DYNAMICS OF SOIL CHEMICAL PROPERTIES UNDER *Illicium verum* Hook FORESTS IN VAN QUAN, LANG SON

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SUMMARY

Dynamics in soil chemical properties are greatly influenced by vegetation. The study was conducted under *Illicium verum* plantations 21 years and 31 years in Van Quan, Lang Son. At each age level of the forest, soil samples were collected at different depths: 0 – 10 cm, 10 – 20 cm and 20 – 50 cm layers. The results showed that there were significant differences in hydrolytic acidity and humus content between the two forest ages and between the soil depths. The amount of soil organic carbon (SOC) differed significantly between 21-year-old forest (19.83 tons/ha in average) and 31-year-old forest (30.13 tons/ha in average) and tended to decrease with soil depths. The content of bio-available nitrogen in soils was poor (reached 0.55 – 1.71 mg/100g dried soil at 21-year-old forest and 1.37 – 1.75 mg/100g dried soil at 31-year-old forest). There was no difference between the two forest age classes and soil depths. Similarly, the content of bio-available phosphorus at the two forest age levels did not differ (all from 0.13 to 0.17 mg/100g dried soil) and tended to decrease gradually with soil depths. The bio-available content potassium was all poor and also did not differ significantly between between 21-year-old forest (3.85 - 4.31 mg/100g dried soil) and 31-year-old forest (3.88 - 4.74 mg/100g dried soil). There was no difference in the potassium content between soil depths in the 21-year-old forest, but there was a statistical difference between the soil depths in the 31-year-old forest. A pathway equation indicated that humus content had a proportional relationship with the soil chemical properties except for the available potassium at both *Illicium verum* forest age levels.

Keywords: chemiscal properties, *Illicium verum* Hook, soil depths, soil organic carbon, Van Quan, Lang Son.

1. INTRODUCTION

Soil chemical properties affect a variety of soil regulatory functions, such as nutrient retention and availability, soil reactions, absorption and breakdown of toxic substances (Blume et al., 2010). The ability of the soil to provide essential nutrients to plants is particularly important. Due to decomposition activities of microorganisms, plant remains become nutritional elements that provide for growth and development of vegetation.

Variations in chemial properties of the soil are driven mainly by two processes: organic matter accumulation and leaching (Jobbágy & Jackson, 2000). The accumulation of organic matter from plants greatly affects the physicochemical properties of the soil from the topsoil to the substratum (Jobbágy & Jackson, 2001). In contrast, the leaching process greatly influences the movement of nutrients in a downward trend. Leaching can increase nutrient content with soil depths (Jackson et al., 2000).

In the topsoil, the amount of humus content accounts for only a few percent, but they have an important influence on all soil functions. More importantly, the humus content plays a central role in the earth's carbon cycle (Blume et al., 2010). Under the influence of environmental conditions and plants, the mineralization and decomposition of dead plants will produce humus, nutrients, microbial biomass and change the soil physical properties such as porosity, moisture holding capacity and soil texture.

Van Quan district, Lang Son province has suitable natural conditions for the development of *Illicium verum*. Currently, the total area of *Illicium verum* in the district is about 12,000 ha, accounting for over one third of the total area of *Illicium verum* plantations in the province (Lang Son Department of Agriculture and Rural Development, 2018). This species products with high economic values have been widely used in many fields such as: medicinal herbs, flavorings, cuisine and handicrafts and so on. This species brings high income and plays an important role in poverty reduction for local people.

However, there are no studies on the

influence of the species plantations on soil properties in Van Quan district, Lang Son province. Therefore, this research results will provide a scientific basis to instruct people to protect and improve the soils in the process of planting and tending *Illicium verum* forests at different ages. Based on soil samples collected at different depths under the forests, this study aim to: (i) analyze changes in hydrolytic acidity and humus content in the soil; (ii) evalute SOC variation; (iii) analyze changing trends in the content of easily digestible nutrients and (iv) to analyze the relationship between humus content and soil chemical properties.

2. RESEARCH METHODOLOGY

2.1. Methods of collecting soil samples in the field

2.1.1. Plot establishment and soil profile arrangement

For each forest age level, 3 plots were established with an area of 1000m^2 (25m x 40m) at representative positions of tree height, coverage, slope, and elevation (Vu Tien Hinh, 1997). Three representative positions were selected to excavate the profile: tow slope, back slope and summit. This ensures the uniformity and accuracy of the research results because the forest is a heterogeneous community (Bui Manh Hung, 2016). In each plot, five locations were selected to excavate and collect soil samples. Soil samples were mixed together to form a composite sample for physicochemical analysis.

(a)

(b)

Figure 1. Sampling sites for soil sample collection under the *Illicium verum* forests 21 years old (a) and 31 years old (b)

2.1.2. Soil samples collection for analysis

In each soil profile, soil samples were taken at 3 depths: 0 - 10 cm, 10 - 20 cm and 20 - 50 cm. At each depth, soil was taken at random points, then mixed and formed into a composite sample for analysis of soil physicochemical properties.

(a)

(b)

Figure 2. Soil depths for sample collection under the *Illicium verum* forests 21 years old (a) and 31 years old (b)

Synthetic soil samples at each depth were taken with a weight of 0.5 - 1 kg and processed according to the process of the Soil and Fertilizer Research Institute for analyzing soil physical and chemical properties (Ministry of Agriculture and Rural Development, 2008). The number of soil samples analyzed for soil physicochemical properties at two ages of the forest and three sampling locations was 18 soil samples.

Soil for density analysis was taken separately, stored in plastic bags, labeled and analyzed immediately after returning to the laboratory. This parameter was used to calculated SOC content in soils.

2.2. Methods of soil analysis in the laboratory

Soil samples were processed and analyzed at the Center for Forestry and Climate Change Research, Vietnam National University of Forestry. The used analytical methods included:

+ Density: Metal cylinder method (D=P/V, where P is the natural mass of soil in the closed cylinder after it has been completely dried, V is the volume of the cylinder).

+ Hydrolyzed acidity: Kapen’s method.

+ Soil organic matter: Tiurin's method.

+ Bio-available nitrogen: colorimetric method

+ Bio-available phosphorus: colorimetric method.

+ Bio-available potassium: flame photometric method (TCVN 4053:1985).

Soil physicochemical properties were analyzed in 3 replicates for each soil sample.

2.3. Soil processing methods

The calculation and processing of research data is supported by the statistical analysis software SPSS version 26.

2.3.1. Calculating variables

* Formulas for calculating indicators including: density, humus content, hydrolyzed acidity, and content of bio-available macronutrients (nitrogen, phosphorus, potassium) were applied according to the Practical Manual (Department of Soil Science, 2015).

* Calculate average values and standard deviations for soil chemical variables such as: density, humus content, hydrolytic acidity, and content of easily digestible nutrients (nitrogen, phosphorus, potassium).

* Calculate the amount of soil organic carbon (SOC) according to the formula of IPCC, 2006:

$$SOC = h \times D \times OM \times 0.58 \times 100$$

In which:

SOC: Soil organic carbon (ton/ha);

h: Depth of soil layer (cm);

D: soil density (g/cm^3);

OM: CHC content (%).

2.3.2. Checking the difference in soil chemical properties between two age classes and soil depths

* Used linear mixed effect model (LMM) to check the difference between the soil properties including: hydrolyzed acidity, humus content, nitrogen, phosphorus, and potassium in the *Illicium verum* forest 21 and 31 years old. Similarly, linear mixed effect model was used to check the differences in chemical parameters between soil depths. If the Sig. value > 0.05, it was concluded that there was no difference between the two forest age classes or between the soil depths. Conversely, if Sig. < 0.05, it was concluded that there was a significant difference between the two forest age classes or between the soil depths.

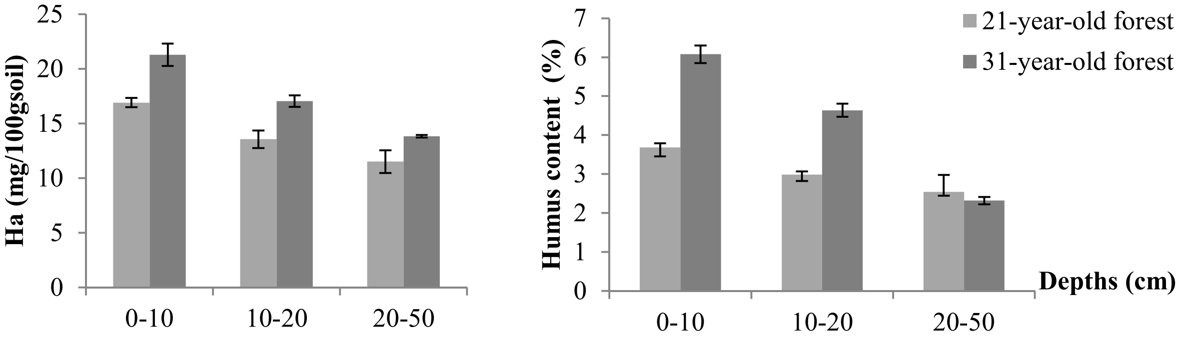
* Analyzed the relationship between SOC and soil chemical properties by pathway analysis.

3. RESULTS AND DISCUSSIONS

3.1. Changes of hydrolytic acidity and humus content in soil

3.1.1. Hydrolytic acidity

Hydrolytic acidity (Ha, mg/100g dried soil) was the largest potential acidity presented in the soil. Therefore, this parameter was determined to offer solutions to reduce soil acidity. The value of exchange acidity depends on soil type, humus content, amount and type of soil colloid, soil mechanical composition, and quantity and composition of exchange base cations (Blume et al., 2010).



(a) (b)

Figure 3. Variation of hydrolytic acidity (a) and humus content (b) with soil depths at two forest ages

The research results showed that the hydrolyzed acidity in the forest at 21 years old ranged from 10.42 to 17.27 mg/100g dried soil and in the 31-year-old forest ranged from 13.68 to 22.17 mg/100g dried soil. Thus, the hydrolyzed acidity value in the 21-year-old forest was smaller and significantly different from that in the 31-year-old forest (LMM, Sig value. = 0.025). Humus compounds were formed most concentrated in the topsoil (0-10cm) where the fall is most returned by plants. Soil acidity is often highest in the forest soil organic matter layer (Blume et al., 2010). The amount of fallen matter is the main cause that governs the change in hydrolytic acidity with soil depth.

In each age, hydrolytic acidity tended to decrease gradually with soil depths and there was a significantly difference between soil depths (LMM, Sig value. < 0.05). Specifically, in both ages, the hydrolytic acidity in the topsoil was greatest, followed by the soil layer 10 – 20 cm and finally 20 – 50 cm (Figure 3).

3.1.2. Humus content in the soil

Humus in the soil is an important reserve of nutrients for plants. In addition, humus increases the ability to absorb cations in the soil, converts phosphorus and phosphorus compounds in the soil that are insoluble into soluble, reduces toxic substances to plants, increases the degree of saturation of bases and soil properties (Ha Quang Khai et al., 2000).

Research results indicated that: Humus content in 21-year-old forests ranged from 2.54% to 3.68%, corresponding to medium to good (MARD, 2008). In which, the humus content in the topsoil was statistically different from the 20 – 50 cm layer (LMM, Sig. = 0.02), while this content was not different between 10 - 20 and 20 – 50 cm layers (LMM, Sig. = 0.085).

The content of humus at the 31-year-old forest run from 2.32% (20 – 50 cm layer) to 6.07% (0 – 10 cm layer), corresponding to medium to rich humus levels. Humus content in the topsoil was siginificantly different from 10 – 20 cm and 20 – 50 cm (LMM, Sig. < 0.001). With the long-term accumulation of plant residues and the shrubs coverage under the forest, the humus content was significantly different between 31-year-old and 21-year-old forests (LMM, Sig. = 0.043) (Figure 3).

This is explained by the fact that the top soil layer accumulates fallen matter most and the humification process is fastest in this layer. At a depth of 0 – 10 cm, there is rich forest vegetation, the microbial activity in this layers is also stronger and the soil is supplemented with a relatively large amount of plant residues. Therefore, the humus content at this depth is highest. Jobbágy & Jackson, 2000 also showed that the distribution of carbon in the soil layers is mainly influenced by the source of organic matter introduced into the soil from plants.

3.2. Amount of soil organic carbon (SOC)

Plant residues under the forest canopy are an important factor for trees and forest soil. Litter is a source of nutrients that plants return to the soil and carry out the carbon cycle in the soil. After decomposition, the fallen material increases the humus content of the soil, retains moisture through the formation of soil texture, increases the porosity of the soil (Kirby, 1985). Furthermore, the litter forms a cover on the ground which reduces the amount of rain that shoots directly onto the soil, prevents erosion, reduces surface water evaporation and keeps the soil moist stably.

Table 1. SOC and estimates of fixed effects of SOC at different soil depths and forest ages

Forest age	Parameter	SOC (tons/ha)	Estimate	Std. Error	t	Sig.	95% Confidence Interval	
							Lower Bound	Upper Bound
Age 21	Intercept		17.75	0.91	19.48	0.00	15.52	19.98
	0-10	23.03 ± 0.47	5.28	1.29	4.10	0.01	2.13	8.43
	10-20	18.70 ± 1.82	0.95	1.29	0.73	0.49	-2.21	4.10
	20-50	17.76 ± 1.98	0[a]	0				
Age 31	Intercept		18.81	0.94	20.03	0.00	16.51	21.10
	0-10	37.64 ± 0.79	18.84	1.33	14.19	0.00	15.59	22.09
	10-20	33.97 ± 2.09	15.16	1.33	11.42	0.00	11.91	18.41
	20-50	18.81 ± 1.71	0[a]	0				

a. This parameter is set to zero because it is redundant.

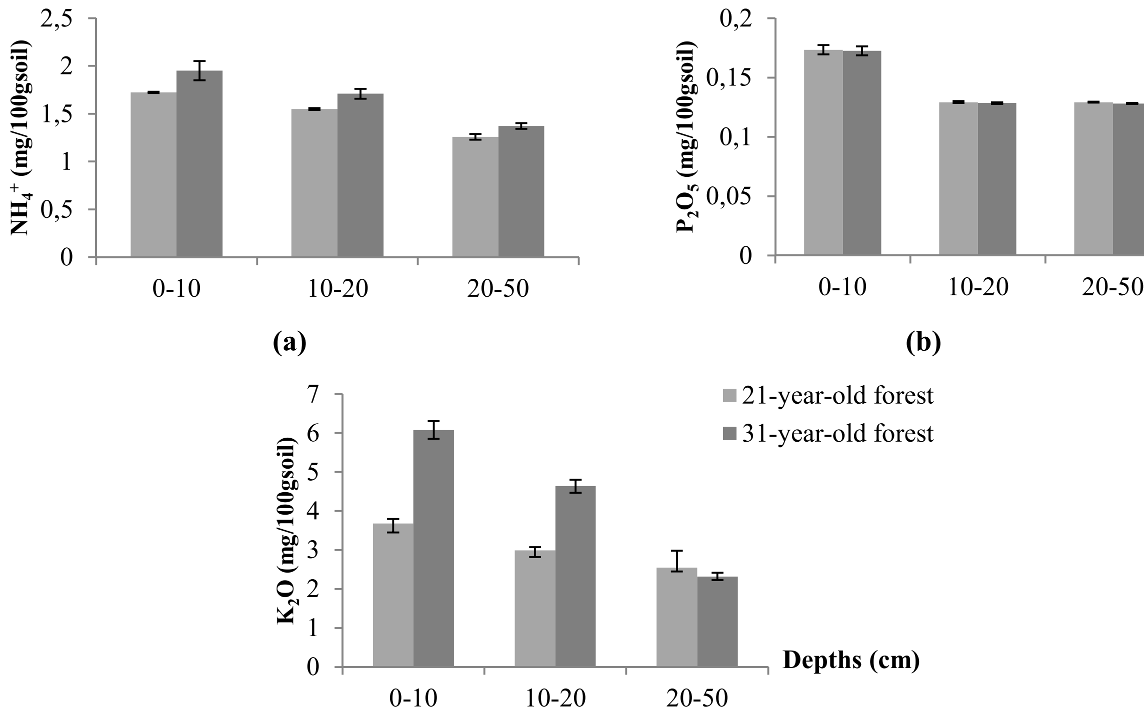
The study results showed that the amount of SOC in the 31-year-old forest was larger and significantly different from that of the 21-year-old forest (LMM, Sig. = 0.004). In both forest ages, the amount of SOC tended to decrease with the depths: from the topsoil layer to 10 - 20 cm layer and 20 – 50 cm layer. Liu W. et al. (2017) also showed that the SOC density was mainly concentrated in the topsoil and decreased with the soil depths.

There was a huge difference in the amount of SOC between the 0 – 10 cm layer and the 20 – 50 cm layer at both forest ages (LMM, Sig. < 0.005) (Table 1). The amount of SOC at the 10 – 20 cm layer was significantly different from the 20 – 50 cm layer (LMM, Sig. < 0.0001) in the 31-year-old forest. Meanwhile, there was no difference between these soil layers in the 21-year-old forest (LMM, Sig. = 0.49).

The significant difference in soil humus content between two forest ages and between soil depths is the main reason for the variation in the amount of SOC accumulated in the soil. Because carbon in the soil is accumulated as organic matter or humus (Gonza´les-Ramı´rez et al., 2012). The changing trend of humus content was similar to that of SOC between forest types and soil depths. Humus content amount was clearly different between the two forest ages. The difference in humus content between the soil depths was extremely clear at forest age 31, whereas there was no big difference between 0 – 10 cm and 20 – 50 cm layers at age 21.

3.3. Variation of available nutrients at different soil depths in the forests

In soil, N-P-K are the three most important elements for plant growth. These primary nutrients are always changing in the soil, the process of nutrient change depends on the processes of weathering, mineralization, leaching or accumulation, especially depending on the activity of microorganisms and the vegetation layer.



(c)

Figure 4. Variation of bio-available nutrients in the soil: nitrogen (a), phosphorus (b) and potassium (c) at different soil depths

3.3.1. Bio-available nitrogen content in soil ($NH4^+$) (mg/100g dried soil)

Nitrogen plays an important role in promoting plant growth and development. According to the amount contained in plants, nitrogen is the leading element that plants get from the soil. The nitrogen content in the soil mainly depends on the organic matter content in the soil, it is always proportional to the content of organic matter, especially humus. Plants can use nitrogen in the form of NH_4^+, NO_3^-, NO_2^-, but NO_2- is almost absent in the soil. Therefore, plants use mainly in two forms NH_4^+, NO_3^-. This is an easily digestible nigrogen that directly affects the life of plants.

The analyzed results illustrated that bio-available nitrogen content ranged from 0.55 to 1.71 mg/100g in the 21-year-old forest and from 1.37 - 1.75 mg/100g in the 31-year-old forest. The bio-available nitrogen content at both forest ages was poor (MARD, 2008). There was no difference between the two forest ages in bio-available content of nitrogen (LMM Sig. = 0.246) (figure 4).

The variation of bio-available nitrogen content between soil depths was also not significant in both forest ages. Particularly, in the 21-year-old forest, the topsoil layer did not differ in digestible nitrogen content with the 10 – 20 cm and 20 – 50 cm layers (LMM, Sig. = 0.293 and 0.267, respectively). Similarly, in the 31-year-old forest, this value was 0.468 and 0.144, respectively. This result may be due to slow decomposition of nitrogen from the fallen matter or the large percentage of total nitrogen.

3.3.2. Bio-available phosphorus content in soil (P_2O_5) (mg/100g dried soil)

Along with nitrogen, phosphorus also plays an vital role in the growth and development of plants. Especially, bio-available phosphorus directly affects the flowering and fruiting process of plants. More than 50% of phosphorus in soil exists in organic form, the rest in inorganic form with very different solubility (Ha Quang Khai et al., 2000).

Research results showed that the content of bio-available phosphorus at two ages ranged from 0.13 - 0.17 mg/100g dried soil in the 21-

year-old forest and from 0.13 - 0.17 mg/100g dried soil in the 31-year-old forest. The available phosphorus content in the soil at both forest ages was very poor (MARD, 2008) and there was no difference between ages (LMM, Sig. = 0.583).

There was a gradual decrease in the bio-available phosphorus content with soil depths at both forest ages. Particularly, in the 21-year-old forest, there was a significant difference in bio-available phosphorus content between the topsoil and the 20 – 50 cm layer (LMM, Sig. < 0.0001). Meanwhile, there was no difference between 10 – 20 cm and 20 – 50 cm horizons. This trend was similar in the 31-year-old forest. The difference testing results indicated that the bio-available phosphorus content in the topsoil layer was clearly different from the 20 - 50 cm horizon (LMM, Sig. = 0.041). However, this content has no difference between 10 – 20 cm and 20 – 50 cm horizons (LMM, Sig. = 1,000) (Figure 4). This result is consistent with the conclusion of Jobbágy & Jackson, 2001: extractable phosphorus is a nutrient that is more concentrated in the topsoil and has the shallowest distributions. In addition, vegetation can also be an important factor controlling the density of phosphorus in the soil layers, and the increase in hydrolytic acidity with soil depth can fix phosphorus in the lower horizons (Sposito, 1989).

3.3.3. Content of bio-available potassium in the soil (K_2O) (mg/100g dried soil)

Potassium is a nutrient element derived mainly from the weathering of mineral compositions in the soil (Trudgill, 1988). Thus, the distribution of potassium concentration depends on the source parent rock and the degree of mineral weathering in the soil. The results of the study revealed that the bio-available potassium content ranged from 3.85 - 4.31 mg/100g dried soil in the 21-year-old forest and 3.88 - 4.74 mg/100g dried soil in the 31-year-old forest. The soil potassium content in both forest ages was very poor (MARD, 2008) and there was no statistical difference in bio-available potassium content between the two forest ages (LMM, Sig. = 0.963) (Figure 4).

In the 21-year-old forest, there was no difference in the bio-available potassium content between the topsoil layer with 10 – 20 cm and 20 – 50 cm horizons (LMM, Sig. = 0.775 and 0.063, respectively). However, in the 31-year-old forest, the potassium content was significantly different between the topsoil layer with 10 – 20 cm and 20 – 50 cm layers (LMM, Sig. = 0.027 and 0.000, respectively). Like phosphorus, soil potassium is derived primarily from minerals in the parent rock. The distribution of potassium concentrated in shallow soils layer occurs only when mineralization is higher. Plants can also produce this nutrient if they are weathered with potassium-bearing minerals (Jungk & Claasen, 1986).

3.4. Relationships between humus content and soil chemical parameters

Humus in soil is the main source to create accumulated carbon, macronutrients for plants and they change the acidity of the soil due to humus-forming activity of microorganisms (Ha Quang Khai et al., 2000). Therefore, this study shows the relationship between humus content in the soil and the remaining factors in the *Illicium verum* plantations.

Table 2. Relationship between humus content and soil chemical parameters under two different forest ages

Forest age	Hydrolytic acidity	Bio-available nitrogen	Bio-available Phosphorus	Bio-available Potassium	SOC	Direct effect	Indirect effect
Age 21	0.400	0.514	0.151	-0.012	0.137	0.466	0.527
Age 31	0.369	0.008	0.018	-0.037	0.602	0.500	0.465

The pathway equation showed that at both forest ages humus content had a proportional relationship with the soil chemical properties, except for readily available potassium. In the 21-year-old forest, humus content had a proportional relationship with hydrolytic acidity, easily digestible nitrogen, easily digestible phosphorus and SOC with β values of 0.400, 0.514, 0.151 and 0.137, respectively. This relationship was clearly explained in section 3.3. Meanwhile, digestible potassium had an positive relationship with humus content with beta of -0.012. This result further confirms the origin of potassium, which is mainly made from the mineral composition of the soil. The relationship between the tested variables in the 31-year-old forest also tended to be similar in the 21-year-old forest. Humus content also had a proportional relationship with most of the soil chemical properties: hydrolytic acidity (β = 0.369), digestible nitrogen (β = 0.008), easily digestible phosphorus (β = 0.018) and SOC (β = 0.602), except for easily digestible potassium (β = -0.037).

The 31-year-old forest had a higher content of organic matter returned to the soil (section 3.1.1), so the relationship between humus and easily digestible nutrients was stronger with a direct influence coefficient of 0.5. This coefficient in the 21-year-old forest was smaller, (about 0.466). Indirect effect of other factors such as elevation, slope, canopy structure, coverage ect on the variability of chemical properties in the 21-year-old forest was higher (0.527) than that of 31-year-old forest (0.465).

4. CONCLUSION

Hydrolyzed acidity in 21-year-old forests was smaller (10.42 – 17.27 mg/100g dried soil) and significantly different from 31-year-old (13.68 – 22.17 mg/100g dried soil). There was a very clear difference in hydrolytic acidity between soil depths. It tended to decrease gradually with depths from topsoil, then 10 – 20 cm layer and finally 20 – 50 cm horizon. There was a statistical difference in humus content between 21-year-old (2.54% - 3.68%) and 31-year-old (2.32% - 6.07%). The humus content in the 0 – 10 cm layer was significantly different from the 10 – 20 cm and 20 – 50 cm layers. However, this concentration was not different in the 10 – 20 and 20 – 50 cm layers under the 21-year-old forest.

The amount of SOC in the 31-year-old forest (30.13 tons/ha in average) was greater and significantly different from the SOC in the 21-year-old forest (19.83 tons/ha in average). In both forest ages, the amount of SOC was significantly different and tended to decrease with depths: from topsoil layer to 10 – 20 cm and 20 – 50 cm horizons. However, the 10 – 20 cm layer was not significant different from the 20 – 50 cm layer in the 21-year-old forest.

The content of bio-available nitrogen in the soil at the two ages was poor level, ranged 0.55 – 1.71 mg/100g dried soil at 21-year-old forest and 1.37 – 1.75 mg/100g dried soil at 31-year-old forest. There was no difference between the two forest ages in bio-available nitrogen content. The variation of bio-available nitrogen content among soil depths also did not have a clear difference. Similarly, the bio-available phosphorus content at the two forest ages was poor level (reached 0.13 – 0.17 mg/100g dried soil at 21-year-old forest and 31-year-old forest) and had no difference and tended to decrease gradually with soil depths. However, the content of this nutrient did not clearly differ between 10 – 20 cm and 20 – 50 cm layers. The bio-available potassium content was also poor level and there was no statistical difference between the two ages (ranged 3.85 – 4.31 mg/100g dried soil at 21-year-old forest and 3.88 – 4.74 mg/100g dried soil at 31-year-old forest). There was no difference in this nutrient content at the soil depths in the 21-year-old forest. In contrast, the phosphorus content was clearly different between the soil depths in the 31-year-old forest. The pathway equation showed that humus content had a proportional relationship with the soil chemical properties except for bio-available potassium at both *Illicium verum* forest age levels.

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SỰ BIẾN ĐỘNG CÁC TÍNH CHẤT HÓA HỌC ĐẤT DƯỚI RỪNG TRỒNG HỒI TẠI VĂN QUAN, LẠNG SƠN

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[1]*Trường Đại học Lâm nghiệp*

TÓM TẮT

Sự biến động các tính chất hóa học của đất chịu ảnh hưởng rất lớn bởi thực vật. Nghiên cứu được tiến hành dưới rừng trồng Hồi 21 năm và 31 năm tại Văn Quan, Lạng Sơn. Ở mỗi cấp tuổi rừng Hồi, mẫu đất được thu thập tại các độ sâu gồm: tầng 0 – 10 cm, 10 – 20 cm và 20 – 50 cm. Kết quả nghiên cứu cho thấy, có sự khác biệt rõ rệt về độ chua thủy phân và hàm lượng mùn giữa hai cấp tuổi rừng và giữa các độ sâu tầng đất. Lượng SOC có sự khác biệt rõ rệt giữa rừng 21 tuổi (trung bình 19,83 tấn/ha) và rừng 31 tuổi (trung bình 30,13 tấn/ha) và có xu hướng giảm theo độ sâu tầng đất. Hàm lượng đạm dễ tiêu trong đất đều ở mức nghèo (0,55 – 1,71 mg/100g đất ở rừng 21 tuổi và 1,37 – 1,75 mg/100g đất ở rừng 31 tuổi) và không có sự khác biệt giữa hai cấp tuổi rừng và các độ sâu tầng đất. Tương tự, hàm lượng lân dễ tiêu ở hai cấp tuổi rừng không có sự khác biệt nào (đều từ 0,13 – 0,17 mg/100g đất) và có xu hướng giảm dần theo độ sâu tầng đất. Hàm lượng kali dễ tiêu đều thuộc mức nghèo và không khác biệt rõ ràng giữa rừng 21 tuổi (3,85 – 4,31 mg/100g đất) và rừng 31 tuổi (3,88 – 4,74 mg/100g đất). Không thấy có sự khác biệt về hàm lượng chất dinh dưỡng này ở các độ sâu tầng đất ở rừng Hồi 21 tuổi nhưng có có sự khác biệt rõ ràng giữa các độ sâu tầng đất ở rừng 31 tuổi. Phương trình hệ số đường ảnh hưởng cho thấy hàm lượng mùn có mối quan hệ tỷ lệ thuận với các biến tính chất hóa học đất ngoại trừ kali dễ tiêu ở cả hai cấp tuổi rừng Hồi.

Từ khóa: độ sâu tầng đất, rừng Hồi, SOC, tính chất hóa học, Văn Quan, Lạng Sơn.

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