การพัฒนาคุณภาพดินโดยใช้ถ่านชีวภาพที่ผลิตจากวัสดุเหลือทิ้งทางการเกษตร
The development of soil quality using biochar amendment from agricultural waste.

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Abstract

The development of highland soil quality using biochar amendment from agricultural waste was aimed to utilize the use of agricultural biomass as the substitution of chemical in agricultural fields. The experiment was conducted by pyrolysis biochar from durian shell, banana peel, and macadamia shell at low temperature (< 400 degree celcius) using Anila stove type gasifier. The biochar obtained in this study had the pH in the range of 7-10 depend on the type of raw materials. Each type of biochar was added to the highland soil from Phuruea, Loei Province, Thailand to study the liming effect. It was found that the 5% wt addition of biochar increased the pH of soil from 6 to 7, and biochar treated soil had more stability than the lime treatment at the same application rate. Moreover, the 5%wt of biochars were then added to the olive tree experiment plot at the Highland Agriculture Research and Development Center, Phuruea, Loei Province. After a year of application, the soil was collected and characterized. The results showed that the biochar application increased the pH of the soil to neutral range and also significantly increased the moisture, organic matter and potassium in soil in compared with non-treated soil.

บทคัดย่อ

การพัฒนาคุณภาพดินในพื้นราบที่สูงโดยใช้ถ่านชีวภาพที่ผลิตจากวัสดุเหลือทิ้งทางการเกษตรเป็นวัสดุปรับปรุงดินมีเป้าหมายเพื่อใช้ประโยชน์จากวัสดุเหลือทิ้งทางการเกษตรในการปรับปรุงคุณภาพของดินแทนการใช้สารเคมี ถ่านชีวภาพจากเปลือกทุเรียน เปลือกกล้วย และเปลือกแมคคาดีเมีย ที่เผาด้วยอุณหภูมิต่ำ (400 องศาเซลเซียส) โดยเตาชีวมวลแบบแก๊สซิไฟเออร์ (Anila Stove type) มีค่า pH อยู่ในช่วง 7-10 ทั้งนี้ขึ้นอยู่กับชนิดของวัตถุดิบ เมื่อนำถ่านชีวภาพแต่ละชนิดที่ได้มาปรับปรุงความเป็นกรดของดินในที่ราบสูง ณ อ.ภูเรือ จ.เลย พบว่าการปรับปรุงดินโดยใช้ถ่านชีวภาพร้อยละ 5 โดยน้ำหนัก สามารถปรับค่า pH ของดินจาก 6 เป็น 7 ได้ และดินที่ได้มีความเสถียรมากกว่าการใช้ปูนขาวที่อัตราส่วนเดียวกัน นอกจากนี้ได้มีการทดลองใช้ถ่านชีวภาพในอัตราส่วนร้อยละ 5 โดยน้ำหนัก ในแปลงปลูกต้นมะกอกน้ำมันที่สถานีวิจัยเกษตรที่สูง อ.ภูเรือ จ.เลย หลังจากใส่ถ่านชีวภาพนาน 1 ปี จึงทำการเก็บตัวอย่างดินมาวิเคราะห์ พบว่าดินที่ทำการปรับปรุงด้วยถ่านชีวภาพมีค่า pH ที่เป็นกลางมากขึ้น รวมทั้งมีค่าความชื้น ปริมาณอินทรียวัตถุ และโปแทสเซียมในดินสูงอย่างมีนัยสำคัญทางสถิติเมื่อเทียบกับดินที่ไม่ได้ใช้ถ่านชีวภาพ

คำสำคัญ: ถ่านชีวภาพ การปรับสภาพดิน วัสดุเหลือทิ้งทางการเกษตร
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1. Introduction

Biochar application for soil management has been studied worldwide due to its multiple advantages from soil physical and chemical properties improvement to carbon sequestration in the soil [1]. Biochar from varieties of agricultural residues has been studied such as wood chip, rice husk, rice straw, and bagasse. Several studies showed that biochar amendment helped to increase the pH of acidic soil, and water retention of the soil [2]. Also biochar can provide the long term carbon sequestration in the soil which improves the fertility and also limited the amount of green house gases released from the soil [3, 4]. The physical and chemical properties of biochar were widely reported depending on the type of raw materials and charring temperature. At high charring temperature, the biochar would have low volatile matters and low pH value, vice versa [5, 6]. The biochar produced at low charring temperature would display high pH which can be a lime substitute in acidic soil treatment [6, 7]. For the soil fertility aspect, the biochar had shown enrichment in major plant nutrients such as K, P, and Ca. More over the addition of biochar into soil could increase the N-use efficiency by retaining N fertilizer within itself which helped to reduce the N_2O emission from soil [2]. Due to the physical porous nature of the biochar, the soil water holding capacity also increased after the application which benefited the soil nutrition by increasing soil solution mobile elements [2, 8]. Moreover, the fixed carbon in biochars provide the inert C content in soil that had strong resistant to the decomposition which allowed the biochar to have the long-term benefit after application [9, 10].

In this study, the effect of biochars from the local available biomass pyrolyzed at low temperature (< 400 degree celcius) in the Northeastern highland soil was investigated. The objectives of this study were to determine the different chemical and physical characterization of biochar from durian shell, banana peel, and macadamia. The effect of biochar amendment on soil chemical and physical properties were also studied especially their liming effect.

2. Materials and Methods

Soil and Biochar Preparation

Soil was randomly collected from 20 sites at Highland Agriculture Research and Development Center, Phuruea, Loei Province, Thailand. Soil from each site was oven dried to completely remove the humidity according to activated carbon standard method (ASTM D2867-04, 140 degree Celsius, 3 hours). Soil samples were then stored in an airtight plastic bag at room temperature for further experiments.

Biochars were produced from three crop residues, durian shell (DB), banana peel (BB), and macadamia nut shell (MB). The durian shell and the banana peel were randomly collected from local fruit stand at Department of Science Service, Bangkok, Thailand. The macadamia nut shell was collected from Highland Agriculture Research and Development Center, Phuruea, Loei Province, Thailand. The durian shell and the banana peel samples were sundried for at least 1 week, then stored at room temperature. All three residues were then pyrolysed separately using the "Anila" stove gasifier at low temperature (less than 400 degree Celsius). Each type of biochar was ground and passed through a 50-mesh sieve. The sieved biochars were oven dried at the same condition as the soil (140 degree Celsius, 3 hours) before stored in an airtight plastic bag at room temperature for further experiment.

Soil incubation

The soil sampling was conducted by collecting soil samples from 20 sites of Highland Agriculture Research and Development Center and mixed together to achieve the homogenous batch for incubation experiment. Five replicates of soil samples was amended with biochar or lime at 5 and 10 %wt. Soil without amendment was served as the control. A 400 grams of mixtures were placed in plastic bag (6X9 inch). A 100 ml of deionized water was then added to adjust the humidity of the mixture to be 20%. The plastic bags with the mixture were sealed and placed in an airtight container. The humidity of the mixture was monitored through digital hygro-/thermometer (Brannan).

The mixtures were incubated at room temperature and subsampled every week for 18 weeks. At each sampling time, the mixture was shaken for 10 minutes and then taken from each bags for the pH measurement.

Olive tree field trial

Each type of 5% wt biochars was randomly amended into the soil of olive tree experimental plot at Highland Agriculture Research and Development Center, Phuruea, Loei Provincer. After 12 months, the soil at each plot was sampled and brought back to the laboratory for further analysis.

Soil and Biochar Characterization

The volatile matters, fixed carbon, and ashes content of the biochars produced were characterized following standard methods of ASTM D 3174, ASTM D 3175 and ASTM D 3172. The chemical compositions of all biochars were analyzed using X-ray fluorescence (XRF, Fisons, ARL8410). The total nitrogen content of the soil and biochar samples was determined using Kjeldahl nitrogen digestion method. The available phosphorus and available potassium of samples were determined using Bray II methods and the flame photometry methods (Department of Land Development soil analysis handbook, [12] respectively. The moister content and pH were characterized following the methods from the soil analysis method handbook, Department of Land Development [12]. The C/N ratio of the sample was calculated using the following equation; C/N ratio = (% total carbon) / (% total nitrogen).

Statistical analysis

For each experiment, five replicates of samples were collected randomly from the batch and used to calculate the mean value and standard deviation. The results were statistically analyzed using the t-test with $p < 0.05$ to determine the differences between each set of data.

3.Result and Discussion

Biochar Characterization

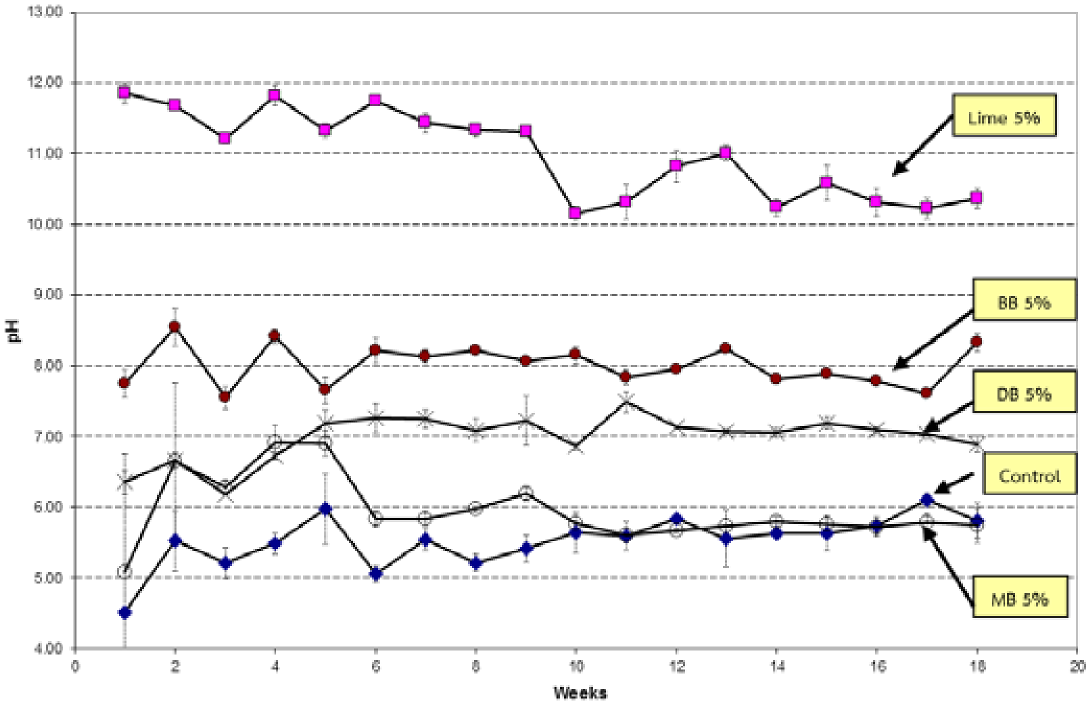
The properties of biochars from durian shell (DB), banana peel (BB) and macadamia shell (MB) were shown in Table 1. The results showed that DB and BB were strong base whereas MB was neutral. The differences of the moisture contents could predict the porosity on the surface of the biochars. The higher percentage of moisture contributed to the higher surface porosity of the biochars due to the capillary conduction of liquid [13]. The volatile matter value indicated the amount of tars and combustible gases in the char [14]. The amount of ash showed the inorganic and non combustible substances in the char which the composition was also thoroughly investigated using XRF as shown in Table 2.

The XRF result showed that the ashes from DB and BB had high percentage of K_2O, MgO, and CaO. These chemical compositions could induce the high pH value of DB and BB because the K^+, Mg^{2+}, and Ca^{2+} cations on the surface of the chars coupling with H_2O on the surface [11]. While the pH of MB was neutral because of its low ash percentage and high value of fixed carbon, but the MB ash also contained high amount of K_2O and other minor elements (ex. MgO, Fe_2O_3, and Al_2O_3) which benefit to plant as well.

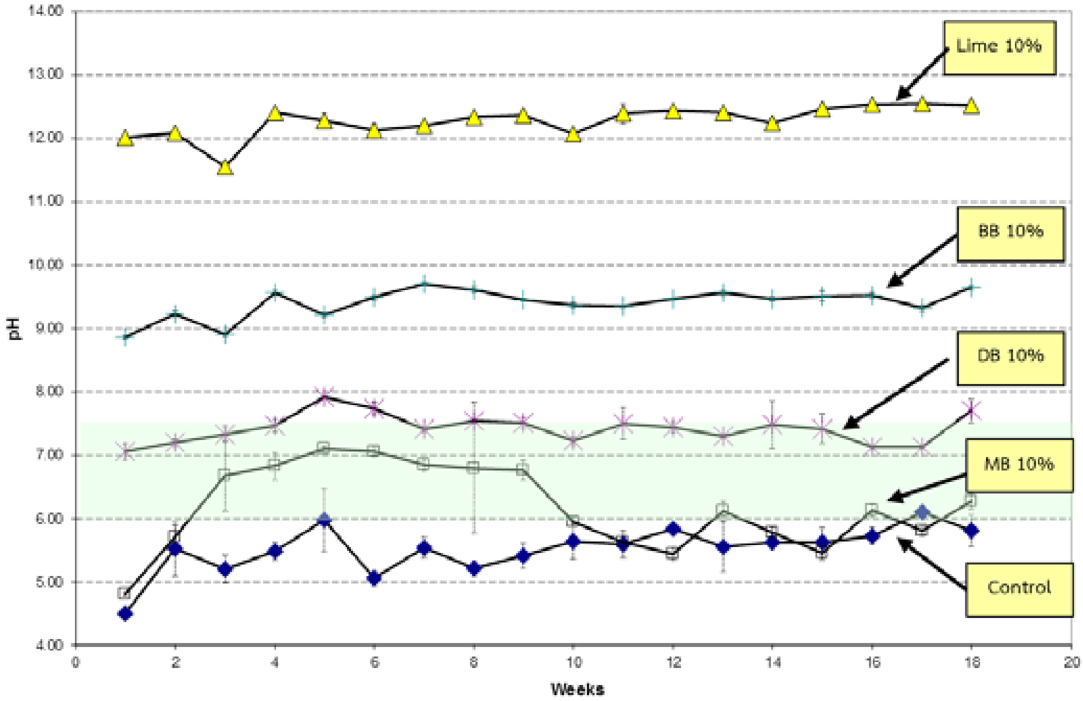
Table 1. Chemical and physical characterization of biochars from durian shell (DB), banana peel (BB), and macadamia (MB)

	Durian Shell Biochar (DB)	Banana Peel Biochar (BB)	Macadamia Shell Biochar (MB)
pH	9.63±0.01	10.08±0.01	6.90±0.05
Moisture (%)	7.37±0.12	7.07±0.10	4.76±0.03
Volatile Matter (%)	5.74±0.06	14.28±0.18	1.59±0.04
Ash (%)	10.75±0.26	14.67±0.08	0.84±0.01
Organic Matter (%)	5.37±0.06	3.98±0.29	1.17±0.04
Fixed Carbon (%)	76.18±0.18	63.71±0.19	92.76±0.06
Total Nitrogen (%)	1.89±0.01	1.49±0.01	0.52±0.01
C/N ratio	41.95±0.02	44.30±0.32	179.69±0.01
Available Potassium (%)	3.59±0.10	5.60±0.30	0.23±0.02
Available Phosphorus (mg/kg)	14.42±0.23	8.62±0.13	0

Figure 1. The liming effect of lime and biochars from durian shell (DB), banana peel (BB), and macadamia (MB) on Phureau Soil at the rate of (a) 5% wt and (b) 10% wt.



(a)



(b)

Table 2. The Chemical composition of biochar ashes from durian shell (DB), banana peel (BB), and macadamia (MB)

Chemical Composition	% by weight		
	DB	BB	MB
K2O	58.81	25.36	23.52
MgO	11.99	17.5	5.22
P2O5	11.21	4.08	2.65
CaO	8.07	17.25	9.63
SiO2	4.08	28.59	17.69
SO3	2.85	2.23	4.61
Na2O	1.37	0.67	3.16
Fe2O3	0.95	1.61	25.86
Cl	0.78	0.08	0.77
Al2O3	0.5	1.48	4.64
MnO	0.13	0.72	0.76
NiO	0.1	0.03	0.17
CuO	0.09	0.05	0.34
Cr2O3	0.08	-	0.56
TiO2	-	0.19	0.43
BaO	-	0.15	-
ZrO2	-	0.02	-

From the soil incubation experiment, the results showed that the DB and BB amendment on soil increased the pH to the range of 6-7.5 while the lime addition changed the pH of soil to strong basic (pH >10) (Figure 1.). The addition of DB increased the pH of the soil to the neutral range and stable of 18 weeks. The addition of BB at the selected rate (5 and 10% wt) shifted the soil pH to the 8-9 value due to the BB's high pH value. The MB could also increase the pH of the soil for 6-8 weeks, afterward the pH reduced to the same range of control due to MB's low % ash which resulted in low inorganic content (K, P, Mg, Ca) that could couple the H^+ ion of the acid soil. Whereas, the lime addition at 5-10% wt increased the soil pH to the strong base which was not the desired value for plant growth. Also, the long-term lime application on soil increased the soil ionic strength causing the electrical double layer compression and led to soil flocculation. [15] The pH of the soil with application of biochars showed more stability than the application of lime at the low rate (5% wt). Therefore, 5% wt biochar was selected for applying into the soil of the olive tree field.

Each type of 5% wt biochars was applied into the olive tree field. The soil was sampled a year after the biochar application date and analyzed moisture, pH, organic matter, and NPK concentration. The results show in Figure 2-5. The results were statistically analyzed using the t-test with $p < 0.05$. It appeared that all three biochars (DB, BB, and MB) addition to soil significantly increased the % moisture, % organic matter and K which related to the biochars properties analyzed in Table 1. The addition of biochar increased the moisture content of the soil by holding the water inside its pores which delayed the water evaporation process from the soil [13]. Only BB effectively increased the pH of the soil with statistical significant ($p = 0.035$) due to the high ash value and the alkalinity of the chars. However, the amount of N, P and K of the soil did not significantly change with the biochar addition.

Figure 2. The effect of biochar addition on the moisture of soil. Biochars from durian shell (DB), banana peel (BB), and macadamia (MB) were added into the soil of olive tree experimental plot for 12 months.

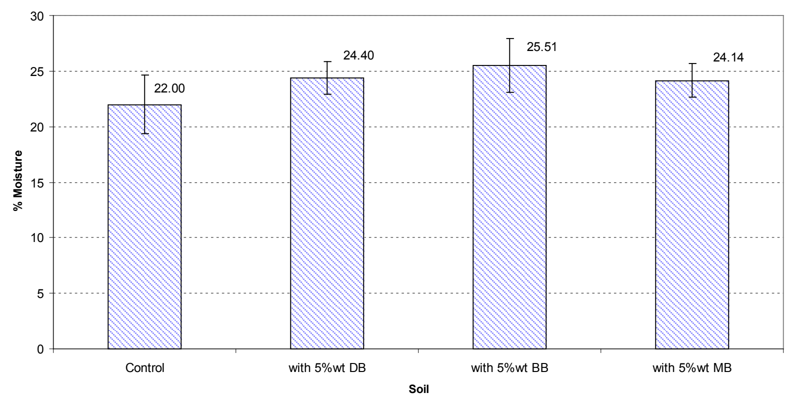


Figure 3. The effect of biochar addition on the pH of soil. Biochars from durian shell (DB), banana peel (BB), and macadamia (MB) were added into the soil of olive tree experimental plot for 12 months.

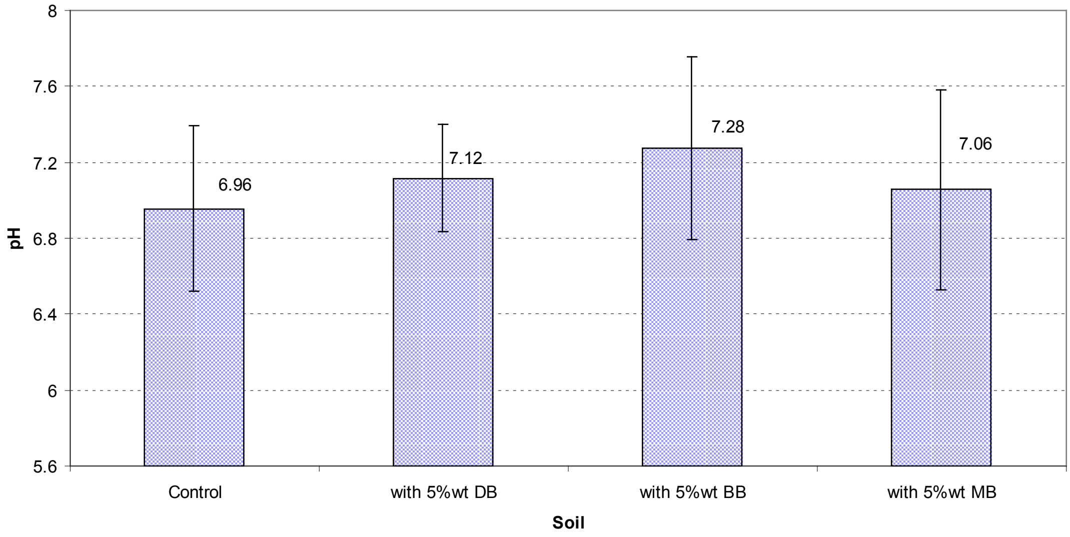


Figure 4. The effect of biochar addition on the organic matter of soil. Biochars from durian shell (DB), banana peel (BB), and macadamia (MB) were added into the soil of olive tree experimental plot for 12 months.

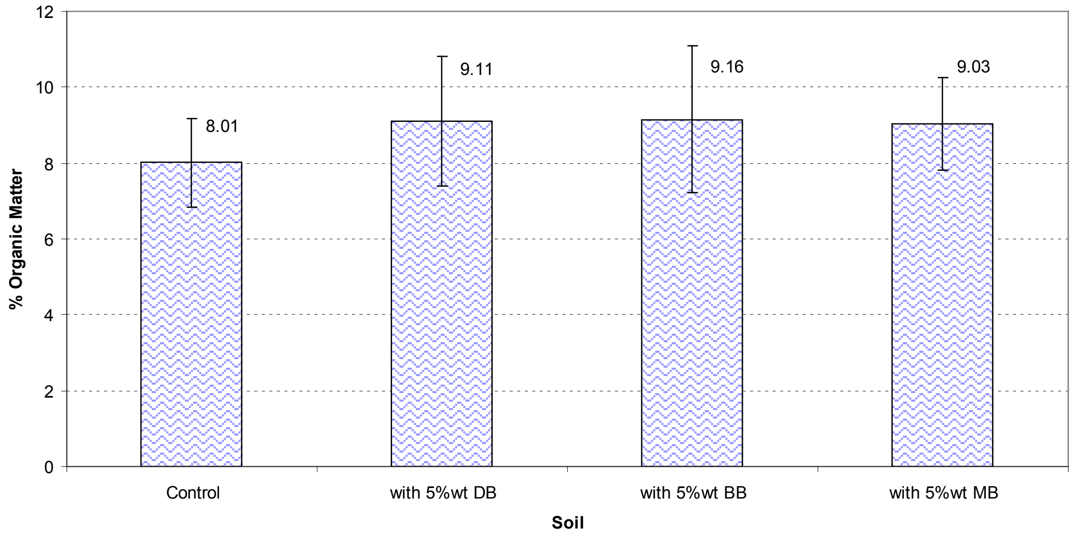
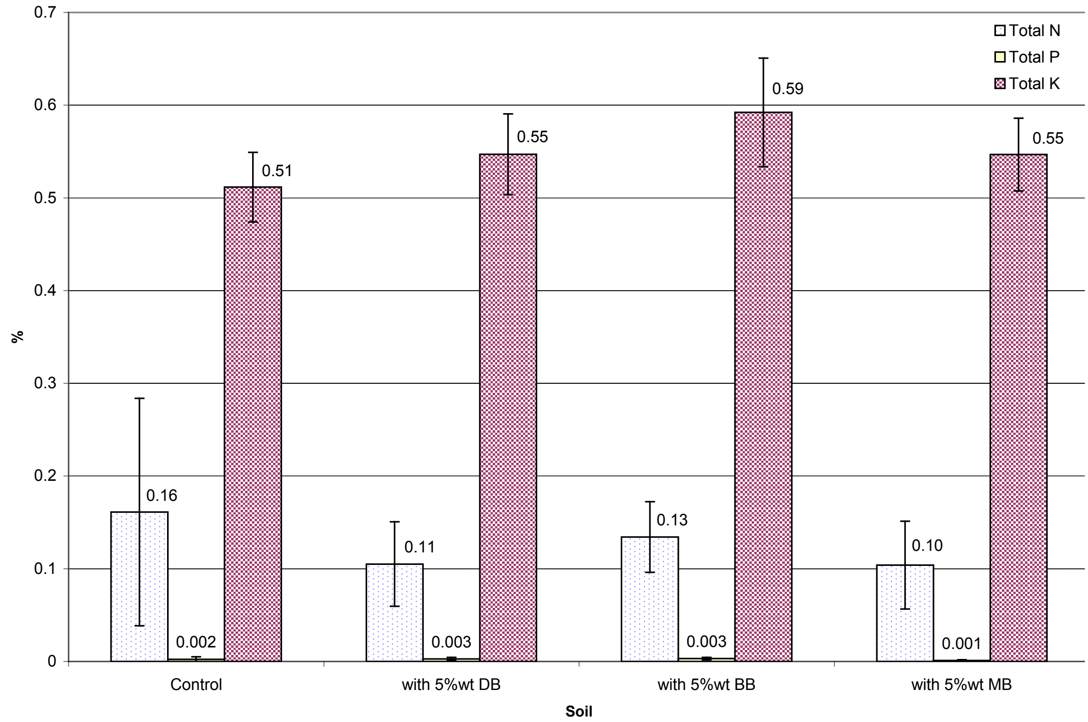


Figure 5. The effect of biochar addition on the NPK of soil. Biochars from durian shell (DB), banana peel (BB), and macadamia (MB) were added into the soil of olive tree experimental plot for 12 months.



4.Conclusion

The chemical and physical properties of biochar were dependent with the type of raw materials. In this study, it was found that the DB and BB had high ashes contents with the large amount of inorganic compound in the char. The ashes content of DB and BB contained high value of K, Mg, Ca, P which are the nutrients benefit the plant growth. This also influenced to the alkalinity of the biochar (pH > 7). MB had a neutral pH, contained highest amount of fixed carbon and lowest ashes. The study showed that the BB and DB had promising potential of being lime substitute for acid soil treatment, due to the high alkalinity of the biochar. After a year of biochar amendment to the soil of olive tree field, the addition of both DB and BB increased the soil pH, moisture content, organic matter, and potassium content. Therefore, the further studies on the proper rate of application of biochars for different crops production around the Northeastern highland soil, and the plant growth should be necessary to investigate.

5.Acknowledgements

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