

Original Research Article

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Assessment of Soil Fertility Status in major Betel Vine Growing Soils of Tumkur District of Southern Karnataka for Sustainable Production

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ABSTRACT

A study was conducted to assess the soil fertility status of major betel vine growing soils of Tumkur district of Southern Karnataka for sustainable soil management and betel vine production. Thirty soil samples were collected at two different depths (0-30 and 31-60 cm) from different betel vine plantations and analysed for pH, electrical conductivity, organic carbon and available macro and micronutrients. Analytical results revealed that the soils of the study area were neutral to slightly alkaline in reaction, non-saline in nature and high in organic carbon status. The organic carbon content ranged from 0.57 to 1.05 per cent with a mean of 0.77 per cent. The distribution of organic carbon in soils showed a decreasing trend with depth. Based on the nutrient indexing in soils, the surface soil was medium in available N (276 to 349 kg ha⁻¹), available P (11.6 to 34.3 kg ha⁻¹) and available K (187 to 243 kg ha⁻¹). The exchangeable Ca content of the soil varied from 2.6 to 4.4 cmol (p⁺) kg⁻¹ and was above 1.5 cmol (p⁺) kg⁻¹ which is the critical value for ideal soils. Exchangeable Mg content of the soils varied from 0.78 to 1.97 cmol (p⁺) kg⁻¹ with an average value of 1.30 cmol (p⁺) kg⁻¹ and found to be higher than the critical value of 1.0 cmol (p⁺) kg⁻¹ soil. The available sulphur in the soils varied from 9.4 to 15.1 mg kg⁻¹. The DTPA extractable Fe, Mn, Zn and Cu contents in surface soils ranged from 12.1 to 22.3, 3.6 to 7.2, 0.80 to 1.7 and 0.3 to 0.9 mg kg⁻¹, respectively and were sufficient in the surface soils. The contents of DTPA extractable Fe, Mn, Zn and Cu decreased with increase in soil depth. Soil analysis up to 60 cm soil depth revealed that betel vine plantations was high in organic carbon, medium in available N, P, K and S, high in exchangeable Ca and Mg, and sufficient in micronutrients. Contrary to the general perception, there has not been much depletion of soil fertility in betel vine growing soils of Tumkur district. Information generated on soil fertility status would be useful for optimum soil and nutrient management for ensuring sustainable betel vine production in the study area.

Keywords

Soil fertility, Soil depth, Betel vine, Nutrients, Sustainable

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Introduction

Betelvine (*Piper betle* L.) is a perennial dioecious climber and believed to have originated in Central and Eastern Malaysia. It

is mainly cultivated in South East Asian countries viz., India, Bangladesh, Sri Lanka, Malaysia, Thailand, Philippines etc., for its leaves, which is mainly used as stimulant. It is a heritage crop of India, being mentioned in

vedic literature and epics. Betel leaves are an integral part of all Hindu customs and religious ceremonies. Chewing pan is an age-old custom in Asia especially in India. In addition, it has many medicinal properties and used widely in Indian system of medicine to cure indigestion, stomach ache, diarrhoea, flatulence and to heal wounds, scales and burns, swellings due to sprains, bruises; respiratory disorders, sore throat, constipation, boils and gum sores (Patra *et al.*, 2016). The volatile oil of betel vine leaves has anti-bacterial and anti-fungal properties. Betel leaves are rich in fibre and minerals. It is one of the important commercial crop grown mostly by small and marginal farmers in the states of Assam, West Bengal, Bihar, Andhra Pradesh, Karnataka, Tamil Nadu, Maharashtra, Madhya Pradesh, Kerala, Uttar Pradesh and Odisha with an estimated area of 53,539ha (Ray, 2008). Annual production is worth Rs. 9000 millions and estimated that about 20 million people earn their livelihood directly or indirectly partly or fully from production, processing, handling, transportation and marketing of betel leaves in India (Tallapragada and Seshachala, 2012; Mazumder *et al.*, 2016). Betel leaves worth 30-40 million rupees are exported to countries like Bahrain, Canada, Great Britain, Nepal, Pakistan, Saudi Arabia, and many other European countries.

It is one of the most important commercial crops of Karnataka grown by small and marginal farmers. In Karnataka, it is grown in an area of 6988 ha with a production of 1,31,795 lakh leaves with a productivity of 18.86 lakh leaves/ha. The important betelvine growing districts are Haveri, Davanagere, Tumkur, Bangalore Rural, Mysore, Dharwad, Shimoga, Chikmagalur, Belgaum and Bijapur. Haveri district is leading in Betelvine production followed by Davanagere, Tumkur and Ramanagara districts. Betelvine plants require partial shade and well-drained

sandy loam or sandy clay soil with pH range of 5.6-8.2 for better production (Guha and Jain, 1997). Clay loam soil with rich of organic matter and adequate drainage also favour betel vine cultivation. It grows best under the shaded, tropical forest ecological conditions with a rainfall of about 2250-4750mm, relative humidity and temperature ranging from 40-80% and 15-40°C, respectively. However, in the areas with lower rainfall (1500-1700 mm) the crop is cultivated with small and frequent irrigations, i.e. every day in summer and every 3-4 days in winter, whereas adequate drainage is required during the rainy season (Jana, 1995; Mishra *et al.*, 1997).

The sustainability of any land use system has become major concern in recent years. Achieving and maintaining appropriate levels of soil fertility, especially plant nutrient availability, is of paramount importance if agricultural land is to remain capable of sustaining crop production at an acceptable level. Therefore monitoring nutrient supplying capacity of soil will be key indicator of improving the sustainable agriculture production (Hartemink, 2006; Pathak, 2012). Soil quality assessment has been suggested as a tool for evaluating sustainability of soil and crop management practices (Hussian *et al.*, 1999; Prabhavathi *et al.*, 2013). Evaluation of soil fertility status of betel vine plantations is necessary because which forms the basis for the fertilizer recommendations for maximizing the crop yields and to maintain the adequate fertility in soils for longer period and also to minimize any adverse environmental impact due to excessive fertilizer application.

Therefore, the objective of this study was to assess/examine the soil fertility status of betelvine plantations for optimum soil management practices and for ensuring sustainable betel vine production in Tumkur districts of South Interior Karnataka.

Materials and Methods

Study area

The study area is situated in a major betel vine growing belt, has red loamy and red sandy soils of the eastern rain shadow region of peninsular India. It is located at 848 m above mean sea level (MSL) with latitude of 13.33°N and longitude of 77.10°E (Fig. 2). The climate is semi-arid tropical with an average annual rainfall of 687 mm, distributed mainly from June to November. The mean annual maximum and minimum temperature are 37.5°C and 12.8°C, respectively. The area has *ustic* moisture regime and isohyperthermic temperature regime and covering both rainfed and irrigated system.

Soil sampling and processing

Soil samples collected at two different depths (0-30 and 31-60 cm) from thirty (30) different betel vine plantations situated in Tumkur taluk of Southern Karnataka for assessing their fertility status. The soil samples collected from dense betelvine land use were bulked for each depth, thoroughly mixed and a composite sample taken for analysis. The soil samples were then air-dried, powdered and sieved using 2 mm sieve. Processed soil samples were then used for characterization of physico-chemical and chemical properties.

Laboratory analysis

Electrical conductivity, pH and organic carbon were determined by standard methods (Jackson 1973). Soil pH and electrical conductivity (EC) were measured in a 1:2.5 (w/v) soil/water mixture. Organic carbon content of the soils was determined using dichromate wet oxidation method of Walkley and Black (1934). Available nitrogen was estimated by alkaline permanganate method (Subbaiah and Asija, 1956). For available

phosphorus, extraction was done using Olsen extracting reagent and determined by molybdophosphoric blue colour method (Jackson, 1973). Available potassium was extracted using neutral normal ammonium acetate and measured with flame photometer (Jackson, 1973). Sulphur was extracted using 0.15 per cent CaCl₂ solution and was made to react with BaCl₂ to form turbid solution of BaSO₄.

The intensity of turbidity was measured using spectrophotometer at a wavelength of 420 nm (Jackson, 1973). Exchangeable calcium and magnesium were determined using versenate (EDTA) titration method. Available micronutrients such as iron, copper, manganese and zinc were extracted using standard DTPA extract at pH 7.3 and the concentration was measured in an atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

Nutrient index calculation

Based on the soil test values for different nutrients, soil samples are generally classified into three categories, low, medium and high (Table 1).

Using these fertility classes' nutrient indexes was calculated as per the following equation given by Parker (1951).

$$\text{Nutrient index} = (N_L * 1 + N_M * 2 + N_H * 3) / N_T$$

Where, N_L, N_M and N_H are number of samples falling in low, medium and high classes of nutrient status, respectively and N_T is total number of samples analyzed for a given area. The nutrient index values less than 1.67 as the indicative of low nutrient status and between 1.67 to 2.33 as medium while higher than 2.33 considered as high nutrient status (Ramamoorthy and Bajaj, 1969).

Statistical analysis

The data for the soil physico-chemical and chemical properties were averaged over the number of sites sampled and the standard deviation as well as standard error computed. Coefficients of variation among the means were also calculated.

Results and Discussion

The summary of the analytical outcomes on soil pH, electrical conductivity, organic carbon and macro and micronutrient status of the soils of betel vine plantations is presented in table 2 and 3.

Soil pH

Soil pH is important estimation for soils, determines the magnitude of the acidity and alkalinity and directly influences agriculture productivity. The pH value reflects the integrated effect of the acid base reactions taking place in the soil system. The surface soil pH of the study area varied from 6.94 to 7.72 with a mean of 7.47 and found to be very much ideal or safest for betel vine cultivation (Guha and Jain, 1997).

Slight increase in soil pH along the depth of the soil was observed and given in Table 2 & 3. The data on soil pH showed least variability (1.8-2.4%) among the soil samples. Neutral to slightly alkaline pH of the soil might be attributed mainly to the prevalence of dry climate in the study area and also the crystalline schists and granitic gneisses parent materials (Srinivasan *et al.*, 2013).

Soil pH was relatively higher in lower depths as compared to higher depths. This could be due to leaching of basic cations from surface layers to the lower layers coupled with higher content of clay in lower layers of soil (Kalaivanan and Sudhir, 2012).

Electrical conductivity (EC)

Electrical conductivity (EC) is a measurement that correlates with soil properties that effect productivity, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, and subsoil characteristics. The electrical conductivity (EC) of the surface soil varied from 0.18 to 0.32 dSm⁻¹ with a mean value of 0.27 dSm⁻¹. The EC of the soil slightly increased with depth. Electrical conductivity of the study area showed moderate variability with CV of 17% for surface soils and 19.1% for subsurface soils compared to soil pH. Study area has EC of less than 1.0 dSm⁻¹ which indicates that the soils are free from salinity and found to be very much suitable for betel vine cultivation. Low EC in the study area could be related to the amount of rainfall of the area and texture of the soil (Kalaivanan and Sudhir, 2012).

Organic carbon

Organic matter is an important store house of plant essential nutrients. It supplies plant nutrient, improve the soil structure, water infiltration and retention, feeds soil microflora and fauna, and the retention and cycling of applied fertilizer. Soils are low in inorganic nutrients rely on the recycling of nutrients from soil organic matter to maintain fertility (Tiessen *et al.*, 1994; Manlay *et al.*, 2007). The organic carbon content ranged from 0.57-1.05 per cent with a mean of 0.77 per cent in surface soils (0-30 cm), indicating that the soils were high in organic carbon status (Table 2 & 3). The distribution of organic carbon in soils showed a decreasing trend with depth. Nutrient index data also indicated that the soil organic carbon was decreased from high (2.57) to medium (2.30) in status with increasing soils depth (Table 4). High organic carbon content in surface soils could be due to leaf litter falls from the standing crop and

addition of organic manures (Srinivasan *et al.*, 2013; Maria and Yost, 2006). Leaf litter fall from the live supports/standards i.e. *Sesbania grandiflora* (Agathi), *Sesbania sesban*, *Erythrina variegata* (Dadap), *Moringa oleifera* (Drumstick), *Ceibapen tandra* (Silk cotton tree) available in the plantations and from betel vine plants itself might have helped in enhancing the organic carbon status of the soils.

Available Macronutrients

Based on the nutrient indexing in soils, the study area surface soil was medium in available N (276 to 349 kg ha⁻¹), medium to high in available P (11.6 to 34.3 kg ha⁻¹) and medium in available K (187 to 243 kg ha⁻¹) (Table 2). Medium status of nitrogen, phosphorus and potassium in betel vine cultivated fields might be ascribed to regular uptake of nutrient by crops, which tended to deplete nutrient status in soils (Somasundaram, 2012). A consistent decrease in the concentration of available N, P and K with the increase in soil depth was noted in Table 3 & 4. Available nitrogen contents of soils were in accordance with the carbon contents of soils in most cases. The relationship between available nitrogen and organic carbon content is well known (Ghosh *et al.*, 2009). However the Available N content was found to be higher in surface soils and decreased with increased soil depth, which might possibly be due to the accumulation of plant residues, debris and rhizosphere (AbdelRahman *et al.*, 2016). The decrease in available nitrogen content with increase in soil depth could be directly related to the lower organic matter content in lower depths.

Availability of phosphorus in soil is related mainly to the soil properties and the total phosphorus content. Highest available P was observed in the surface horizons and decreased regularly with depth (Fig. 1).

Higher P in the surface horizon might be due to the confinement of crop cultivation to this layer and supplementation of the depleted phosphorus through external sources i.e. fertilizers (Srinivasan *et al.*, 2013). The reasons for higher soil available phosphorus in betel vine plantations could be attributed to the neutral soil reaction and release of phosphorus unavailable forms from organic materials due to higher activity of microorganisms in soils (Mallikarjuna *et al.*, 2003). Low available phosphorus in subsurface soils was due to fixation of phosphorus by iron and Al oxides. The lower phosphorus content in sub-surface horizons could also be attributed to the fixation of released phosphorus by clay minerals and the presence of Ca. The highest available K content was noticed in the surface horizons and showed decreasing trend with depth. This could be attributed to more intensive weathering, release of labile K from organic residues, low amounts of rainfall and application of K fertilizers (Srinivasan *et al.*, 2013; AbdelRahman *et al.*, 2016). The available sulphur in the soils varied from 9.4 to 15.1 mg kg⁻¹ and most of the soils were medium in ratings. Due to higher amount of organic matter in surface than in subsurface layers, the available sulphur was more in surface horizons than the sub-surface horizons.

Exchangeable Calcium

Exchangeable calcium plus magnesium usually accounts for more than sixty percent of exchangeable cations occurring in soils of pH 5.5 or more. Soils usually contain less magnesium than calcium because Mg²⁺ ion is strongly adsorbed by clay and organic matter and further Mg²⁺ ions are more susceptible to leaching than Ca²⁺ ions.

The exchangeable Ca content of the soil varied from 2.6 to 4.4 cmol (p⁺) kg⁻¹ soils with a mean value of 3.51 cmol (p⁺) kg⁻¹. The

exchangeable Ca content of the betel vine plantations soil was above 1.5 cmol (p⁺) kg⁻¹ which indicates that Ca is sufficient in

different depths of the soils. Exchangeable Ca content of the soil showed irregular trend with depth.

Table.1 Soil fertility ratings based on soil test values

Soil nutrients	Low	Medium	High
Organic C (%)	<0.5	0.5-0.75	>0.75
Available N (kg ha ⁻¹)	<280	280-560	>560
Olsen P (kg ha ⁻¹)	<10	10-25	>25
Ammonium acetate extractable K (kg ha ⁻¹)	<108	108-280	>280
Critical level in soil			
Available S (mg kg ⁻¹)	10		
Exchangeable Ca (c mol (p ⁺) kg ⁻¹)	1.5		
Exchangeable Mg (c mol (p ⁺) kg ⁻¹)	1.0		
DTPA extractable Fe (mg kg ⁻¹)	4.5		
DTPA extractable Mn (mg kg ⁻¹)	2.0		
DTPA extractable Zn (mg kg ⁻¹)	0.6		
DTPA extractable Cu (mg kg ⁻¹)	0.2		

(Source: Muhr *et al.*, 1965; Lindsay and Norvell, 1978)

Fig.1 Available N, P and K status in surface and subsurface soils of betel vine plantation

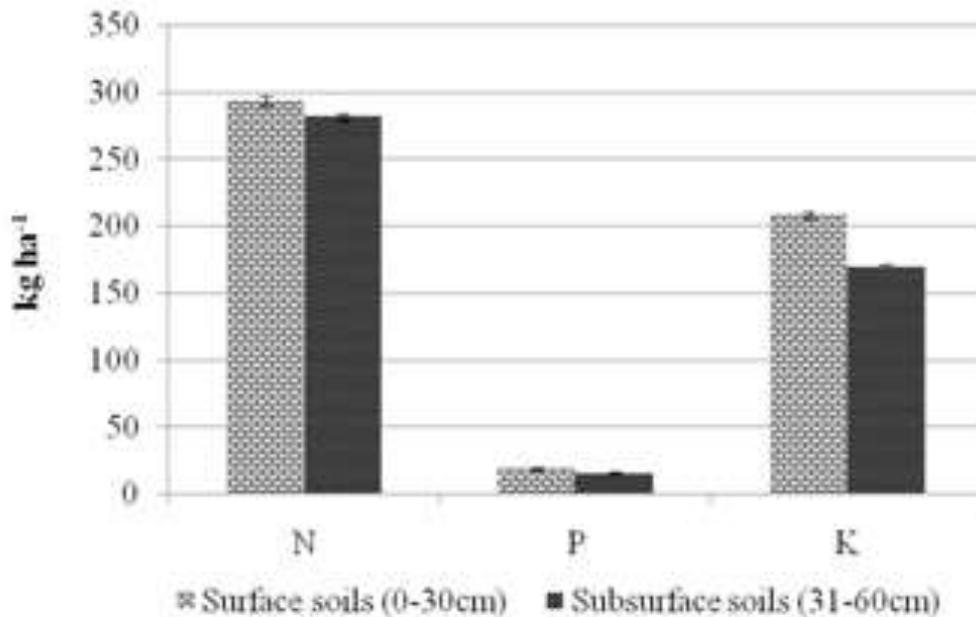


Table.2 Physico-chemical properties of surfaces soils (0-30 cm) of betel vine growing areas of Tumkur district

Sample No	pH (1:2.5)	EC dSm ⁻¹	OC (%)	Available Macro Nutrients			Exchangeable		Available S mg kg ⁻¹	Available Micro Nutrients			
				N	P	K	Ca	Mg		Fe	Mn	Zn	Cu
				kg ha ⁻¹			c mol (p ⁺) kg ⁻¹			mg kg ⁻¹			
1	7.43	0.25	0.92	302	21.9	194	3.7	1.62	12	22.3	7.2	1.2	0.6
2	7.52	0.18	1.02	349	34.3	224	4.4	1.75	13.4	18.6	6.6	1.6	0.9
3	7.55	0.27	0.78	310	11.6	197	4.1	1.67	13.8	18	6.3	1.5	0.6
4	7.57	0.25	0.94	323	24.8	215	4.4	1.84	10.9	17.4	5.6	1.7	0.8
5	7.45	0.23	0.83	289	12.3	237	3.5	1.48	12.3	16	5.9	1.3	0.6
6	7.40	0.32	0.76	295	15.2	221	3.2	1.52	11.7	17.3	5.2	1.4	0.7
7	7.62	0.23	0.81	310	16.7	212	4.1	1.97	13.2	14.6	4.6	1.5	0.5
8	7.65	0.26	0.66	278	15.8	200	3.8	1.42	9.8	14	4.3	1.1	0.3
9	7.54	0.34	0.78	288	17.8	208	3.4	1.03	10.2	13.4	3.6	1.2	0.4
10	6.98	0.19	0.89	294	18.2	202	3.6	1.12	11.4	13	4.9	1.4	0.4
11	7.46	0.22	1.05	326	21.5	243	4.2	1.43	14.5	18.3	4.2	1.5	0.7
12	7.51	0.25	0.57	276	18.7	214	3.2	0.97	10.1	14.8	4.6	0.9	0.3
13	7.58	0.32	0.65	286	18.5	198	3.4	1.17	11.5	14.2	4.3	1	0.4
14	7.35	0.25	0.78	281	15.3	204	3.5	1.02	11.7	14.4	3.6	1.2	0.4
15	7.40	0.36	0.67	279	17.2	194	2.6	0.78	10.2	12.1	3.9	0.8	0.3
16	7.36	0.28	0.72	287	18.5	203	3.2	1.02	12.5	16.3	4.2	1.2	0.4
17	7.71	0.26	0.68	278	17.4	195	3.5	1.12	9.7	14.7	4.6	1	0.3
18	6.94	0.2	0.74	284	18.6	201	3.1	1.24	10.4	17	4.8	1.3	0.5
19	7.62	0.31	0.68	281	17.2	198	3.7	1.32	10.2	13.5	3.6	1.1	0.4
20	7.44	0.28	0.92	328	25.6	224	4.3	1.54	15.1	16.2	4.9	1.6	0.8
21	7.38	0.26	0.58	277	16.7	198	3	0.96	9.4	18.3	4.3	0.9	0.3
22	7.69	0.24	0.75	285	17.3	212	3.1	1.24	11.5	17.5	3.6	1.2	0.4
23	7.72	0.31	0.81	289	18.4	214	3.3	1.26	12.2	16.8	4.9	1.4	0.5

24	7.64	0.32	0.64	276	17.1	187	3.1	1.01	10.3	17.2	4.2	1.1	0.3
25	7.39	0.28	0.78	282	17.8	192	3.6	1.28	11.2	14.6	4.6	1.3	0.4
26	7.51	0.26	0.74	291	19.2	210	3.2	1.31	12.5	13.2	4.3	1.2	0.6
27	7.38	0.3	0.7	278	16.7	189	2.8	0.92	10.2	18.3	4.9	1	0.4
28	7.65	0.36	0.78	288	17.3	204	3.2	1.22	12.1	14.6	4.3	1.2	0.4
29	7.36	0.26	0.67	283	16.4	215	3.4	1.28	11.3	17	3.6	1.1	0.5
30	7.42	0.28	0.81	310	18.9	234	3.7	1.34	13.8	13.4	4.9	1.4	0.7
Mean	7.47	0.27	0.77	293.43	18.43	207.97	3.51	1.30	11.64	15.9	4.68	1.24	0.49
Max	7.72	0.36	1.05	349	34.3	243	4.4	1.97	15.1	22.3	7.2	1.7	0.9
Min	6.94	0.18	0.57	276	11.6	187	2.6	0.78	9.4	12.1	3.6	0.8	0.3
Stdev	0.18	0.05	0.12	18.41	4.15	14.23	0.46	0.29	1.49	2.25	0.90	0.23	0.17
Stderr	0.03	0.01	0.02	3.36	0.76	2.60	0.08	0.05	0.27	0.41	0.16	0.04	0.03
CV%	2.4	17.0	15.3	6.3	22.5	6.8	13.2	22.2	12.8	14.1	19.2	18.1	34.5

Table.3 Physico-chemical properties of subsurface soils (31-60cm) of betel vine growing areas of Tumkur district

Sample No	pH (1:2.5)	EC dSm ⁻¹	OC (%)	Available Macro Nutrients			Exchangeable		Available S mg kg ⁻¹	Available Micro Nutrients			
				N	P	K	Ca	Mg		Fe	Mn	Zn	Cu
				kg ha ⁻¹			c mol (p ⁺) kg ⁻¹			mg kg ⁻¹			
1	7.34	0.21	0.89	293	9.8	152	3.2	1.07	11.6	19.2	5.4	0.9	0.3
2	7.45	0.21	0.81	272	11.6	157	4.6	1.6	9.0	16.5	4.1	1.1	0.5
3	7.51	0.29	0.69	298	10.3	155	3.4	1.3	12.2	16.2	3.8	1.1	0.3
4	7.72	0.32	0.71	284	11.9	197	3.8	1.33	8.6	17	2.6	0.7	0.2
5	7.53	0.17	0.78	262	9.5	177	3.6	1.36	11.2	15.1	3.0	0.5	0.1
6	7.51	0.35	0.74	291	13.8	181	2.8	0.92	10.2	14.2	3.2	0.7	0.3
7	7.42	0.26	0.76	302	15.2	172	3.5	1.07	11.4	12.8	4.0	0.9	0.4
8	7.67	0.29	0.61	270	14.4	160	3.2	0.92	8.7	12.4	3.5	0.5	0.2

9	7.45	0.32	0.74	278	16.2	166	3.7	1.13	9.2	13.1	2.9	0.6	0.2
10	7.18	0.22	0.82	282	17.5	182	2.8	0.88	10.1	12.5	3.4	0.6	0.2
11	7.44	0.26	0.87	312	20.3	212	4.0	1.24	10.8	16.2	3.6	0.7	0.4
12	7.56	0.28	0.55	268	17.3	174	3.5	1.12	8.1	14.5	2.8	0.4	0.1
13	7.68	0.33	0.62	278	14.5	172	3.2	1.11	9.6	15.2	3.4	0.5	0.2
14	7.55	0.27	0.75	280	15.8	164	3.8	1.04	10.3	16.1	3.8	0.6	0.3
15	7.44	0.32	0.64	277	17.4	154	2.8	0.65	9.4	14.2	4.1	0.5	0.2
16	7.56	0.36	0.7	282	18.1	163	3.0	0.68	10.6	14.4	4.2	0.6	0.3
17	7.61	0.29	0.62	271	16.3	175	3.2	0.82	9.8	13.5	3.5	0.5	0.2
18	7.14	0.23	0.69	280	18.2	161	3.0	0.86	10.6	13.2	2.9	0.7	0.3
19	7.65	0.35	0.64	275	16.5	168	3.1	1.01	10.3	16.2	4.1	0.7	0.2
20	7.47	0.28	0.86	314	23.4	174	3.4	1.32	13.8	12.5	3.7	1.2	0.4
21	7.43	0.25	0.52	272	16.5	178	3.2	0.98	9.2	13.5	2.8	0.5	0.2
22	7.66	0.28	0.74	275	16.3	182	3.4	1.05	10.2	14.3	3.2	0.6	0.2
23	7.7	0.34	0.78	284	16.8	164	2.8	0.72	11.3	15.2	4.3	0.7	0.3
24	7.54	0.31	0.63	270	17.2	156	2.6	0.76	9.4	16.3	2.6	0.4	0.2
25	7.59	0.34	0.67	272	17.3	163	3.2	0.89	10.1	12.5	3.4	0.5	0.2
26	7.61	0.24	0.68	288	18.9	170	3.0	1.02	10.7	11.9	4.3	0.6	0.3
27	7.48	0.37	0.65	276	16.2	168	2.6	0.71	9.4	13.4	2.9	0.5	0.2
28	7.56	0.41	0.72	282	16.7	162	3.3	1.24	10.2	14.3	4.1	0.6	0.2
29	7.38	0.24	0.64	263	16.5	155	3.0	0.87	9.5	13.6	3.6	0.3	0.1
30	7.47	0.33	0.71	289	17.8	164	3.2	1.23	10.4	15.3	4.2	0.6	0.3
Mean	7.51	0.29	0.71	281.3	15.9	169.3	3.3	1.0	10.2	14.5	3.6	0.6	0.3
Max	7.72	0.41	0.89	314	23.4	212	4.6	1.6	13.8	19.2	5.4	1.2	0.5
Min	7.14	0.17	0.52	262	9.5	152	2.6	0.65	8.1	11.9	2.6	0.3	0.1
Stdev	0.14	0.06	0.09	12.77	3.02	13.04	0.43	0.23	1.16	1.69	0.64	0.21	0.09
Stderr	0.02	0.01	0.02	2.33	0.55	2.38	0.08	0.04	0.21	0.31	0.12	0.04	0.02
CV(%)	1.8	19.1	12.7	4.5	19.0	7.7	13.3	22.4	11.4	11.6	17.8	32.8	37.5

Fig.2 Location map of the study area

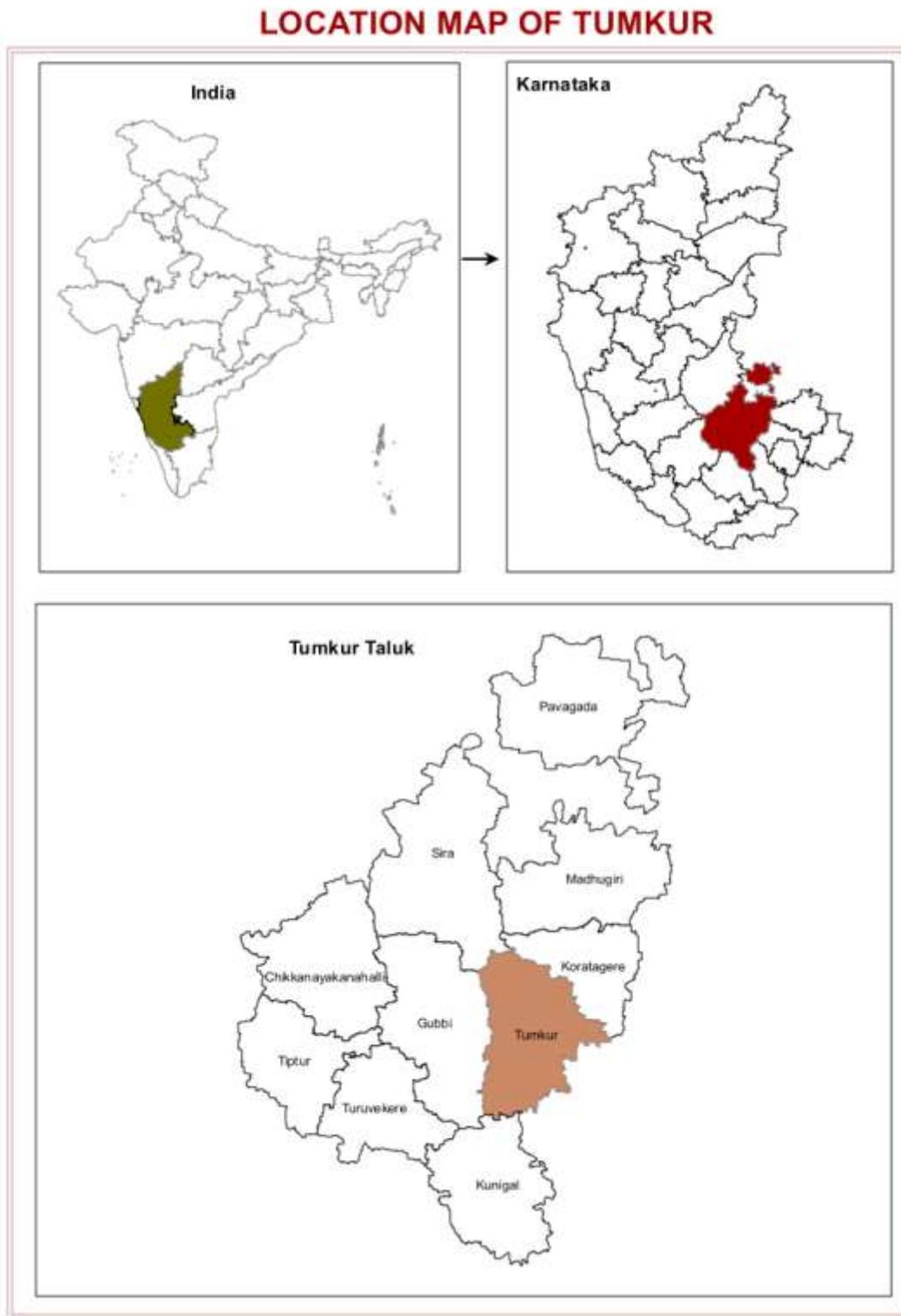
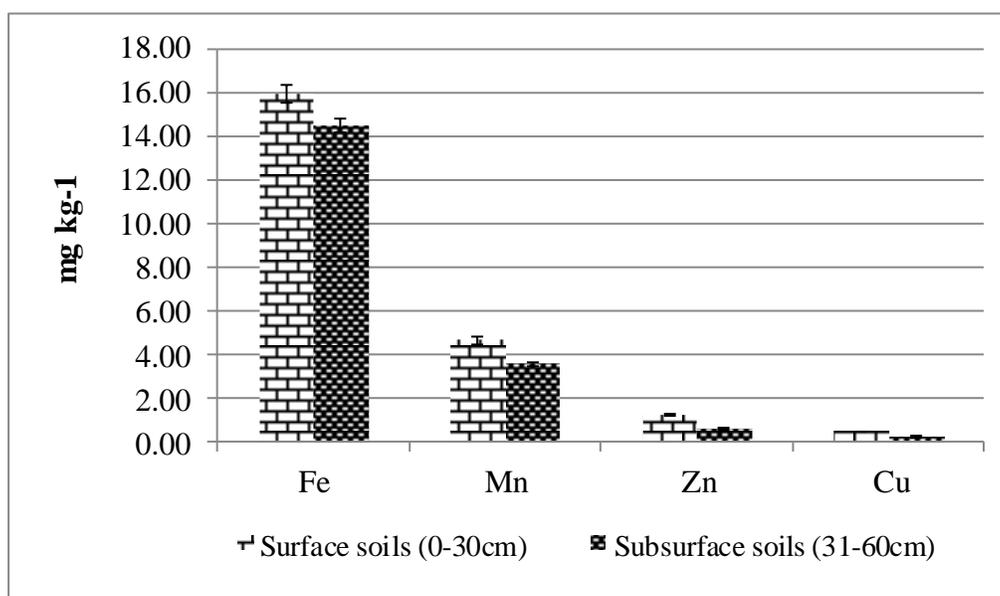


Table.4 Nutrient index of betel vine growing soils of Tumkur district.

Soil properties	Surface soils (0-30cm)	Subsurface soils (31-60cm)	Entire soil depth (0-60cm)
Organic carbon	2.57 (H)	2.30 (M)	2.44 (H)
Nitrogen	1.90 (M)	1.50 (L)	1.70 (M)
Phosphorus	2.10 (M)	1.93 (M)	2.02 (M)
Potassium	2.00 (M)	1.98 (M)	1.99 (M)

L-Low in nutrient status, M-Medium in nutrient status and H-High in nutrient status.

Fig.3 Micronutrient status in surface and subsurface soils of betel vine plantation



The results of the study indicated that the exchangeable calcium content was reasonably high in soils of all the sampling locations. The presence of higher amounts of calcium in the soil could not only be attributed to its high total content, but also due to the easy release of calcium in soluble forms from the solids to the solution phase. If soil conditions are ideal to retain Ca²⁺ ions on soil solid surfaces in exchangeable form, its content will hardly diminish even under continuous cropping situation (Sudhir and Jayaprakash 2004). The reason for relatively higher available calcium content in lower depths of soil could be attributed to the accumulation of carbonates

and phosphates at lower depths.

Exchangeable Magnesium

The trend in the distribution of available magnesium in the soils was more or less similar to that of the distribution of available calcium in the soils. Exchangeable Mg content of the soils varied from 0.78 to 1.97 cmol (p⁺) kg⁻¹ with an average value of 1.30 cmol (p⁺) kg⁻¹. Exchangeable Mg content of most of betel vine plantations was higher than the critical value of 1.0 cmol (p⁺) kg⁻¹ soil. Depth wise distribution of Mg also followed a similar trend to that of exchangeable Ca.

Calcium and magnesium in their ionic forms behave similarly in soils with respect to their retention by soil colloids and leaching under acidic soil conditions. Hence, the reasons similar to the one quoted for exchangeable calcium could be given even for the distribution of available magnesium in soils.

The clay complex was dominated by exchangeable Ca in surface and subsurface horizons of most soils followed by Mg (Behera and Shukla, 2015). Exchangeable Ca and Mg showed irregular trend with depth of soils. Shanthakumari (2007) reported that the exchangeable calcium and magnesium content did not have a definite pattern with increase or decrease in the depth of soil.

Available micronutrient

The DTPA extractable Fe, Mn, Zn and Cu contents in surface soils ranged from 12.1 to 22.3, 3.6 to 7.2, 0.80 to 1.7 and 0.3 to 0.9 mg kg⁻¹, respectively and were nearly sufficient in the surface soils (Table 2, 3 and Fig. 3). The critical limit for deficiency of the DTPA extractable Fe, Mn, Zn and Cu is 4.5, 2.0, 0.6 and 0.2 mg kg⁻¹, respectively (Tandon, 1999). The high contents of DTPA extractable Fe, Mn, Zn and Cu in the surface soils could be due to the high organic matter content of the soil and addition of sufficient organic manures to the betel vine plantations (AbdelRahman *et al.*, 2016). The contents of DTPA extractable Fe, Mn, Zn and Cu decreased with the increase in soil depth. The range of CV (14.1 to 34.5% for surface soils and 11.6-37.5% for subsurface soils) for the area suggested different degrees of heterogeneity among the DTPA extractable micronutrients studied.

The relatively high content of available zinc in surface horizons may be attributed to variable intensity of the pedogenic processes and complexing with organic matter which resulted in chelation of Zn. The available Cu

content was more in surface layers and decreased with depth, which might be due to association with organic carbon. The higher concentration of DTPA-Fe in subsurface soils might be due to the accumulation of iron brought down as a result of illuviation of clay from the upper horizons. However, the higher DTPA-Fe in surface horizons of all the pedons might be due to accumulation of organic carbon in the surface horizons. The organic carbon due to its affinity to influence the suitability and availability of iron by chelating action might have protected the iron from oxidation and precipitation, which consequently increased the availability of iron in the surface horizons (Prasad and Sakal 1991). The higher content of available Mn in surface soils was attributed to its chelation by organic compounds. These observations are in accordance with the findings of Verma *et al.*, (2005). To optimize the productivity of fertilizer usage, it is imperative that the fertility status of the soil is known. Soil analysis up to 60 cm soil depth revealed that betel vine plantations of the study area was high in organic carbon, medium in available N, P, K and S, high in exchangeable Ca and Mg, and nearly sufficient in DTPA extractable Fe, Mn, Zn and Cu. All the nutrients were higher in surface than subsurface soils. Contrary to the general perception, there has not been much depletion of soil fertility in betel vine growing soils of Tumkur district.

Results reported in this paper may be useful for optimum soil management practices for ensuring sustainable betel vine production in the region. Enhancement of soils in N, P, K and S elements could significantly increase crop yields.

Therefore, the application of organic manures viz., FYM, vermicompost and neem cake etc. along with recommended dose of fertilizers needs to be continued to improve soil fertility and crop productivity on sustainable basis.

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