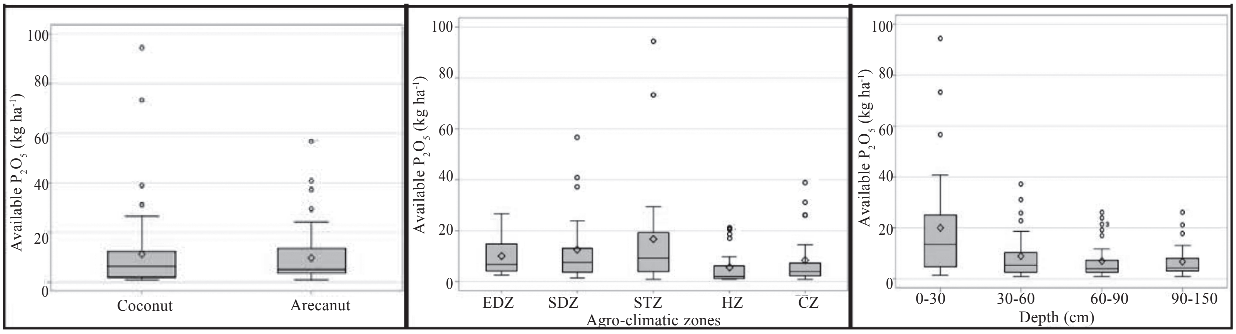

Fig. 4b. Distribution of available P_2O_5 (kg ha^{-1}) in (a) coconut and arecanut plantations (b) different agro-climatic zones (c) different depths of soil pedons

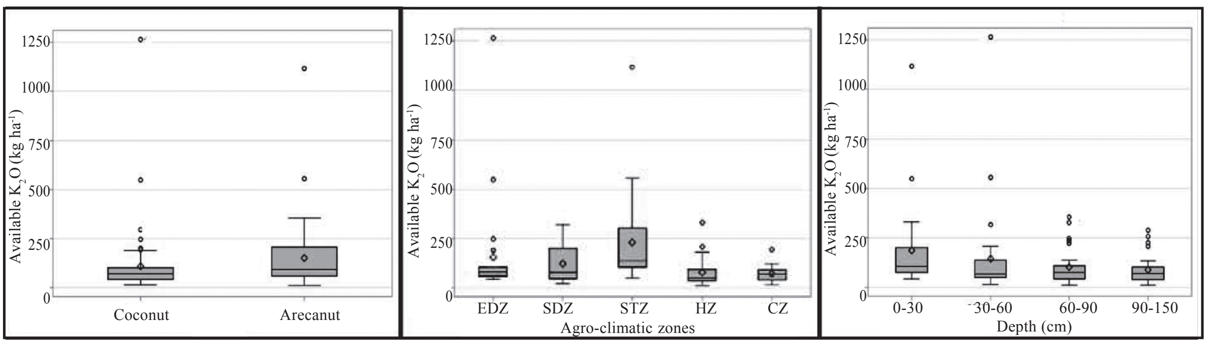

Fig. 4c. Distribution of available K_2O (kg ha^{-1}) in (a) coconut and arecanut plantations (b) different agro-climatic zones (c) different depths of soil pedons

The pooled data of available P_2O_5 content in different ACZs were 16.70, 12.11, 10.05, 8.34 and 5.47 kg ha^{-1} for STZ, SDZ, EDZ, CZ and HZ, respectively.

Lower available P_2O_5 content was observed in HZ, and CZ attributed to the lower application of fertilizers and fixation of P in acidic soils of hilly and coastal zones. The low status of P in these regions is due to the soils rich in hydrated and amorphous oxides of Fe and Al, which are potential phosphorus fixers (Perur, 1996: West *et al*., 1997). SDZ and EDZ zones recorded lower P_2O_5 than STZ due to the higher soil pH that cause P fixation in soil. The higher amount of available P_2O_5 in STZ might be due to the application of FYM and recommended dose of fertilizer, which enhances the availability in soil, and the neutral pH of these soils. An increase in P status was mainly attributed to the addition of FYM and chemical fertilizers in coconut plots (Maheswarappa *et al.*, 2008). During decomposition of organic manure, various organic acids will be produced, which solubilize phosphates and other phosphate bearing minerals, thereby lowering the phosphate fixation and increasing availability. Manna *et al.* (2006) reported that available phosphorus content increased due to the addition of FYM over initial and control. The organic matter also forms a cover on sesquioxides. It makes them inactive and thus reduces the phosphate fixing capacity of the soil, which ultimately helps in the release of an ample quantity of phosphorus (Bhardwaj *et al.*, 2010).

Higher available P_2O_5 content was observed in surface (0-30 cm) in coconut soils and ranged from 4.1 to 64.4 kg ha^{-1} with a mean of 21.82 kg ha^{-1}. In arecanut soils, available P_2O_5 at the surface (0-30 cm depth) varied from 5.9 to 33.1 kg ha^{-1} with a mean of 17.71 kg ha^{-1}. Available P_2O_5 was the least in the depth of 90-120 cm in both arecanut and coconut soils in ACZs. The declining trend in available P_2O_5 with depth was observed in soils of all zones. There was a significant difference in available P_2O_5 among depths and zone, crops and zone in the soil.

Available K_2O

The maximum amount of available K_2O content was recorded in arecanut (151.71 kg ha^{-1}) compared to coconut (110.1 kg ha^{-1}). In arecanut soils, available K_2O content ranged from 66.8 to 511.7 kg ha^{-1} in the surface and 48.4 to 308.5 kg ha^{-1} in the sub-surface. Available K_2O content in coconut soils varied from 79.4 to 233.6 kg ha^{-1} and 37.6 to 461.2 kg ha^{-1} in surface and subsurface, respectively (Table 5).

Available K_2O levels in coconut and arecanut plantations were in the order of STZ > EDZ > CZ > SDZ > HZ and STZ > SDZ > HZ > EDZ > CZ, respectively. Among the zones, irrespective of crops, STZ recorded higher available K_2O (228.1 kg ha^{-1}) followed by SDZ (124.5 kg ha^{-1}), EDZ (155.3 kg ha^{-1}), HZ (77.5 kg ha^{-1}) and CZ (69.0 kg ha^{-1}). Available K_2O was the lowest in coastal zone (laterite) soils due to heavy rainfall (>3000 mm) and topography, which accentuate the process of leaching of nutrients resulting in poor nutrient retention capacity, and these soils are poor in bases of native soil fertility with abundant sesquioxides (Babu,1981). The deficiency of nitrogen and potassium is due to the dominant clay mineral kaolinite, which has a low K fixation capacity (Badrinath *et al.*, 1998). Available nitrogen and potassium were significantly (P < 0-05) lower in soil under coconut plantations compared with double fruit crops (Manna and Singh, 2001).

In general, higher available K_2O was observed in surface (0-30 cm), and with increasing depth to the extent of 187.9, 143.5, 103.7 and 88.5 kg ha^{-1} for 0-30 cm, 30-60 cm, 60-90 cm and 90-120 cm, respectively. There was a significant difference between depths, zone and crop zone for available K_2O. At the same time, the interaction effect for crop depth and zone depth and crop×zone×depth was found to be non-significant.

Conclusion

The fertility status of coconut and arecanut growing soils of different agro-climatic zones of Karnataka indicated that soils are low to medium in available N and K in surface and sub-surface. The soils were low in available phosphorus due to high P fixing capacity and also removal than replenishment. Higher available N and K_2O were observed in arecanut soils than coconut soils. However, hilly and coastal zone have higher nitrogen than other zones due to higher biomass addition. Soils from STZ have higher inherent available K_2O related to mixed clay mineralogy.

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