Journal of Mining and Earth Sciences

Website: http://jmes.humg.edu.vn

Preliminary research results on the use of volcanic ash and felsic volcanic rock in Vietnam as materials to support crop growth

Vinh Thi Dang [1,*], Giang Khac Nguyen [2]

[1] *Hanoi University of Mining and Geology, Hanoi, Vietnam*
[2] *Vietnam Association for Geochemistry, Hanoi, Vietnam*

ARTICLE INFO

Article history:
Received 14h July 2022
Revised 24th Oct. 2022
Accepted 15th Nov. 2022

Keywords:
Amaranth,
Caviar Cockatio,
Experiment,
Felsic tuff,
Volcanic ashes.

ABSTRACT

As we know, vascular plants (Tracheophyta) in general and crop plants require a defined amount of trace elements to ensure normal growth and development. In many developed countries, some natural materials have been used as an addition for growing ornamental plants, vegetables, and hydroculture plants. In Vietnam, natural minerals to support plant growth is still very limited. Meanwhile, the source of raw materials in the territory of Vietnam is quite popular, so the research and experiments using Vietnamese volcanic ash and felsic volcanic rocks as improving materials for plant growing is important and very necessary work. Analytical methods such as Ronghen Fluorescence (XRF), Mass Spectrometry (ICP-MS), Scanning electron microscopy (SEM) and calcination at $650^{0}C$*,* $750^{0}C$*, and* $900^{0}C$ *have been used to determine the composition of felsic tuff samples belonging to the Don Duong Formation (PY19) and mafic ash samples of the Dai Nga Formation (KR2/2). In addition, control sample matching method was also used in the research process to evaluate the growth plants. The experiment materials (raw samples and calcined samples at* $900^{0}C$*) were mixed with the soil for planting (in different proportions); two types of plants, named Caviar Cockatio (Chicken Crest Vegetables) and Amaranth Asiatica (Purple Amaranth), were selected for experimenting. In general, both Caviar Cockatio and Amaranth Asiatica developed quicker when grew on a ground of soil mixed with the experiment material. The plant's growth rate depends on the type of material (unbaked, calcined), support material content, plant type and stage of growth. Primary research results show that volcanic materials in Vietnam can support the growth of plants.*

*Corresponding author
E - mail: dangthivinh@humg.edu.vn
DOI: 10.46326/JMES.2022.63(6).02

1. Introduction

According to published documents, in Vietnam's territory, igneous rocks are widely present in the Northeast, Northwest and Central regions of Vietnam, including volcanic rocks and debris (tuff and ash) with a relatively glassy composition (Ha et al., 2011; Le et al., 2018). The typical of this group of rocks are the tuff and felsic volcanic rocks of the Don Duong Formation and volcanic ash in the lower part of Dai Nga and Tuc Trung Formations.

The felsic volcanic rocks of the Cretaceous age of the Don Duong Formation are quite widely distributed in the Central and South Central regions, extending from Phu Yen, Khanh Hoa, Lam Dong, Ninh Thuan and some islands in the southwestern sea coast. They have a thickness varying from 300 m to 1,200 m, of which the volcanic composition accounts for 60÷80%, sometimes up to 100%. There are areas containing tuff beds with a thickness of hundreds of meters such as in the Khanh Vinh - Da Lat area. Volcanic rocks with high felsic composition are distributed in Don Duong - Da Chay, west Da Lat areas and in the upstream areas of Long Song River and upstream of Luy River. The volcanic rocks assign to the Don Duong Formation with felsic composition in the Da Lat zone, covering the Jura sediments of the Ban Don Formation (J_{1-2}*bđ*) as well as the granodiorite of the Dinh Quan type and are intersected by granitoids of the Deo Ca Formation (Nguyen et al., 2018).

Volcanic ash of the Tuc Trung and Dai Nga formations are widely distributed in the Central Highlands and central coastal areas (Gia Lai, Phu Yen, Khanh Hoa), etc. Volcanic glass-rich felsic tuff samples of the Don Duong formation were collected along provincial road 417 from Da Lat to Khanh Vinh, in Lac Duong district, about 25km from Da Lat city (Figure 1). The mafic volcanic ash sample was taken from the Kroong area, about 7 km north of K'bang town (Gia Lai), in the volcanic ash layer with about 0.3÷0.5 m (Figure 2).

Previous publications (Le & Pham, 2005; Bui et al., 2010; Dao and Huynh, 1995; Nguyen et al., 2018) showed the mineral composition of the felsic volcanic rock of the Don Duong Formation includes: Phenocrysts (15÷17%) consisting of plagioclase, K-feldspar, quartz, biotite and hornblende (little). The groundmass consists of feldspar, quartz, sericite (litle), chlorite, and epidote microcrystals. Minor minerals include magnetite, hematite, ilmenite, pyrotine, apatite and zircon.

The technological properties of ash, volcanic glass and perlite have widely used them in practice and production. Perlite is used in the construction sector (as a filler for pavement concrete) (Morsy et al., 2008); using natural minerals as supplement to improve degraded soil (Kirk et al., 2000; Fyfe et al., 2006; Theodoro et al., 2006); perlite used quite widely in environmental remediation (Roulia et al., 2006; Ghassabzadeh et al., 2010). After heat treatment (heated to 900^{0}C), this type of material has strong adsorption and ion exchange capacity, leading to a very good applicability in environmental pollution treatment, especially for the pollution of heavy metals in water. In our experiment, the volcanic material (sample PY19) modified after calcination can adsorb Pb^{2+} and Cu^{2+}, organic complexes such as blue methylene in wastewater samples (Le et al., 2018).

Recently, there has been a research in the direction of processing ash, volcanic glass as a substrate used to support plant growth with the ability of this material to absorb and retain water and nutrients. However, the research in this direction is still quite new and inevitably has limitations. Meanwhile, in our country, the source of volcanic glass and ash is quite popular, so it is necessary to research and use these materials in the agriculture sector. In this paper, the authors present experimental results on the ability of these materials as plant care support materials.

To serve as primary material for the experiment, two volcanic rocks types have been selected: a fresh rock sample of felsic tuff of Don Duong formation (Figure 2a) and weakly weathered volcanic ash of Dai Nga Formation (Figure 2b). The raw materials were ground to the size of 0.01 mm before being used in the experiment. In our test, two types of plants, Caviar Cockatio (Chicken Crest Vegetables) and Amaranth Asiatica (Purple Amaranth) were selected. Because Caviar Cockatio is a very popular food crop in regions from the North to the

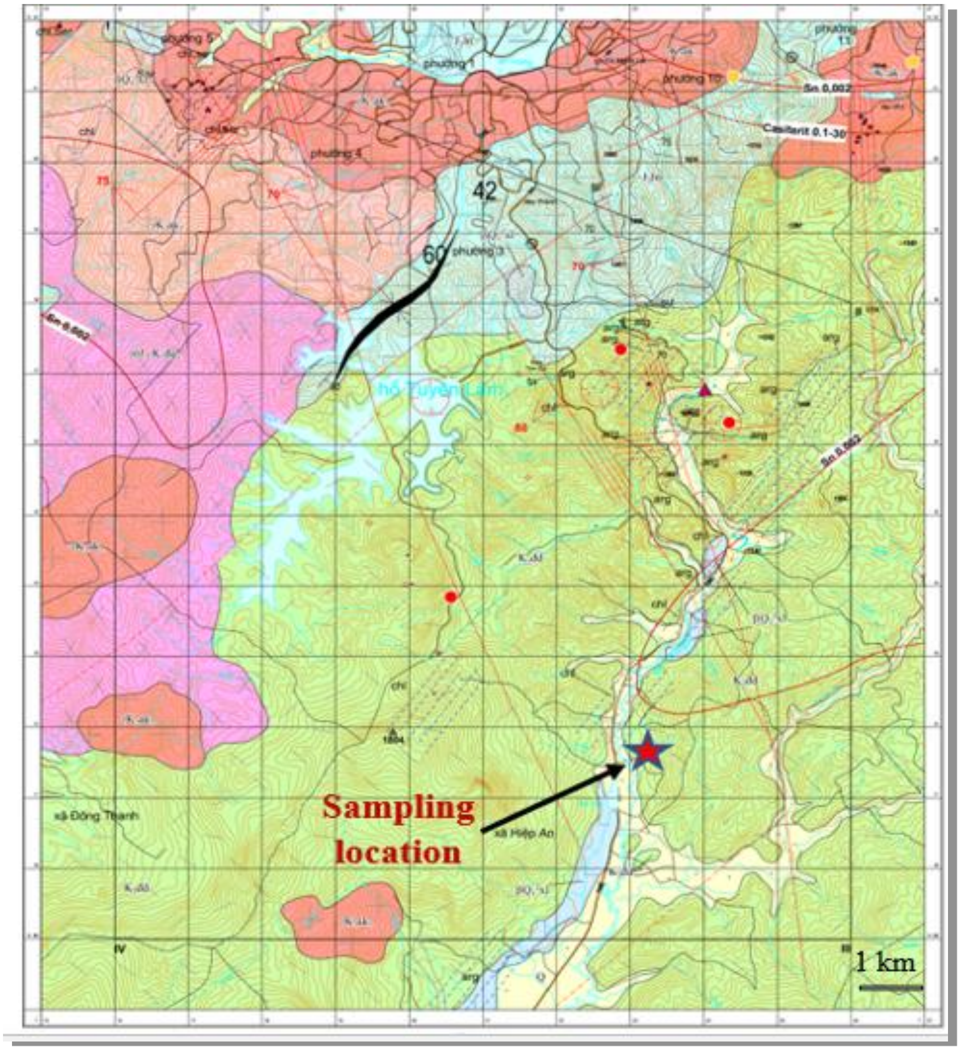

Figure 1. Sampling location of Don Duong volcanic rock in Lac Duong District, Lam Dong province.

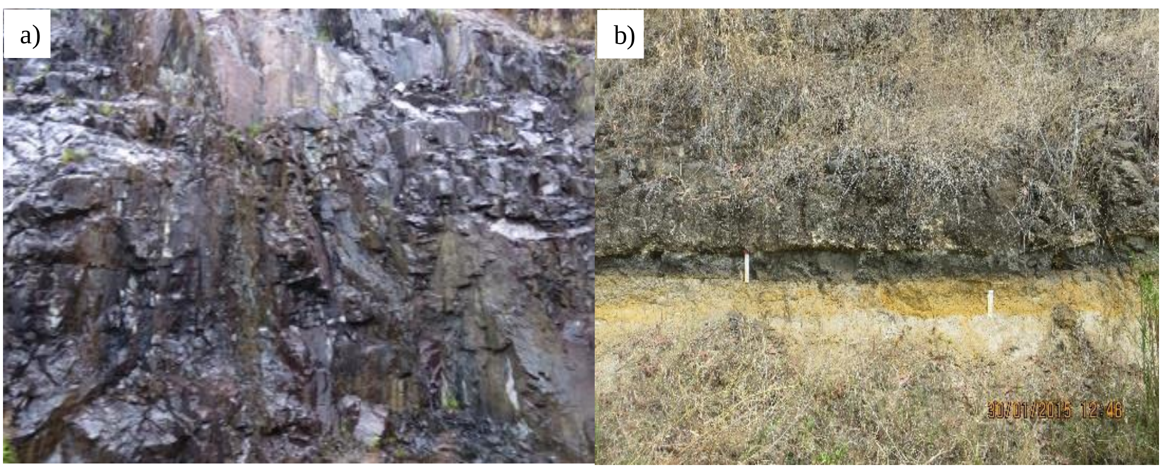

Figure 2. Sampling site of PY19 felsic tuff of Don Duong Formation (a) anf volcanic ash layer of Da Nga Formation (b).

South, with a moderate short growth time (from planting to flowering about 2÷2.5 months), it will be easy to closely supervise in the first stage of plant development. Purple Amaranth is also a vegetable that is very popular in Vietnam, because it has a growth time similar to that of Caviar Cockatio (about 3÷4 months), so it was selected for the experiment as an offering object to compare the material's ability to support plant development. The experiment has been conducted by authors in the Lab of Center for Mineral Technology Development. Hanoi University of Mining and Geology in the period from August, 2018 to April, 2019.

The experiment results showed a difference in the growth rate of Chicken Crest Vegetable and Purple Amaranth on the soil supplemented with unburnt material and the soil supplemented with calcined material. However, the growth rate of the vegetables depends on the type of material, the content of the material and the development stages of each plant.

2. Theoretical and practical basis in the use of natural stones in the field of agriculture

Volcanic ash and tuff are composed mainly of glass (non-crystallized) materials. This material differs from materials in the crystalline state with very high energy. Volcanic glass is an amorphous material, with internal energy much greater than that of the crystalline state. If the materials being in the crystalline state, the crystal is chemically inert, and the lattice cell has been filled and equilibrated. In contrast, materials in the glass state have many distinct characteristics, always containing a large amount of water, ions oscillating more freely than in the crystalline state. Therefore, they have great surface adsorption capacity and volume increase when finely crushed as well as heated, or through a reasonable technological process. Products made from volcanic glass will have high-tech properties, used as a growing medium.

In another aspect, in the composition of Biota, most of the chemical elements of the periodic table are present with concentrations ranging from a few tens of % to several parts per million/or billion (Table 1).

According to the composition of elements in the biosphere, based on their concentration, they are divided into three groups: major-elements (elements with high mass or dominant elements, contributing 1÷60% organisms composition), minor elements (elements contributing 0.01 to 1% organisms composition), trace elements (elements with very small content, contributing less than 0.01% organisms composition), the latter group in plants is commonly referred to as microelements. In addition, there are medicinal elements which are used in medicine (Figure 3).

In the Biota, elements can also be divided depending on their concentration and bio-function as follow: 1) The Bulk biological element group present in large quantities in organisms; 2) The trace (or micro) element group is essential for animals, plants, and algae; 3) The group may be essential for some species (Figure 4).

Table 1. Average chemical composition in Biota.

Element	Content	Element	Content (%)	Element	Content (%)	Element	Content (%)
O	70.0	Na	2.10^{-2}	F	5.10^{-4}	As	3.10^{-15}
C	18.0	Cl	2.10^{-2}	Zn	5.10^{-4}	Co	2.10^{-5}
H	10.5	Fe	1.10^{-2}	Rb	5.10^{-4}	Li	1.10^{-5}
Ca	0.5	Al	5.10^{-3}	Cu	2.10^{-4}	Mo	1.10^{-5}
K	0.3	Ba	3.10^{-3}	V	$n.10^{-4}$	Y	1.10^{-5}
N	0.3	Sr	2.10^{-3}	Cr	$n.10^{-4}$	Cs	1.10^{-5}
Si	0.2	Mn	1.10^{-3}	Rr	1.10^{-4}	Se	1.10^{-5}
Mg	4.10^{-2}	B	1.10^{-3}	Ge	$1,5.10^{-4}$	U	1.10^{-6}
P	7.10^{-2}	Tr	$n.10^{-3}$	Ni	5.10^{-5}	Hg	$n.10^{-7}$
S	5.10^{-2}	Ti	8.10^{-4}	Pb	5.10^{-5}	Ra	$n.10^{-12}$

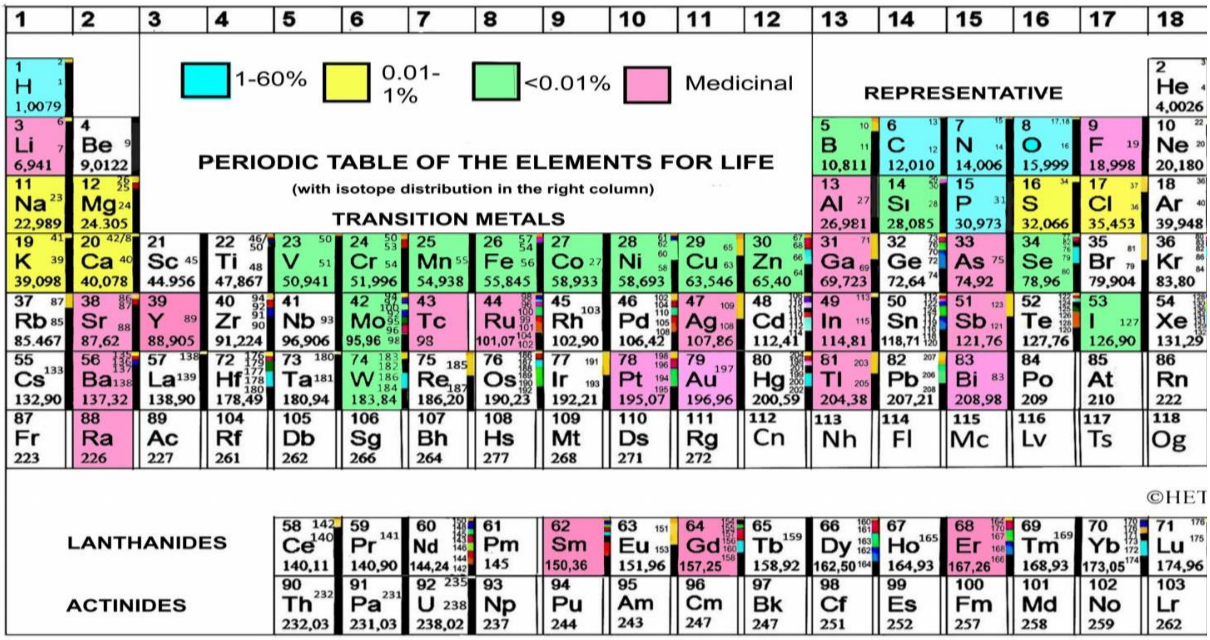

Figure 3. Classification of periodic table elements for life (After Toma, 2019).

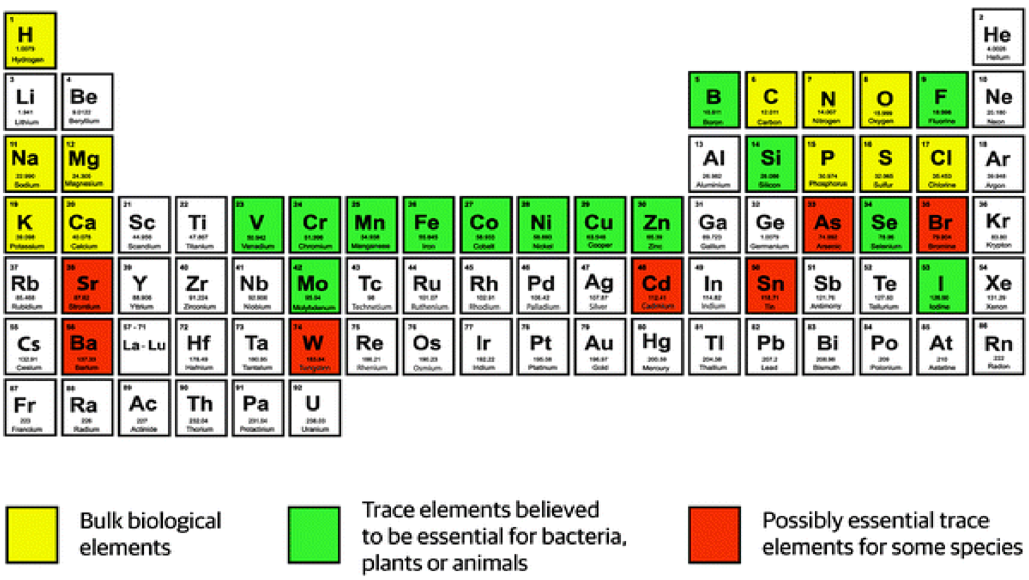

Figure 4. Bulk and essential elements for life in general and for some species in particular (after Maret & Copsey, 2012).

From Figure 4, it can be seen that in addition to the important essential elements presented in organisms in large quantities (C, H, N, O, K, Ca, P, Cl, S, etc.). There are also important minerals nutrient elements in vascular plants such as V, Cr, Mn, Fe, Ni, Cu, Zn, Mo, Co and Se. In addition, some plants may also need Br, Sn, Sr, etc. The lack or shortage of these elements will lead to distored plant development.

Thus, the superior organism in general and vascular plants require a definite amount of trace elements to ensure normal growth and development. When the soil does not provide enough of these components, it will lead to slow

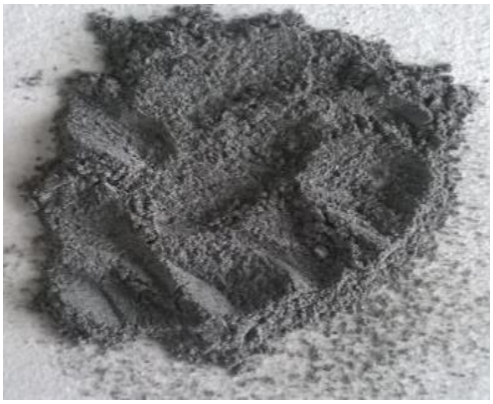

Figure 5. Raw gray/dark gray tuff material before heating.

Figure 6. Brown/redish brown tuff material after heating.

the growth, even death of those plants. Therefore, providing additional nutrients for plants is a very necessary work.

In the world, perlite and some other volcanic rocks are currently being widely used in many developed countries such as the United States, Israel, and Canada as filler and addition material for ornamental plants and vegetables. In the US, most gardeners growing seedlings use mixed perlite with a ratio of 10÷30% (depending on the type of plant) with nutrient soil to grow popular vegetables. In Japan, people have used volcanic pebbles as a substrate to grow flower pots with very good results. In some parts of Africa, crushed basalt has been used to add iron to weathered soils from iron-poor carbonate rocks. Since the 70s of the last century, there have been initial ideas and experiments using natural minerals in the cultivation field to supplement the deficiency of essential trace elements for plants.

In the last few years, many farmers and gardeners have begun to use crushing products of igneous rocks including volcanic ash and other natural materials (namely as mineral nutrients) to supplement microelements and micronutrients in eroding and degraded soils (Fyfe et al., 2006, Alihosseini et al., 2010; Kabra et al., 2013). When added to degraded soil, these minerals have a very clear effect on stimulating the growth and development of plants (Van Straaten, 2006). Recent research indicates that polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat (Assainar et al., 2020) informed that Siliceous Natural Nanomaterials Applied in Combination with Foliar Fertilizers on Physiology, Yield and Fruit Quality of the Apricot and Peach Trees.

In Vietnam, perlite for growing vegetables is not yet popular. However, there have been initial experimental works on natural mineral materials in cultivation in recent years.

Lab works: Ronghen Fluorescence (XRF) method; Mass Spectrometry (ICP-MS) method; Scanning electron microscopy (SEM) and control sample matching method.

3. Selecting and processing tuff and volcanic ash materials

Two typical samples widely popular in Vietnam have been selected to test the ability to support crops. The testing substrates are the tuff of the Don Duong Formation (PY19) and the volcanic ash of the Dai Nga Formation (KR2/2) (Figures 5 and 6).

The processing and processing materials works for plant support as follows:

Raw samples were collected in the field with a weight from 10 to 20 kg/sample (Ash and tuff samples).

Crush the samples to a particle size <5 cm using a hammer grind.

Fine grind the sample with a pulverizer to a particle size <1.4 mm.

Divide the sample into two batches: one is brought to test with plants without heat treatment, another is heated at 900^0C before testing with plants.

The testing plants are all plants with a short growth period and the tests focused on the ability of the material to affect growth in the first stage of plant development for convenient monitoring. The trial period is calculated from the time of seeding. The test samples were all placed in the same location with the same light level and normal water feeding conditions, without any other fertilizers. The test time is divided into 3 phases:

Phase 1 carried out seeding to monitor the growth of Caviar Cockatio (Chicken Crest Vegetables) within four weeks from seeding time and the plant developed shape: compare the plant samples with those in two other substrates: the soil without mixing the test materials and the soil mix 20% (1/5) of test substrate.

Phase 2 was conducted in 6 weeks using Amaranth Asiatica seeds (which have a longer growth and development time than Caviar Cockatio). The test materials are similar to the first batch to evaluate the effect on another crop.

Phase 3 was conducted in 4 weeks, continued to use Caviar Cockatio seed since seeding time and the plant developed its body and leaf shapes: comparing the plant samples with those in the soil without mixing the test materials and in the two other substates (the soil mixed with 20 % test material and the soil mixed with 33 % test material). The test results are compared with the controlling samples simultaneously containing perlite and volcanic materials.

4. Results and Discussion

4.1. Chemical composition and surface morphology of the acid tuff and mafic ash

4.1.1. Chemical composition

After being selected, the samples PY19 and KR2/2 were sent for analysis at the Institute of Geological Sciences - Vietnam Academy of Science and Technology to determine the composition of the major elements by Ronghen Fluorescence (XRF) method and the composition of trace elements (heavy metals, microelements) by Mass Spectrometry (ICP-MS) method to serve as a basis for the accurate assessment of the chemical composition of testing materials as well as the ability to provide mineral micronutrients for plants. The results of the chemical composition analysis of 2 testing samples are shown in Tables 2 and 3.

Table 2. Content of major oxides in testing samples (unheated).

	Sample Nr. / Major oxides	PY19	KR2/2
Content (%)	SiO_2	68.51	61.34
	TiO_2	0.35	0.78
	Al_2O_3	14.54	10.61
	FeO	3.52	6.94
	MnO	0.09	0.03
	MgO	1.04	1.44
	CaO	2.71	1.12
	Na_2O	3.60	018
	K_2O	4.29	1.92
	P_2O_5	0.07	0.04
	LOI	0.69	15.03

Table 3. Concentration of significant trace elements in testing samples (unheated).

	Sample Nr. / Elements	PY19	KR2/2
Content (ppm)	Li	46.36	8.57
	Be	2.90	1.62
	Ba	639.22	270.08
	V	23.62	60.72
	Cr	10.70	65.23
	Co	3.36	26.84
	Ni	5.44	53.22
	Cu	15.01	45.94
	Zn	20.13	6.43
	Sn	19.20	3.50
	Pb	37.18	36.23
	Rb	170.21	67.94
	Ta	0.61	0.27
	Sc	9.39	7.84
	Y	33.24	30.67
	La	35.08	107.60
	Ce	72.37	237.30
	Nd	32.27	98.14
	Yb	3.79	2.75
	Th	16.73	46.99
	U	5.04	1.82

The results of the ICP-MS analysis of the testing samples (Table 3) showed that the Don Duong tuff material (PY19) has a quite high content of Zn (20.13 ppm), Sn (19.20 ppm), V (23.52 ppm), Ba (639.33 ppm). In comparison, the volcanic ash material (KR 2/2) has a very high content of Cr (65.23 ppm), Co (26.84 ppm), V (60.72 ppm), Ni (53.22 ppm), Cu (45.94 ppm). Both can be used as a direct micro-mineral addition of nutrient for plants.

4.1.2. Determination of surface morphology and structure of materials

The surface morphology of PY19 was determined by scanning electron microscopy (SEM). Material samples were taken with HITACHI S – 4,800 instrument, a specific surface area determined by BET measurement performed on MicroAcitve for TriStar II Plus Version 2.03 by Nitrogen adsorption at 77.35^{0}K at the Institute of Geological Sciences - Vietnam Academy of Science and Technology.

The initial analysis results showed that in the raw samples, apart from the crystalline and microcrystalline feldspar and quartz minerals, micas and colored minerals, the amount of amorphous silicon oxide (glass) is quite large (accounting for 20÷30%) in the sample.

The SEM image (Figure 7) shows the rough tuff morphology and changes on the tuff sample upon calcination. For the raw sample with cubic shape, crystalline structure, smooth surface, less porous due to water still existing in the structure.

Meanwhile, upon heat treatment, the morphology of the modified sample (when calcined at high temperature) has a highly porous structure, and rough surface, with appearing crystals which can be confirmed to be due to water released from the material during heating. Thus, when the tuff sample is heated, it structure's opening, creating small holes (due to the water release process) making the material more porous (Nguyen et al., 2018).

4.2. Results of testing and evaluation of the possibility of using tuff materials and volcanic ash as plant care support materials

4.2.1. Test results

Phase 1: Trial of growing with soil mixed with 1:5 test materials:

This experiment lasted four weeks, the purpose of which was to evaluate the impact of testing materials on vegetable growth and development. The test sample consists of 5 pots (all pots are labeled with Etiket with clearly marked sample number), including soil sample mixed with materials (ratio 1:5): tuff PY19 sample heated at 900^{0}C, raw (unburnt) PY19, raw volcanic ash (unburnt) KR2/2 and heated KR2/2 at 900^{0}C, and comparing (unmixed) soil sample. The trial period is calculated from the start of seeding. The test samples were all placed in the same location with the same sunlight exposure level and normal watering conditions, without using any other fertilizers. The growth and

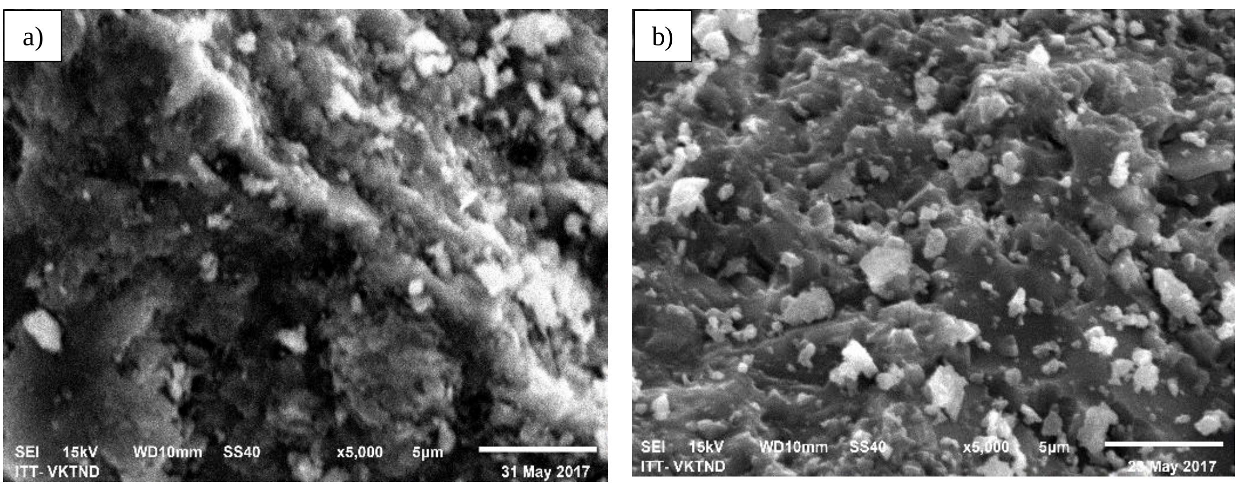

Figure 7. SEM image with 5000x magnification of the original tuff sample (a) and the modified (heated at 900^{0}C) sample (b).

development of the test plants were checked daily and briefly described at several times as follows:

On the 4^{th} day after seeding, the seeds in KR2/2 mixed sample heated at 900^0C have germinated, baby plants which are about 0.5 cm tall. In contrast, those in unbaked KR2/2 mixed sample have not germinated yet; in comparing soil sample (control sample) seeds begin to be cracked their cover (germination). The baby plants in the unburnt PY19 mix showed better growth than those in the 900^0C heated PY19 mix (greener leaves, taller plants) (Figure 8). Thus, there is a different development between the two materials PY19 and KR2/2. PY19 tuff material seems to stimulate plant growth better in the early stages of development (germination).

On the 10^{th} day after seeding (Figure 9), different growths were observed between plants growing on different substrates: (description in descending order of growth): Plants on soil mixed with unheated PY19 material → calcined PY19 at 900^0C → KR2/2 heated at 900^0C → Comparing soil sample → unheated KR 2/2.

On the14^{th} day after seeding.

General comment: The growth rate of plants in the mixed sample of PY19 unheated and KR2/2 heated at 900^0C was similar. However, the plants in the unbaked sample PY19 had darker green leaves and fatter plants. The order of growth from fast to slow is as follows (Figure 10): Plants grew in unburnt PY19 mixed soil → KR2/2 baked at 900^0C → PY19 baked at 900^0C → control soil sample → unbaked KR 2/2.

On the 22^{nd} day after seeding.

According to the increase in stem height (from tall to short), the general assessment: 1. The plant in the mixed sample PY19 (unheated), → 2. The plant in the sample KR2/2 (unheated), → 3. The plant in the sample PY19 (heated at 900^0C), → 4. Plants in KR2/2 sample (heated at 900^0C) and

Figure 8. Experimental samples of the first phase on the 4^{th} day after seeding.

Figure 9. Experimental samples of the first phase on the 10^{th} day after seeding.

Figure 10. Experimental samples of the first phase on the 14^{th} day after seeding.

Figure 11. Experimental samples of the first phase on the 22^{nd} day after seeding.

comparing soil samples. In addition, plants grew in the mixed samples had a darker green color of leaves than those grew in the comparing soil samples. Two samples of KR2/2 were found the pale purple on the veins in the underside of the leaf (Figure 11). In the first stage, the plants in the unheated PY19 mix soil grew better than those in the 900^0C mixed heated PY19 sample, while the KR2/2 mixed sample heated at 900^0C grew better than the vegetable in the unheated KR2/2, and finally, the lowest growth plants in the comparing soil sample.

In the later stages (from day 14 onwards), in general, the Caviar Cockatio (Chicken Crest Vegetables) in the mixed sample of PY19 unheated, PY19 heated at 900^0C and the mixed sample KR2/2 without burning developed better than plants in the mixed sample KR2/2 heated at 900^0C and comparing soil samples.

Phase 2: Experimenting with growing purple Amaranth with soil mixed with 1: 5 test materials:

In general, purple Amaranth vegetables in the second experiment germinated more slowly than Caviar Cockatio due to the different growth characteristics of the two plants.

Experimental samples of phase II, observed and described at day 17, day 25 and day 33 after seeding:

In general, purple Amaranth vegetable growing in the experimental soil media had a very clear development: in which the vegetable growing in the samples mixed with unheated materials developed much faster than those in the sample mixed with heated materials and comparing soil sample, in which the vegetable

Figure 12. Experimental samples of the second phase on the 17th day after seeding.

Figure 13. Experimental samples of the second phase on the 25th day after seeding.

Figure 14. Experimental samples of the second phase on the 33rd day after seeding.

Figure 15. Testing materials in the 3rd phase.

planted in the soil mixed with unheated KR2/2 material grew fastest (Figures 12, 13 and 14).

The reason is that amaranth plants that grew in unheated KR2/2 volcanic ash mixed soil samples had outstanding growth. Next, the plant growth in unheated PY19 mixed samples, and two soil samples mix the heated material and the comparing soil sample, and the vegetable plants grow very slowly. It is possible that the calcined material is deformed, unsuitable for the growth of amaranth. In contrast, the unburnt materials have a chemical composition (Tables 2 and 3) suitable for the growth of this plant.

Phase 3: Trial of growing Caviar Cockatio with soil mixed with 1:3 test materials:

This phase of testing also lasts about four weeks. The purpose is to check and confirm the first test results and at the same time compare with the test results on the comparing perlite samples. The method and procedure are similar to the first batch of samples. The experiment samples include seven types, including: unheated mixed tuff sample (PY19), mixed tuff sample (PY19) calcined at 900^{0}C; unburnt volcanic ash mixed sample (KR2/2), volcanic ash mixed sample (KR2/2) calcined at 900^{0}C, comparing soil sample, perlite mixed sample and calcined pumice mixed sample (basalt ash) (purchased from the market) as a controlling (comparing media (Figure 15).

Test results after 14 days of seeding.

In general, the growth of vegetables in the testing samples after 14 days of seeding decreased gradually in the following order: Perlite mix sample → KR2/2 mix sample heated at 900^{0}C → Unheated PY19 mix sample → Pumic mix sample → comparing Soil sample → Unheated KR2/2 mix sample → PY19 mix sample heated to 900^{0}C (Figure 16).

Test results after 22 days of seeding.

In general, the growth of Caviar Cockatio vegetables in the samples decreased in the following order: Perlite mix sample → Unheated KR2/2 mix sample PY19 → mixed sample heated at 900^{0}C → comparing soil sample → Pumic mixed sample → mixed sample Unburnt PY19 → mixed sample KR2/2 and calcined at 900^{0}C. The plant in the perlite sample has the largest leaves, and the next is those in the KR2/2 is heated at 900^{0}C. The plants in unheated PY19 and KR2/2 samples have the same small leaves at 900^{0}C. Figure 17).

For Cocktail Caviar, the growth depends on the type of mixing material and the mixing ratio, specifically: the unheated KR2/2 mixed sample is more suitable for the testing plant than the 900^{0}C heated KR2/2 sample at both mixing ratios; Mixed sample PY19 (both unheated sample and 900^{0}C calcined sample) is suitable for testing plants when mixed at 1:5 ratio. Meanwhile at the ratio of 1:3, the mixed sample PY19 burnt at 900^{0}C is more suitable for plant growth than the unburnt PY19 mixed sample. Perhaps the reason that the material PY19 heated at 900^{0}C is a material in the form of recrystallization (microcrystalline) with the distribution of elements Si, O, Al, Na in each site evenly and closely linked to each other, helping to form a strong mutual affinity with

Figure 16. Overall comparison of growth of Caviar Cockatio vegetables on different types of testing soil after 14 days of seeding.

Figure 17. Overall comparison of growth of Caviar Cockatio vegetables on different types of testing soil after 22 days of seeding.

strong ion exchange and adsorption capacity, which supports plants to better exchange nutrients with the soil environment.

4.2.2. General evaluation of test results to using crop support materials

It can be seen from the results of three phases of testing:

In general, vegetables planted in soils with supplementary materials grew faster (larger in height and thicker leaf plates) than plants grew in soil. This is an evident for plants to grow in soils supplemented with untreated (unburnt) materials during the first stages of plant growth;

The supporting effect of the material is different depending on the type of plant (e.g. Caviar Cockatio and purple Amaranth), the ratio (content) of the supporting substances (e.g. 1:5 and 1:3), type of support material (e.g. tuff, volcanic ash, perlite, pumice) and stage of plant growth;

The test results showed a clear effect of the tuff and volcanic ash materials of the Don Duong and Dai Nga formations, which are named "Stonemeal" rich in mineral nutrients, capable of supporting the growth of vegetables and other crops, especially on soils poor in micro-mineral nutrients such as degraded gray soil, which are widely distributed in the low hill areas in Northern Part and Central Coast of Vietnam. However, these are only the initial research results based on preliminary and qualitative experiments; there is a lack of accurate quantitative data and in-depth biochemical explanationsthen further studies are necessary to conduct.

5. Conclusion

Studying the material composition of felsic tuff of the Don Duong Formation and mafic ash sample from the Dai Nga Formation showed that in the raw materials, apart from the phenocrysts, microcrystalline of feldspar, quartz, micas and other colored minerals are rich in glass in the samples.

The raw tuff morphology is different from the calcined tuff sample. The raw tuff samples have a cubic shape, crystalline structure, smooth surface, and less porosity. Meanwhile, the morphology of the modified sample (when calcined at high temperature) has a highly porous structure a rough surface, with appearing crystals which can be confirmed to be due to water released from the testing material during calcination.

The acid tuff samples of the Don Duong Formation (PY19) have quite high Zn, Sn, V, and Ba concentrations. In contrast, the volcanic ash samples of the Dai Nga Formation (KR 2/2) have a very-high content of Cr, Co, V, and Ni and Cu so that these materials can be used as direct micro-mineral fertilizers for crops.

Felsic tuff materials of the Don Duong Formation and mafic ash samples of the Dai Nga Formation can support plant growth. The level of plant growth depends on the type of material (unheated, calcined), the content of supporting materials, the type and stage of the plant's development.

Acknowledgments

The data is published by the B2016-MDA-16DT project.

The authors' contributions

The manuscript was prepared by Vinh Thi Dang; Comments and edits of the manuscript made by Giang Khac Nguyen.

References

Alihosseini, A., Taghikhani, V., Safekordi, A. A., Bastani, D. (2010). Equilibrium sorption of crude oil by expanded perlite using different adsorption isotherms at 298.15 k. *International Journal of Environmental Science & Technology*, *7*(3), 591-598.

Assainar, S. K., Abbott, L. K., Mickan, B. S. (2020). Polymer-coated rock mineral fertilizer has potential to substitute soluble fertilizer for increasing growth, nutrient uptake, and yield of wheat. *Biology and Fertility of Soils, 56*, 381–394. https://doi.org/10.1007/s00374-019-01428-w

Bui, M. T. (eds.). (2010). *Activities of Magma in Vietnam*. National Institute of Geology and Minerals, 369 pages. (in Vietnamese).

Dao, D. T., Huynh, T. (1995). *Geology of Vietnam. Episode II. Magma Formations*. Department of

Geology of Vietnam, Hanoi, 359 pages. (in Vietnamese).

Fyfe, W. S., Leonardos, O. H., & Theodoro, S. H. (2006). Sustainable farming with native rocks: the transition without revolution. *Anais da Academia Brasileira de Ciências*, *78*, 715-720.

Ghassabzadeh, H., Mohadespour, A., Torab-Mostaedi, M., Zaheri, P., Maragheh, M. G., & Taheri, H. (2010). Adsorption of Ag, Cu and Hg from aqueous solutions using expanded perlite. *Journal of Hazardous Materials*, *177*(1-3), 950-955.

Ha, T. N., Pham, T. H., Le, T. D. (2011). New Results of the stud on isotopic age of the granodiorite Chieng Khuong Complex in Song Ma area by U-Pb Zircon isotopic dating method. *Journal of Mining and Earth Sciences, 35*(7), 38-47.

Kabra, S., Sharma, A., Katara, S., Hada, R., Rani, A. (2013). DRIFT- Spectroscopic study of modification of surface morphology of perlite during thermal activation. *Indian Journal of Applied Research, 3*(4), 40-42.

Kirk, S., Edwards, A., & Sese, J. (2000). Making good use of volcanic ash in the Philippines. In *Proceedings of the 10th REAAA Conference*.

Le, T. D., Pham, T. V. A. (2005). Late Mesozoic volcanic and plutonic formations in Aluoi-Dak Rong band. *Journal of Earth Sciences, 2*(T.27), 133-141. (in Vietnamese).

Le, T. D., Nguyen, K. G., Pham, T. H., Nguyen, H. T., To, X. B., Le, T. N. T., Dang, T. V., Pham, T. V. A., Ha, T. N., Vu, Q. L., Nguyen, T. L. L. (2018). Characteristics of Petrological Composition of Carbonate-Terrestial Sediment Formations and the relationship to volcanic rocks in Tu Le area. *Journal of Mining and Earth Sciences, 59*(5), 1-13. (in Vietnamese).

Maret, W., & Copsey, M. (2012). Metallomics: whence and whither. *Metallomics*, *4*(10), 1017-1019, https://doi.org/10.1039/c2mt90041f

Morsy, M. S., Shebl, S. S., Abd E. G., Saif, M. (2008). Development of perlite-gypsum-slag-Lime sludge-composite system for building application. *Building Research Journal, 56*, 49-58.

Nguyen, K. G., Le, T. D., Pham, T. V. A, Pham, X. N., To, X. B. (2018). Studying to use volcanic ashes and felsic volcanic rocks in Vietnam teritory as the treatment materials for environment pollution – preliminary results. *IPN Conferences 2018 Hanoi*, Vietnam, 1-8.

Roulia, M., Chassapis, K., Kapoutsis, J.A., Kamitsos, E. I., Savvidis, T. (2006). Influence of thermal treatment on the water release and the glassy structure of perlite. *Journal of materials science*, *41*, 5870-5881.

Theodoro, S. H., & Leonardos, O. H. (2006). The use of rocks to improve family agriculture in Brazil. *Anais da Academia Brasileira de Ciências*, *78*, 721-730.

Toma, H. E. (2019). IYPT-2019 (International Year of the Periodic Table of the Chemical Elements-2019). *Quimica Nova, 42*, 468-472.

Van Straaten, P. (2006). Farming with rocks and minerals: challenges and opportunities. *Anais da Academia Brasileira de Ciências*, *78*, 731-747.