

NUTRIENT CONTENTS IN THE ORGANS AND SOIL OF YOUNG AND MATURE *CAMELLIA OLEIFERA* C. ABEL FORESTS IN CHINA

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Abstract

Nutrient contents in the organs and soil of the young and mature *Camellia oleifera* C. Abel were determined to study the demand and supply of nutrients for trees and soil, respectively. The young and mature *C. oleifera* forests were selected in the south suburb of Changsha, China. Results showed that the nutrient contents in the different tree organs of the mature forest in florescence period were in the order of leaf > flower > root > trunk > branch, and in the young forest were leaf > flower > branch > root > stem. In mature and young *C. oleifera* forests, the highest demand of macroelements in tree organs was for N and the lowest was for P. For microelements, the highest was for Mn and the lowest was for Cd. The soil nutrient supply in the mature and young *C. oleifera* forests consisted mainly the available N and K, and the available P in the least. The most macroelements were the total P and Ca, while the least was Mg. The nutrient demand of microelements was the highest for Fe and the lowest for Cd. The nutrient requirement of tree organs in mature and young *C. oleifera* forests was: young (2094.13 ± 656.79 mg/kg) > mature (1763.31 ± 419.27 mg/kg), while the soil nutrient supply was mature (2612.81 ± 756.68 mg/kg) > young (2312.99 ± 659.85 mg/kg). The nutrient content in the organs of the mature and young *C. oleifera* forest was high in the fructescence period as compared during the florescence period, while the soil nutrient supply was high in the florescence period than in the fructescence. Results could provide a scientific basis for the nutrition diagnosis and nutrition management of *C. oleifera* and other plants.

Introduction

Camellia oleifera C. Abel belonging to Theaceae is a typical oleiferous oil yielding tree species in China (Wang *et al.* 2014, Gong *et al.* 2015). The planting area of the species has exceeded 3 mio hm² with the centralized distribution in the Yangtze River basin, as well as in its southern area. The annual production of camellia oil is up to 240 K MT (Luo *et al.* 2017). Thus, *C. oleifera* industry is important to solve the imbalance between the demand and supply of edible oil as well as to increase the income from forests and farms. However, the current soil nutrient supply to the *C. oleifera*-forest is seriously insufficient, which often results in low yield. Nowadays, research related to nutrients is mainly focused on the unilateral study of soil or forest stand, wherein the supply of soil nutrients is mainly focused on the change in the soil nutrients. Vegetation heterogeneity is another important factor in the study of the soil vegetation system, as it affects the rainfall interception, runoff reduction, soil keeping, anti-erosion, soil improvement as well as the ecological environmental improvement, etc. (Li and Li 2012). It is known that there is a significant variation in the nutrient composition of the trees at different growth periods. Zhou *et al.* (1996) proposed that the nutrient content of young fir forest was in the order of Ca > N > K > Mg > P, whereas that of the mature forest was in an order of N > Ca > K > P > Mg. Besides, over-mature forest demonstrated that the nutrient content was in an order of Ca > N > K > P > Mg. Reports on the variation in the nutrient demand and nutrient management of *C. oleifera* in different growth periods are not available. Hence, the present work was aimed to study

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the young and mature *C. oleifera* forests in southern suburbs of Changsha, and the soil nutrient contents in the different tree organs of the young and mature *C. oleifera* forests in fructescence and florescence periods. Further research goals would be based on the variation in the nutrient demand of *C. oleifera* trees in different age periods, as well as soil nutrients.

Materials and Methods

The research area was Du Jiachong experimental forest farm of the Hunan Academy of Forestry in the southern suburbs of Changsha City, China (N28°06'40", E113°01'30"). The total area of forest farm was 265.14 hm², which belonged to a hillock area of the central Hunan in the transition zone of alluvial plain of the Dongting Lake. The terrain was an alternate distribution of a hilly forest land and a valley farm land. Physiography of the study area are presented in Table 1.

Table 1. Physiographic characteristics of the study area (units are provided in parentheses).

Altitude of the forest farm, between - (m AMSL)	60 and 80
Central part of the farm has highest altitude (m AMSL)	115.9
Lowest altitude of the farm (m AMSL)	51.4
Relative altitude difference	64.5
Terrain slope relatively gentle, slope gradient (°)	<20
Weather typical subtropical continental monsoon, annual average temperature (°C)	17.2
Average temperature of the coldest month (January) (°C)	4.7
Extreme minimum temperature (°C)	-9
Average temperature in the hottest month (July) (°C)	29.4
Extreme maximum temperature (°C)	40.6
Annual average precipitation (mm)	1411.4
Number of annual average rainy days (d)	152
Annual average relative humidity (%)	80
Annual sunshine hour (h)	1717.34
Annual no-frost period (d)	272
Number of annual snow fall days (d)	6

The regional zonal vegetation is an evergreen broad-leaved forest with sparse native vegetation. This work is guided on "Observation Methodology for Long-term Forest Ecosystem Research" of National Standards of the People's Republic of China (GB/T 33027-2016).

Young and mature forests with consistent site conditions of the gradient slope, altitude, soil layer depth, soil type, and the slope direction were selected. Three experimental plots with an area of 20 × 20 m having corners marked with PVC pipe labels were selected. In fructescence of *C. oleifera*, fruits and tree types were observed. Five sample trees with consistent fruit characteristics and tree shape in each experimental plot were selected as standard samples for fixed position observation.

In the fructescence of *C. oleifera*, samples were collected from 5 standard sample trees in each experimental plot. The collected leaves were the third to fifth mature leaves from the base of the annual shoot in the central part, east, west, north and south of the tree crown with relatively consistent growth conditions. In the meantime, the annual shoots and the peripheral fruits were

collected from the tree crown in the central part, east, west, north, and south of the branching layer with similar growth conditions. When collecting roots, a slide with a depth of 40 cm was dug in the south-north direction at the base of each standard tree. Rootlets with a diameter less than 2 mm were collected and alive rootlets were selected according to their color, elasticity, and shape. These were and put into the paper bag.

To reduce the effect of sampling on trees, a hole with a diameter of 0.5 cm was dug in the upper part of the sample tree, with 10-15 cm to the top when collecting trunks. To minimize the individual difference in each experimental plot, leaves, flowers, fruits, branches, trunks, and roots were collected, mixed, and divided into three replicates, separately. Each replicate with a fresh weight of 300 g was transported to laboratory and dried in the oven at 65°C, until the weight was constant. Nutrient element contents were determined for the samples after a prior grinding and filtering by 0.25 mm sieves.

At a 1 m radius of the sample tree in each standard experimental plot, soil samples were collected from three different depth ranges. Those were: 0-20, 20-40, and 40-60 cm, respectively. Soil samples of five sites in each plot were thoroughly mixed immediately and subsequently dried naturally in the laboratory. Soil nutrients were determined after the removal of stone and roots after grinding and filtering by the 2 mm sieve (Xiang *et al.* 2014).

In the present investigation, the concentration of 11 nutrient elements including 5 major elements and 6 microelements were determined. After digestion by H₂SO₄-H₂O₂, the N, P and K in plant samples were determined by the Kjeldahl nitrogen determination method, Mo-Sb colorimetric method, and the atomic adsorption method (AA-7000, China), respectively. The elements Cu, Ca, Mg and Fe and the microelements of Zn, Mn, Cd and Pb were determined by the HP3510 atomic absorption spectrophotometer (Germany, Wavelength range: 190.0nm-860.0nm; Wavelength accuracy: full band $\leq \pm 0.5$ nm; Wavelength repeatability: ≤ 0.3 nm; Blaze wavelength: 250nm). Soil organic matters in soil samples were determined by external heating by the dichromate oxidation method. The total N, P and K in soil were determined by semi-quantitative Kjeldahl nitrogen, alkali-fusion Mo-Sb colorimetric, and alkali-fusion flame photometer method (M410, the United Kingdom), respectively. Besides, hydrolyzed N, effective P, and available K in soils were determined by the alkaline hydrolysis diffusion method, bi-acid leaching method, and ammonium acetate leaching flame photometer, respectively. Ca, Mg and other microelements in soil was determined by atomic absorption spectrophotometer (Chen 2013).

Results and Discussion

In fructescence, the average major element contents of the mature and young forests were in an order of N > Ca > K > Mg > P (Table 2). The microelement contents in the mature and young forests were in orders of Mn > Fe > Pb > Zn > Cu > Cd and Mn > Fe > Zn > Cu > Pb > Cd, respectively. Nutrient contents in different organs of the mature and young forests were in orders of leaf > branch > flower > fruit > trunk and leaf > branch > flower > root > trunk, respectively. In florescence, the average major element and microelement contents in the mature and young forests were in orders of N > Ca > K > Mg > P and Mn > Fe > Zn > Pb > Cu > Cd, respectively. The nutrient contents in different parts of mature and young forests were in orders of leaf > flower > root > trunk > branch and leaf > flower > branch > root > trunk, respectively. Thus, K and Cu contents in different parts of *C. oleifera* changed dramatically in case of the mature forest. Besides, N, P, Mg, Fe, and Mn contents changed dramatically in the young forest. Calcium, Zn, Cd, and Pb contents in different stages changed slightly and were found to be stable in the young and mature forests.

Table 3. Nutrient contents of each soil layer in different periods of *Camellia oleifera* mature and young forest.

Time	Forest age	Soil layer/cm	Available nutrients (mg/kg)			Major elements (mg/kg)							Organic matter (mg/kg)	Mean value				
			Avail-able N	Avail-able P	Avail-able K	Total N	Total P	Total K	Ca	Mg	Cu	Fe			Zn	Mn	Cd	Pb
Flore-scence	Mature forest	0-20	108.0	91.3	85.5	840.0	3830.0	550.0	1058.0	210.0	15.8	4715.2	57.3	79.0	1.9	52.5	43300.0	3666.30
		20-40	58.3	62.3	89.6	390.0	2720.0	450.0	1043.0	199.0	14.8	4794.8	53.9	40.4	1.9	34.3	23679.0	2248.76
		40-60	32.5	41.8	79.2	430.0	2150.0	420.0	1489.0	152.0	10.5	4555.8	50.7	33.3	1.5	34.3	19240.0	1923.38
	Young forest	Mean value	66.3	65.2	84.8	553.3	2900.0	473.3	1196.7	187.0	13.7	4688.6	54.0	50.9	1.8	40.3	28739.7	2612.81
		0-20	68.5	1.2	52.4	390.0	570.0	400.0	3415.0	212.0	16.8	4858.6	57.5	53.6	0.9	47.9	38315.0	3230.63
		20-40	39.4	0.9	50.4	270.0	550.0	300.0	3208.0	173.0	14.8	3970.5	51.4	34.3	1.5	47.9	21303.0	2001.02
Fructe-scence	Mature forest	40-60	42.9	1.3	23.5	190.0	300.0	280.0	3407.0	198.0	11.0	2603.6	49.1	26.2	1.9	43.4	18432.0	1707.32
		Mean value	50.3	1.1	42.1	283.3	473.3	326.7	3343.3	194.3	14.2	3810.9	52.7	38.1	1.5	46.4	26016.7	2312.99
		0-20	86.6	0.7	24.3	1610.0	810.0	2150.0	1284.0	146.0	9.6	4759.0	57.2	59.7	1.7	66.2	41001.0	3471.06
	Young forest	20-40	68.7	0.8	20.4	1290.0	480.0	2050.0	2223.0	160.0	11.0	4535.9	49.9	44.5	2.6	52.5	21987.0	2198.42
		40-60	51.8	0.8	22.3	880.0	450.0	1950.0	2113.0	118.0	7.2	4069.8	38.2	20.1	1.7	29.7	12938.0	1512.71
		Mean value	69.0	0.8	22.3	1260.0	580.0	2050.0	1873.3	141.3	9.2	4454.9	48.4	41.4	2.0	49.4	25308.7	2394.06
Young forest	0-20	30.6	0.9	24.3	560.0	340.0	5960.0	3282.0	253.0	7.2	4396.5	42.7	56.7	1.1	34.3	13655.0	1909.60	
	20-40	23.8	0.7	16.4	460.0	460.0	4150.0	3668.0	254.0	9.1	4253.0	42.5	56.7	1.3	29.7	11380.0	1653.68	
	40-60	20.6	0.8	8.5	510.0	310.0	6020.0	3841.0	270.0	7.6	4269.0	43.3	83.0	1.7	25.2	10729.0	1742.64	
Young forest	Mean value	25.0	0.8	16.4	510.0	370.0	5376.7	3597.0	259.0	8.0	4306.2	42.9	65.4	1.4	29.7	11921.3	1768.64	

After variance analysis, there were no significant differences between all rows, but significant differences between all columns at 0.05 level ($p < 0.05$).

The average root nutrient content of the tree organs during florescence of *C. oleifera* was higher in the mature forest than that in the young forest (Fig. 1). Flower nutrient contents in mature and young forests were similar, whereas those of leaves, branches and trunks were all higher in the young forest, than those in mature forest. Besides, all the average organ nutrient contents were higher in the young forest (2094.13 ± 656.79 mg/kg) than that in mature forest (1763.31 ± 419.27 mg/kg). Nutrient contents of flowers and leaves were higher in the young forest than those in the mature forest, whereas the nutrient contents of the branches and trunks were higher in the mature forest than those in the young forest. Besides, the average organ nutrient content was higher in the young forest (2182.88 ± 809.83 mg/kg) than that in mature forest (1979.98 ± 606.04 mg/kg). In florescence, the tree organ nutrient distribution in the mature and young forests were in orders of flower (26.07%) > leaf (25.32%) > root (17.94%) > trunk (15.54%) > branch (15.13%) and leaf (30.76%) > flower (21.99%) > branch (9.65%) > root (14.03%) > trunk (13.58%), respectively. In fructescence, the tree organ nutrient distribution in the mature and young forests were in orders of leaf (29.04%) > branch (22.53%) > flower (19.54%) > fruit (14.57%) > trunk (14.31%) and leaf (32.33%) > branch (19.39%) > flower (19.38%) > root (16.25%) > trunk (12.66%), respectively.

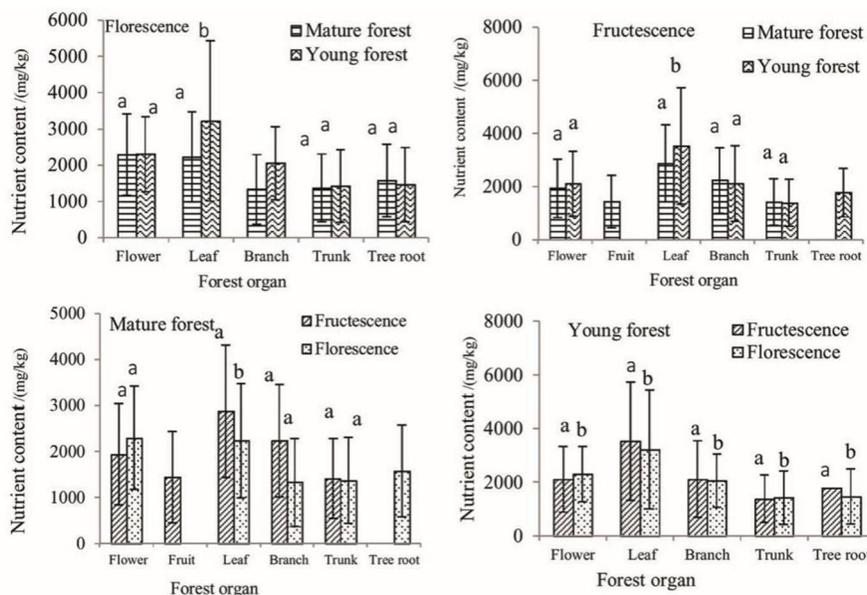


Fig. 1. Nutrient distribution of the organs in mature and young *C. oleifera* forest at different stages.

The nutrient contents in the organs of the mature and young *C. oleifera* forests were higher in fructescence than those of florescence period. Other nutrient contents in the organs such as leaf, branch, and trunk were all higher in fructescence than those in florescence. The average organ nutrient content in the mature forest was higher in fructescence (1979.98 ± 606.04 mg/kg) than that of florescence (1763.21 ± 419.27 mg/kg). Similarly, average nutrient content of young forest was also higher in fructescence (2182.88 ± 809.83 mg/kg) than that in florescence (2094.13 ± 656.79 mg/kg). From the different tree organ nutrient distribution characteristics, the highest nutrient demand of leaf occurred in fructescence for the mature forest, while in both fructescence and florescence for the young forest. Besides, the highest nutrient demand of flower occurred in the florescence of mature forest.

In fructescence, the nutrient concentration in the mature and young *C. oleifera* forests was in an order of available N > K > P (Table 2). The average major element concentration in soil were in an order of total K > Ca > total N > total P > Mg. Besides, the soil microelement concentration in the mature and young forests were in orders of Fe > Pb > Zn > Mn > Cu > Cd and Fe > Mn > Zn > Pb > Cu > Cd, respectively. In addition, the organic matter content of soil was higher in mature forest than that in young forest.

In fructescence, the nutrient concentrations in different soil layers in the mature and young forests were in orders of 0 - 20 > 20 - 40 > 40 - 60 cm and 0 - 20 > 40-60 > 20 - 40 cm, respectively. In florescence, the nutrient concentration in the mature and young forest soil were in orders of available K > N > P and N > K > P, respectively. The average major element concentration in the mature and young forest soils were in orders of total P > Ca > total K > total N > Mg and total Ca > P > K > N > Mg, respectively. Microelement concentration in the mature and young forest soil were in orders of Fe > Zn > Mn > Pb > Cu > Cd and Fe > Zn > Pb > Mn > Cu > Cd, respectively. The organic matter content in soil was higher in the mature forest than that of the young forest. In fructescence, the nutrient concentration in different soil layers of both the mature and young forests were in an order of 0 - 20 > 20 - 40 > 40 - 60 cm. Thus, soil nutrient supply of available P, and K, and total N, P, and Ca, Mn, and Cu changed dramatically in the mature forest, whereas available N, total K, Mg, Pb, and organic matter changed dramatically in young forest. Besides, the contents of Fe, Zn, and Cd changed slightly and were stable in of both the mature and young forests.

In the florescence period of *C. oleifera*, the nutrient concentrations of different soil layers including 0 - 20, 20 - 40 and 40 - 60 cm were all higher in the mature forest than those in the young forest (Fig. 2). The mean nutrient concentration in 0-60 cm soil was 2612.81 ± 756.68 mg/kg in the mature forest, which was larger than that of 2312.99 ± 659.85 mg/kg in case of the young forest. In fructescence, the situation was similar with mean nutrient content in different soil layers of 2394.06 ± 811.37 mg/kg in the mature forest and 1651.75 ± 211.32 mg/kg in the young forest. In florescence, the soil nutrients of both the mature and young forest mainly were distributed centrally in the surface layer of 0 - 20 cm. In addition, the soil nutrient content decreased with an increase in the soil depth. The soil nutrient content ratios in the different soil layers of the mature and young forests were in orders of 0 - 20 (46.77%) > 20 - 40 (28.89%) > 40 - 60 cm (24.54%) and 0 - 20 cm (46.56%) > 20 - 40 (28.84%) > 40 - 60 cm (24.60%), respectively. In fructescence, the soil nutrient of both mature and young forest was also centrally distributed in the surface layer of 0 - 20 cm. In addition, the soil nutrient content decreased with an increase in the soil depth. The soil nutrient content ratios in the different soil layers of the mature and young forests were in orders of 0 - 20 (48.33%) > 20 - 40 (30.61%) > 40 - 60 cm (21.06%) and 0 - 20 (38.54%) > 20 - 40 (33.37%) > 40 - 60 cm (28.09%), respectively.

The soil nutrients in different layers of mature and young *C. oleifera* forests were all higher in the florescence than those of the fructescence period. Soil nutrient contents in the mature forest were 2612.81 ± 756.68 mg/kg in florescence and 2394.06 ± 811.37 mg/kg in fructescence, whereas the soil nutrient contents in the young forest were 2312.99 ± 659.85 mg/kg in florescence and 1651.75 ± 211.32 mg/kg in fructescence, respectively.

Thus, the soil nutrient content of different soil layers in the mature *C. oleifera* forest in florescence was 1.09 folds of that in fructescence. In the young forest, soil nutrient content in florescence was 1.40 folds of that in fructescence.

From soil nutrient distribution characteristics of different soil layers, the soil nutrients of both mature and young *C. oleifera* forests were all centrally distributed in the surface layer of 0 - 20 cm. Besides, the soil nutrient content in the florescence period was higher than that in the fructescence period.

Table 2. Nutrient contents (mg/kg) of organs in the mature and young *Camellia oleifera* stands at different stages.

Time	Age of stand	Organ	Major elements							Microelement					Mean value
			N	P	K	Ca	Mg	Cu	Fe	Zn	Mn	Cd	Pb		
Fructescence	Mature forest	Flower	11300.0	111.0	2300.0	5582.0	998.0	7.2	65.3	8.8	894.1	0.3	10.8	1934.33	
		Fruit	9500.0	102.0	2600.0	2334.0	669.0	3.3	137.7	6.7	506.7	0.2	11.9	1442.88	
		Leaf	17100.0	366.0	1600.0	10173.0	817.0	9.5	63.4	9.1	1480.7	0.3	7.4	2875.13	
		Branch	12500.0	48.0	2500.0	7414.0	863.0	10.4	253.1	25.4	892.2	1.2	30.2	2230.67	
		Trunk	7700.0	12.0	1400.0	4983.0	693.0	5.2	69.3	23.4	685.3	0.7	14.3	1416.91	
		Mean value	11620.0	127.8	2080.0	6097.2	808.0	7.1	117.8	14.7	891.8	0.5	14.9	1979.98	
Young forest	Young forest	Flower	13700.0b	371.5	2150.0	5413.0	863.5	9.3	77.6	10.8	667.1	0.2	4.6	2115.23	
		Leaf	22150.0b	306.0	1750.0	12037.5	1013.0	5.7	85.3	10.2	1447.8	0.5	5.1	3528.28	
		Branch	13750.0b	246.0	1350.0	6138.0	944.0	8.6	104.5	24.4	703.8	0.4	7.4	2116.09	
		Trunk	8200.0b	283.0	1300.0	3764.0	455.0	5.3	476.1	17.4	691.7	0.5	5.1	1381.63	
		Tree root	12700.0b	266.5	2000.0	2823.0	742.0	6.1	535.0	20.3	403.3	0.4	8.0	1773.14	
		Mean value	14100.0	294.6	1710.0	6035.1	803.5	7.0	255.7	16.6	782.7	0.4	6.1	2182.88	
Florescence	Mature forest	Flower	16000.0	374.0	2100.0	5092.0	683.0	6.9	60.4	10.9	948.7	0.2	6.3	2298.40	
		Leaf	15800.0	290.0	1400.0	5531.0	400.0	4.1	92.9	6.8	1026.0	0.2	9.7	2232.79	
		Branch	7100.0	190.0	1200.0	4623.0	537.0	8.5	221.6	27.5	754.0	0.7	9.7	1333.82	
		Trunk	7100.0	260.0	1200.0	4851.0	547.0	5.0	171.6	26.2	902.3	0.7	6.3	1370.01	
		Tree root	8500.0	230.0	1400.0	5865.0	646.0	3.1	310.0	17.1	419.3	0.3	6.3	1581.54	
		Mean value	10900.0	268.8	1460.0	5192.4	562.6	5.5	171.3	17.7	810.0	0.4	7.6	1763.31	
Young forest	Young forest	Flower	17350.0	592.5	2250.0	3611.0	806.0	6.7	80.5	11.6	602.7	0.3	12.5	2302.17	
		Leaf	18350.0	605.8	1600.0	12590.0	991.5	4.4	100.6	10.8	1157.8	0.5	15.4	3220.61	
		Branch	12050.0	343.3	1650.0	7027.5	890.0	10.4	150.9	24.1	466.7	0.6	18.2	2057.42	
		Trunk	7800.0	105.7	1350.0	4927.0	774.5	6.8	208.0	26.6	420.9	0.4	17.1	1421.54	
		Tree root	10650.0	147.9	1400.0	1962.0	1467.0	6.6	182.2	35.7	294.6	0.7	11.4	1468.92	
		Mean value	13240.0	359.1	1650.0	6023.5	985.8	7.0	144.4	21.8	588.5	0.5	14.9	2094.13	

After variance analysis, there were no significant differences between all rows, but significant differences between all columns at P<0.05 level.

In the present research, results showed that the major element demand in the mature and young *C. oleifera* forests, in both florescence and fructescence, was in an order of $N > Ca > K > Mg > P$. The highest major element demand was of total N and the lowest was of total P. Besides, the highest microelement demand was of Mn and the lowest was of Cd.

This was due to the fact that the total N content was not only related to soil texture itself and soil parent material, but also to the application of fertilizers. *C. oleifera* is an oleiferous tree species, thus, N fertilizer intake was increased to facilitate a high yield. Hence, the total N content was the highest. However, total P content was influenced significantly by soil parent material and pedogenesis. Besides, total P content was also related to the soil texture (Sheng *et al.* 2013). The research site was at the hillock area in the central Hunan, which has been a highland for a long time and where soil has been generated. Thus, due to soil parent material, total P content of the soil was relatively low, resulting in low absorption of total P content by the plants. The N and P contents in the plants were significantly positively related to the corresponding total N and total P content in soil, illustrating that soil was an input terminal of the plant nutrients and determined the absorption and accumulation of nutrients by plants (Li and Li 2012). Mn element widely existed in the natural environment. There was 0.25% of natural Mn in the soil, which was relatively high. Thus, Mn content which could be absorbed by plants was also higher, resulting in the higher Mn demand in the mature and young *C. oleifera* forests.

However, the microelement Cd exhibited a very small ratio to material in the earth of 0.1-0.5:1000000, which resulted in the low content of Cd itself. Thus, the absorption amount of different *C. oleifera* forests was limited, resulting in the lowest Cd content.

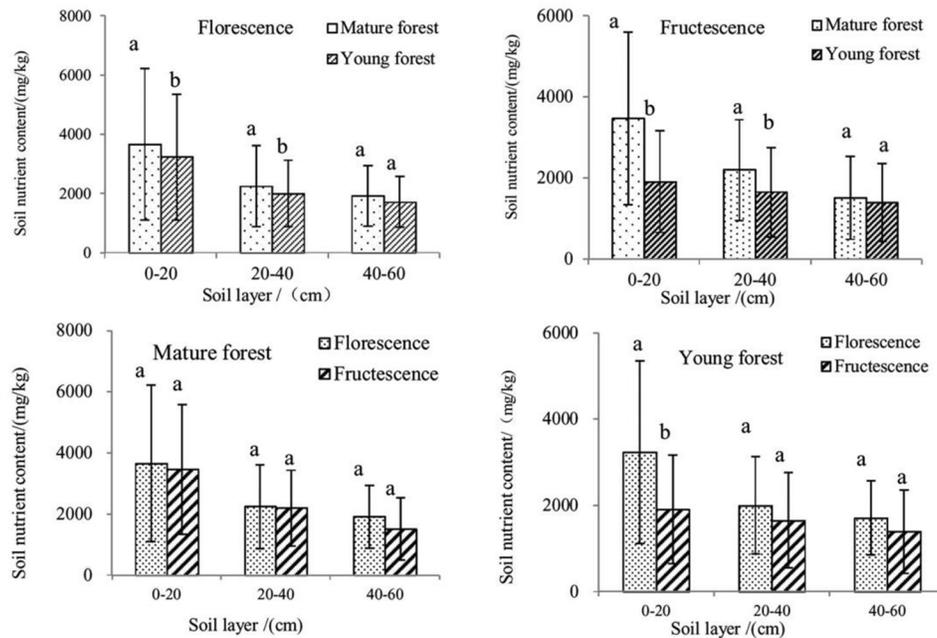


Fig. 2. Nutrient distribution of different soil layers in mature and young *Camellia oleifera* plantation.

Due to the different functions of the different organs of forest, the nutrient element absorbed from the outside by forest would be largely used by the parts of assimilation organs, sprout, spire etc. that exhibit a vigorous growth (Yin 2004).

Furthermore, it was seen that, the highest tree organ nutrient content of mature and young *C. oleifera* forests occurred in leaf and branch not only in fructescence but also in florescence, and the lowest organ nutrient content occurred in trunk. This might be due to the accumulation of nutrient element in the plant system that was determined by the biomass to a large extent (Ji 2016).

Previous research showed that the largest biomass distribution of the plant occurs in leaf followed by the branch (Xia and Liang 2009). Thus in the present research, the highest accumulated nutrients in the mature and young *C. oleifera* forests occurred in the leaf and branch. Lu *et al.* (1995) studied the nutrient element space of *Castanopsis fargesii* Franch. forest in the northeastern Guangxi and found that the nutrient content in different organs of tree layer was in an order of leaf > annual shoot > perennial branch > dry branch. A similar observation was made by Zhou *et al.* (1996) who showed that the distribution of nutritional elements was in an order of leaf > branch > root > dry wood. Results of the present work are in agreement with the findings of above researchers, illustrating the correctness of the corresponding conclusions.

Under natural conditions, the soil nutrient content is totally determined by the natural material basis as well as environmental conditions (Lin *et al.* 2009). Besides, the available nutrient content is the intensity index that describes the soil nutrient supply (Wang and Zhang 2014). The soil nutrient content of different soil layers in fructescence and florescence of *C. oleifera* was higher in the mature forest than that in young forest. This illustrates that the mature *C. oleifera* forest obtained more available nutrients, major elements, and microelements. The reason was that the increase of soil nutrient materials resulting from the dissolved litter in the soil after a long time of decomposition due to the long growth time of the mature forest, whose forest floor litter and crown width were all larger than those of young forest (Wang *et al.* 2010).

Thus the soil nutrient content was lower in the young forest than that in the mature forest. In this work, it was seen that the soil nutrients were mainly centrally distributed in the surface layer of 0-20 cm, in both fructescence and florescence of the mature and young forests. Besides, the soil nutrient composition decreased gradually with the increase in the soil depth. Soil nutrient content ratio in the different soil layers of the mature and young forests was in orders of 0-20 (48.33%) > 20 - 40 (30.61%) > 40 - 60 cm (21.06%) and 0 - 20 (38.54%) > 20 - 40 (33.37%) > 40 - 60 cm (28.09%), respectively. It illustrates that the soil nutrients including the available nutrients, major elements and microelements were mainly and centrally distributed in the surface layer of soil. Thus, the nutrient content was more in the soil surface than that of the bottom layer, as the soil nutrients mainly originated from the soil organic matter which are mainly originated from litter of plants on the ground and roots under the ground. The next source was the atmospheric rainfall, slope seepage, and underground water. Thus, the sources of soil nutrients were mainly above the ground. For example, the soil surface with which was first contacted by plants absorbed relatively more nutrient elements which reached the bottom layer of soil afterwards by leaching out or root absorption. Thus, during fructescence and florescence of mature and young *C. oleifera* forests, the soil organic matter, total P, and N, and available K, P, and N as well as microelement contents decreased with the increase of the soil depth.

It was observed that in the present study the highest major element demand of mature and young *C. oleifera* forests was of total N and the lowest was of total P. Whereas, the highest microelement demand was for Mn and the lowest for Cd. The available nutrient supply of the soil nutrients in the mature and young *C. oleifera* forests mainly included the available N and K, whereas the supply of available P was the lowest. The highest macroelement supply was of total P and Ca and the lowest was of Mg, whereas the highest microelement supply was Fe and the lowest was Cd. This illustrated that there was a difference between the nutrient element demand in the mature and young *C. oleifera* forests and the nutrient element supply of soil.

The highest demand of mature and young *C. oleifera* forests was for total N and Mn, whereas the highest supply in the soil were total P and Fe, which was related to properties of soil parent material and litter, illustrating that it was necessary to apply more P fertilizer as well as to supplement Mn in *C. oleifera* forest.

The tree organ demand of the *Camellia oleifera* forests was higher in mature forest than that in the young forest, whereas the nutrient supply of soil was larger in the mature forest than that of the young forest. There was a difference between plant demand and soil supply, because the young forest was in the period of vigorous growth, whereas the mature forest transformed to an aged forest with the decrease in the nutrient element demand. Thus, tree organ nutrient content was higher in young forest than that in mature forest. The nutrient content in the soil was related to productivity and litter amount. For example, the litter amount of mature forest was larger than that of young forest, which was dissolved in the soil after decomposition. Thus, the nutrient content in soil was higher in the mature forest than that in the young forest.

Tree organ nutrient contents of the mature and young *C. oleifera* forests were higher during fructescence than those in florescence, whereas the soil nutrients in different soil layers were higher in florescence than those in fructescence, due to growth characteristics of *C. oleifera*. Florescence of *C. oleifera* occurs every November after the fructescence in October. Florescence is the new beginning of *C. oleifera* and the plant needs nutrients during flowering. In addition, fructescence marks the end of the whole growth period. After one whole year growth, the *C. oleifera* accumulates nutrients. Thus, different organ nutrients of *C. oleifera* were more in fructescence than those in florescence. Fructescence occurs in the harvest period, with the stoppage of the plant growth. Thus, absorption of nutrients from the soil gets decreased in this period. Besides, there is no need of large amounts of nutrients for nourishment during this period. Thus, soil nutrient contents were higher in florescence than those in fructescence, which was in accordance with the research of Yang *et al.* (2010).

The highest macroelement demand of the mature and young *C. oleifera* forests was of total N and the lowest was of total P, whereas the highest microelement supply was Mn and the lowest was Cd. In addition, the available nutrients from soil nutrient supply of mature and young *C. oleifera* forests were mainly the available N and K and the least was Mg. The highest supplied microelement was Fe and the lowest was Cd. The tree organ demand of young *C. oleifera* forest was lower than that of mature forest, whereas the soil nutrient supply of the mature forest was higher than that of the young forest.

Tree organ nutrient contents of mature and young *C. oleifera* forests were higher during fructescence than those of during florescence, whereas soil nutrient supply was higher in florescence than that in fructescence. There was a difference between the nutrient element demand and the soil nutrient element supply in the mature and young *C. oleifera* forests.

According to current fertility of soil, the scientific ratio of N, P, and K as well as the appropriate addition of microelements could control the fertilizer amount to a scope which can fulfill the requirement of the scientific and environmental protection, not only by increasing the yield, but also by protecting environment and developing the *C. oleifera* industry scientifically. Finally, the research result will provide scientific evidence for nutrition diagnosis and nutrient management of *C. oleifera*.

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