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Petrography of the Altered Basaltic Rocks and their Evaluation as a Media for Plant Growth and Enrich Nutrients in Rhizosphere

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ABSTRACT

This study investigates the potential of altered basaltic rocks as a source of a sustainable soil amendment (media) for enhancing plant growth and soil quality in arid and semi-arid regions, particularly the sandy soils of Wadi El-Natrun, Egypt. The basaltic material was collected from El-Haddadin area near El Sheikh Zayed, Greater Cairo on area geologically part of the Tertiary volcanic episodes in Egypt. Based on the integrated petrographic investigation using the thin section microscopic examination and X-ray diffraction analysis, the composite sample of El- Haddadin area is heterogonous amygdaloidal glassy display significant alteration marked by calcite, smectite, illite, and celadonite minerals. The dominant amygdaloidal texture, variolitic groundmass, and calcite and smectite filling alteration products may contribute potential pedogenic implications. The rock was manually processed and mixed with the Wadi Natrun sandy soil in varying proportions. A greenhouse experiment was conducted using Basil (*Ocimum basilicum*) as a test crop to evaluate the agronomic benefits of basalt-amended soil. The results showed that the mixture of 75:25 sand: basalt ratio significantly improved plant morphological traits (leaf area, root length, biomass fresh and dry weights), outperforming either sand or basalt media. Biochemical analyses revealed substantial increases in the concentration of essential nutrients (phosphorus, potassium, zinc, manganese, and iron) in plant tissues. Moreover, total flavonoid content was significantly enhanced with the mixture of 75:25 sand: basalt ratio. Textural features such as amygdaloidal structures, variolitic groundmass, and calcite-filled vugs reveal alteration processes improved the pedogenic properties. It might be concluded that basalt amendments (media) represent a cost-effective and environmentally friendly practice to improve crop productivity and soil fertility in arid and semi-arid ecosystems. Further research for its long-term impacts and synergistic interactions with other soil- nano-technologies are recommended.

Keywords: Basil (*Ocimum basilicum*) altered basaltic rocks, soil amendment, semi-arid regions, sandy soils,

1. Introduction

The main obstacle for sustainable agriculture in arid and semi-arid regions is the limited availability of water resources. Inadequate soil moisture content, and resources mismanagement, poses a serious challenge that must be addressed to ensure effective land utilization in these regions. Among the various strategies to mitigate water deficit induced yield losses, soil amendments have gained considerable attention due to their ability to improve soil physical properties, enhance water retention, and reduce abiotic stress effects. Basalt, a volcanic rock rich in silica, iron, magnesium, and trace elements, has shown promising potential as a sustainable soil amendment. It enhances soil cation exchange capacity, improves soil structure, and increases water holding capacity, which is beneficial under moisture stress conditions (Darmawan *et al.,* 2020). The effectiveness of basalt can be further enhanced when combined

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with foliar applications of nano-silicon (nano-Si) and nano-zeolite, both of which are known to improve physiological and biochemical parameters such as chlorophyll content, photosynthetic rate, stomata conductance, and antioxidant activity in plants under stress (Xie *et al.,* 2012; Abdelwahab & Swaefy, 2020; Abdelwahab *et al.,* 2021 & 2023) .Another useful soil conditioner is bentonite which can be useful as an adsorbent for some heavy metals and water purification (Li *et al.,* 2010, and Semi & Gomes 2011). Fortunately, most basaltic rocks around the Greater Cairo (El-Haddadin area) are altered and contain high concentrations of hydrous secondary minerals such as smectite, illite, celadonite, and chlorite. Applying natural powdered of these rocks directly to sandy soils enhances its fertility. The use of basalt rock ash as a fertilizer reduces chemical fertilizers application, offering health ecosystem (El-Alfy and El-Sharkawi, 2015). These benefits are especially valuable in arid regions like Wadi El-Natrun, where water scarcity and infertile soils are the major limitations for agricultural productivity. A promising solution lies in the application of basaltic soil amendments, which gradually release essential nutrients such as calcium, magnesium, potassium, and trace elements in root zone. This improves the nutrient-holding capacity and structural integrity of sandy soils (Manning, 2010) Moreover, basalt facilitates microbial activity and promotes soil aggregation, both of which are essential for moisture retention and plant health under moisture stress conditions (Anda *et al.,* 2015).

This study aims to insure suitable conditions for enhancing sandy soil productivity. Greenhouse experiments will evaluate basalt amendment materials and their appropriate ratios to support sustainable agricultural production in desert regions. The research also aligns with international circular economy strategies and arid zone sustainability initiatives by converting natural waste materials into valuable agricultural resources.

2. Material and Methods

2.1. Collection of the basaltic soil amendment samples

In Egypt, basaltic rocks utilized for soil improvement are primarily extracted from the El Sheikh Zayed area, particularly around El-Haddadin area and its northwestern extension near Cairo–Alexandria Desert Road (latitudes 30°00′N to 30°08′N and longitudes 30°53′E to 31°04′E, covering approximately 30,000 km²) and located around 38 km west of Cairo (Figure 1). It represents a typical flat desert plateau with terrace-like landforms and scarps covered with flint cobbles. El-Haddadin Hill, the highest elevation at 186 m above sea level, has witnessed increasing urban and agricultural development, highlighting its importance as a source of soil amendment materials.

El- Haddadin area contains the basaltic soil amendment. This area consists of the following rock units from bottom to top: Cretaceous limestone and clastic sequence (Kuu), Oligocene Gebel Qatrani Formation (Toq), Oligocene basalt flows and volcaniclastic (Vb), Early Miocene Gebel Khashab formation (Tmk), Early Pliocene Hagif formation (Tplh), Quaternary Proto Nile deposits (Qn1) and Quaternary Cultivated land (Qns) which they are shown in Fig. (3).

The collected material is a natural mixture primarily composed several types of basaltic rocks with a rarely impurities. The collection process involved manual excavation using a shovel, starting from the upper surface layer down to the bottom of the rock dish to ensure a representative and homogeneous sample. Total of 250 kilograms of the basalt mixture was gathered and immediately placed into durable plastic bags to preserve its physical integrity and avoid its contamination during transport. The collected samples were then delivered to the Faculty of Agriculture, Cairo University, for further processing and preparation.

2.2. Laboratory analysis

The compact and friable collected bedrock samples were subjected to petrographical and mineralogical investigations. Representative samples were petrographically investigated at Geology Department, Faculty of Science, Cairo University laboratories using thin-section microscopic description. Selected samples underwent detailed mineralogical study using X-ray diffraction (XRD) analysis at the Tebein Research Center, Helwan. Both powdered bulk samples and separated clay fractions (>2 µm) were X-rayed using an XRD Bruker Co. D8 Discover (Germany), with Ni filters, Cu target (wavelength 1.54 Å), 40 KV, and 40 mA. Clay minerals were identified based on the XRD charts of untreated, glycolated, and heated (550°C for 2 hours) oriented clay fraction slides. Minerals in both bulk samples and clay fractions were identified using ASTM cards and other standard published data. These minerals were semi-quantitatively estimated in terms of relative abundance using the relative

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peak areas following the procedure similar to that of Schultz (1964) and Pierce & Siegel (1969) of their characteristic diffraction lines. The initial basaltic soil paste was chemically analyzed using standard methods (Jackson, 1973) to determine ions and trace elements in the saturated samples.

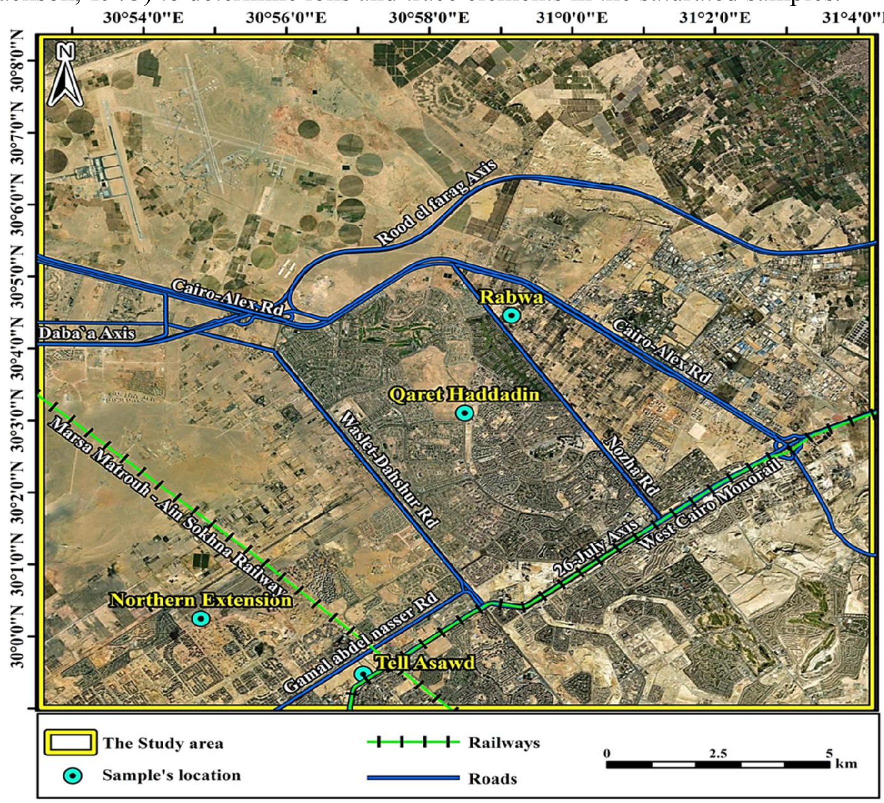

Fig. 1: The location map of El- Haddadin area. The basaltic soil amendment samples were collected from the El-Haddadin domal volcanic - clastic isolated hill (Qaret El-Haddadin). The landform of Qaret El-Haddadin area is presented in Fig. (2)

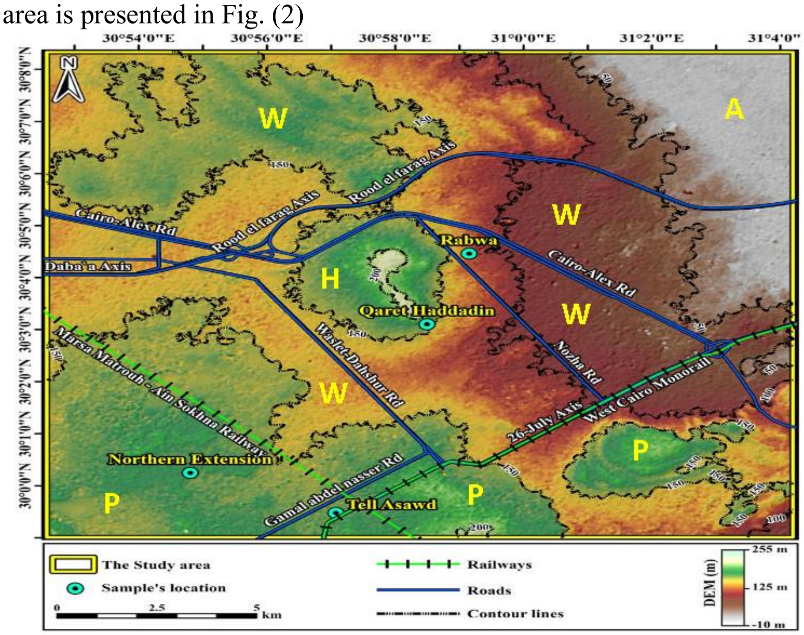

Fig. 2: Land forms map showing the basaltic hill Qaret El- Haddadin area and surrounding units. Escarpment plateau is more than 192m, the volcanic-Clastic Hill is more than 168m, the Wadi Plain is more than 144m and the Nile Flood Plain is less than 24m.

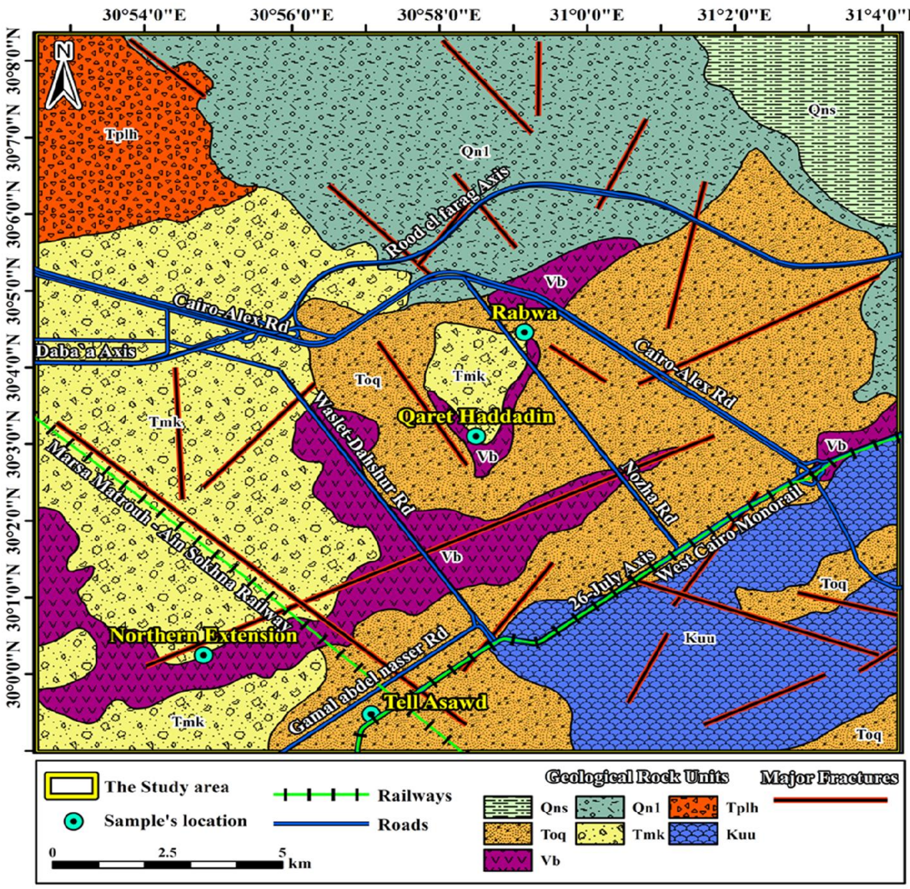

Fig. 3: Map of geological rock units of El- Haddadin area (modified after Conco, 1987). The volcanic succession (Vb) in El-Haddadin area is composed of three basaltic flows (Shallaly, 1998). It represents a sandwiched between the Qatrani Sandstone (Toq) in the bottom and the Gabel Khahab (Tmk) on the top (Fig. 3).

2.3. Agricultural investigations

The basalt material was transferred into pots for preliminary handling. The rocks were manually crushed using a hammer to fracture them into smaller grains size (70-75 mesh) then mixed with soil. This increased the surface area of the basalt particles, enhancing their effectiveness as a soil amendment and allowing for consistent incorporation into experimental soil mixtures. Sandy soil derived from Wadi El-Natrun desert (90.71- 98.52% sand, and traces of silt and clay fractions, (Ahmed *et al.,* 2020) was mixed with basalt particles in varying proportions and placed in containers. The sand soil characterized by poor water retention and low cation exchange capacity causing harsh agriculture conditions unless effective amendments were applied. Several altered basalt types were used along with a defined amount of crushed impurities. These mixtures were arranged into five different experimental treatments to assess the extent of basalts contribution to soil fertility through weathering and dissolution. Each treatment represented a unique combination and quantity of materials. The experiment was carried out under greenhouse conditions at the Department of Plant Physiology, Faculty of Agriculture, Cairo University, Giza Governorate, Egypt (latitude 30°03′N, longitude 31°13′E, elevation 19 m above sea level)., Basil seedlings (*Ocimum basilicum*), measuring 6–8 cm in height (two months old) with healthy root systems, were obtained from the Ornamental Planting Department, Faculty of Agriculture, Cairo University. Basil seedlings were selected because of its sensitivity to soil nutrient availability and rapid growth, making it a suitable test plants for short-term soil amendment studies.

2.4. Chemical analysis

The plant material was dried in an electric oven at 70 C° for 24 hours according to Helrich, (1990), then finely ground for chemical determination of elements. The wet digestion of 0.2g plant material with sulphuric and perchloric acids was carried out on samples by adding concentrated sulfuric acid (5 ml) and the mixture was heated for 10 min. 0.5 ml perchloric acid was then added and heating continued till a clear solution was obtained (Jackson, 1973 and Helrich, 1990).

Total nitrogen content of the dried leaves was determined using the modified micro-Kjeldahl method as described by Helrich, (1990). Phosphorus was determined colorimetrically using the chlorostannous molybdophosphoric blue colour method in sulphuric acid according to (Jackson, 1973). Potassium concentration was determined using the flame photometer apparatus (CORNING M 410, Germany). Concentrations of Zn, Mn and Fe in plant samples were determined using atomic absorption spectrophotometer with air-acetylene and fuel (Pye Unicam, model SP-1900, US). Total chlorophyll content was measured by spectrophotometer and calculated according to the equation described by Moran *et al*. (1982). Total carbohydrates in plant samples were determined by phosphomolybdic acid method according to Helrich, (1990). Total phenolic contents of the extracts were determined spectrophotometrically according to the Folin–Ciocalteu colorimetric method (Singleton & Rossi 1965). Tannin contents were determined using Folin-Ciocalteu reagent method as described by Chahardehi *et al.* (2009). Total flavonoids were determined using the method of Meda *et al*. (2005).

2.5. Vegetative growth parameters

2.5.1. Data recorded:

After 60 days, the samples collected where three plants were randomly chosen from each treatment in the end of the growing season to be subjected for samples collection. The following data were recorded and statistically analyzed.

2.5.2. Vegetative growth parameters

1. Plant height (cm). 2. Number of branches. 3. Leaves area $(cm)^2$ 4. Root length (cm). 5. Leaves fresh weight (g/plant). 6. Leaves dry weight (g/plant).

Although Basil plants (*Ocimum basilicum*) did not continue their life cycle completely (only 2 months of the growing season) the plants harvested before passed away due to the diminishing of essential elements in the growth media. To investigate the effect of basalt and sand media individually or in combination on Basil plants, morphological and chemical analyses were run as follows:

3. Results and Discussion

3.1. Petrographic description of basaltic material

The basaltic sequence in El-Haddadin hill could be divided into two groups: the first one (samples No VB, S3C and U7B) is slightly to moderately altered hard basaltic rocks contains plagioclase, augite and olivine with notably amygdaloidal texture and secondary minerals (smectite, zeolite, celadonite, iron hydroxide) as revealed from the petrographic description (Figure 4). The second group is highly altered basaltic rocks (Samples No S3D and S8) contains secondary minerals (calcite, clay minerals and iron-oxides and hydroxides) indicative of pedogenic processes and possible calcrete development. The following is a brief description of these basaltic samples, the mixture of which forming the amendment material (media) for the agricultural practices.

1 -**Sample (VB):** This sample is glassy dolerite that shows the combination of glassy mesostasis and large plagioclase and pyroxene glomero-phenocryst with massive irregular amygdules (figure 4a). The glass is brown gel-like palagonite that is formed as a response to the hydration of basaltic glass. The augite and plagioclase glomero-phenocrysts form symplectite texture since both minerals inter-grown with each other. The amygdules are brown, large, and composed of reddish-brown palagonite, yellow smectite, and colorless fibrous zeolite. Calcite may fill the cores of the amygdules as a late stage.

2 -**Sample (S3C):** The rock is medium-grained dolerite that is made up of fresh plagioclase and pyroxene (augite), with glassy mesostasis in between (figure 4b). The glassy matrix contains numerous plagioclase microlites with a characteristic variolitic texture and large, irregular green vugs and amygdules. They are rimmed dark brown iron-rich clay minerals and filled with bluish-green fibers of celadonite.

3 -**Sample (U7B):** The rock is slightly altered basalt with augite and plagioclase phenocrysts, which are surrounded by a glassy groundmass. The augite and plagioclase are slightly altered to calcite (figure

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4c). The glassy groundmass is partially replaced by smectite and illite, which contain skeletal iron oxide minerals.

4 **-Sample (S3D):** This sample represents veins invading the basalts; it is composed of alternating parallel yellow and colorless bands. Sometimes, the colorless bands is cross-cut the yellow ones. The yellow bands are not homogeneous and they are composed of a fibrous mixture of smectite and illite or kaolinite. The colorless bands are composed of calcite, dolomite rhombs, quartz, plagioclase, and pyroxene (figure 4d).

5 **-Sample (S 8):** This rock mainly consists of interlocking calcite crystals. Brown material defines sectors in the calcite to give it a zoned feature (figure 4e). Calcite forms a spherulitic texture with numerous ghost structures and remains of bluish-green celadonite fibrous crystals are common. Large basaltic remnants with numerous plagioclase and ilmenite crystals and pseudomorphs of pyroxene and olivine are recorded. Iron-oxy-hydroxide of blood red to brownish-red are concentrated with the celadonite remnant.

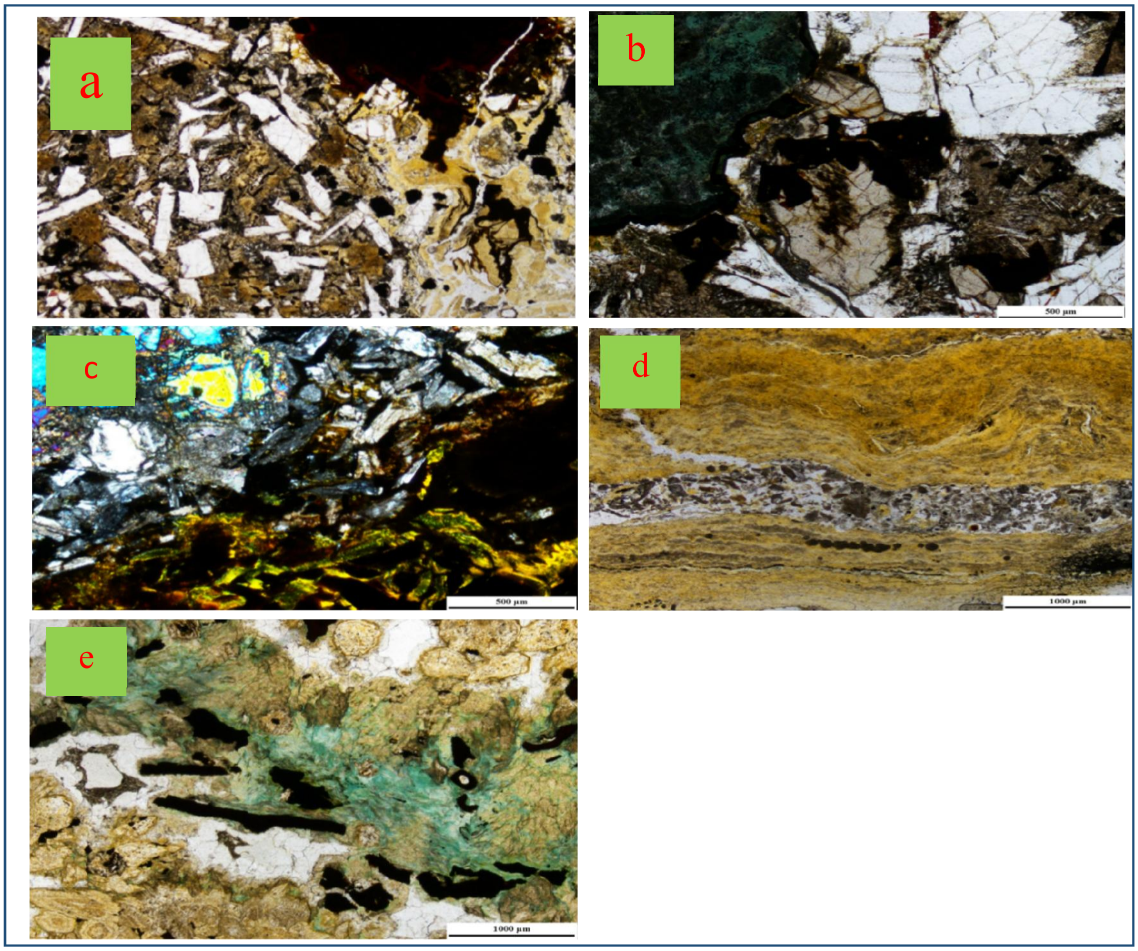

Fig. 4: Petrographical description of the **basaltic material**: (a.) Dolerite basalt shows the combination of glassy mesostasis and large plagioclase (sample No. VB) (b) The rock is medium-grained dolerite that is made up of fresh plagioclase and pyroxene (augite) (Sample No. S3C) (c) The rock is slightly altered basalt with augite and plagioclase phenocrysts (Sample No. U7B) (d) This sample represents veins invading the basalts it is composed of alternating parallel yellow and colorless bands (Sample No. S3D) (e). The rock mainly consists of interlocking calcite

3.2. Mineralogical and chemical properties of the basaltic soil media

According to the X-ray diffraction (XRD) analysis of El-Haddadin basalt samples, figure (5) shows a mix of original volcanic minerals and secondary alteration products. Sample (VB) mainly contains augite and plagioclase, with a large amount of volcanic glass that has altered to palagonite. Smectite,

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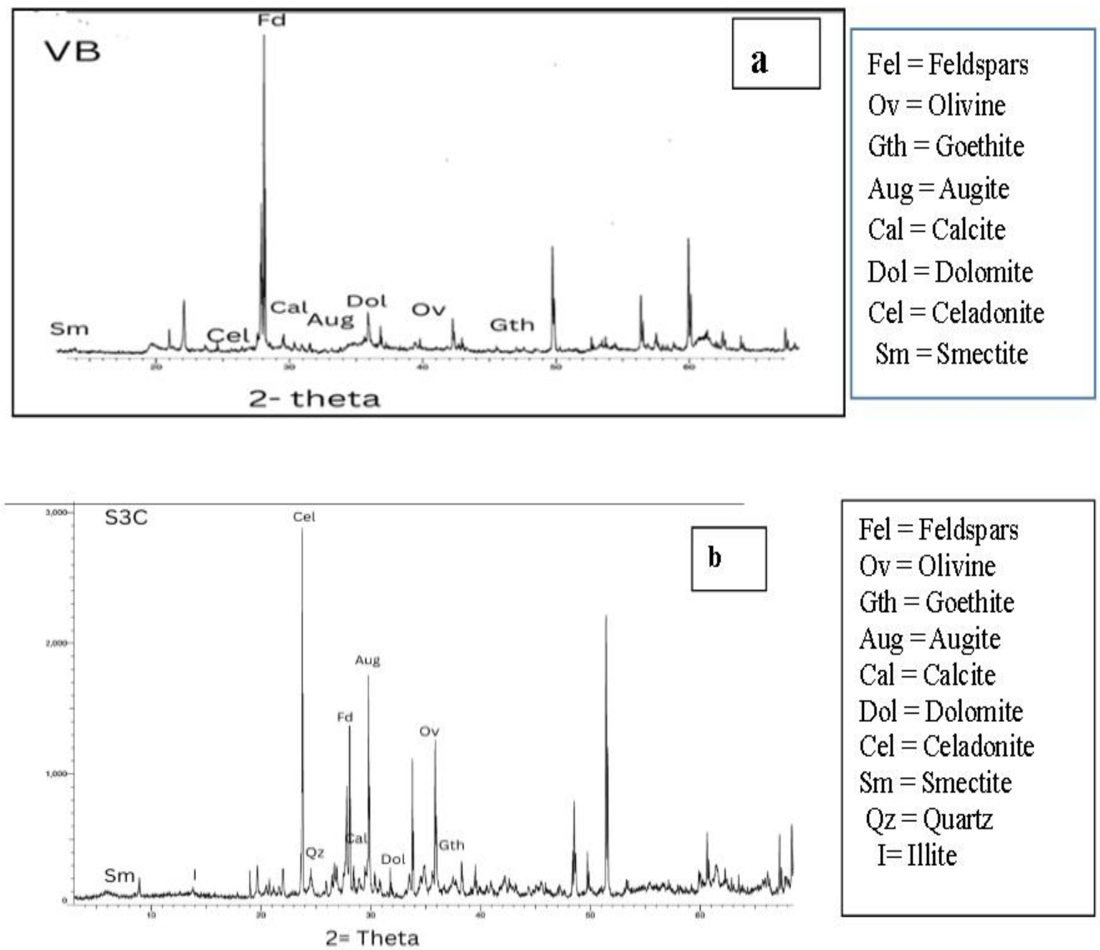
Dolomite and some calcite are also present, especially in the amygdules. Sample (S3C) includes fresh augite and plagioclase, along with celadonite, quartz, and calcite, which reflect chemical alteration and fluid activity. Augite and plagioclase are partly replaced by smectite, quartz, and calcite as shown in sample U7B. Iron oxides are also present, giving the rock a brownish color. Sample (S3D) shows a layered structure with clays like smectite and illite or kaolinite in one layer, and calcite, dolomite, quartz, and feldspar in another, pointing to both hydrothermal and soil-forming processes. Sample (S8) is mostly made of calcite, with traces of celadonite, iron oxides, and remnants of basaltic minerals like plagioclase and pyroxene. The presence of voids filled with quartz sand suggests that this rock may have formed as a calcrete soil after the basalt was altered.

The results of the X-ray analysis of the bulk samples (figure 5) and clay fractions (figure 6) of the same samples are given in Table (1). The data indicates that the basaltic soil media sample is heterogonous in mineral composition. It contains moderately to traces amount of the basaltic minerals, such as augite, olivine and feldspars (mainly basic plagioclase) in addition to larger quantities of secondary minerals that filling the amygdules and vesicles. The secondary minerals includes celadonte, goethite and clay minerals (smectite, illite and kaolinite in addition to evaporate minerals such as gypsum and halite). Both types of smectite were encountered, namely Ca and Na montmorillonite. The Ca-montmorillonite is identified in the untreated clay fractions by d-spacing's ranging between 14.64 and 15-36 Å while Na - montmorillonite is identified by 12.05 Å. Both d-spacing's are shifted to about 17 Å and 10 Å upon glycolation and heating, respectively (Figure 6). The illite is identified by a peak at about 10 Å which was neither affected by glycolation nor heating. Koanlite is characterized by its basal reflection d-spacing 7.2 and 3.58 Å. These reflections are not affected by glycolation while disappeared upon heating.



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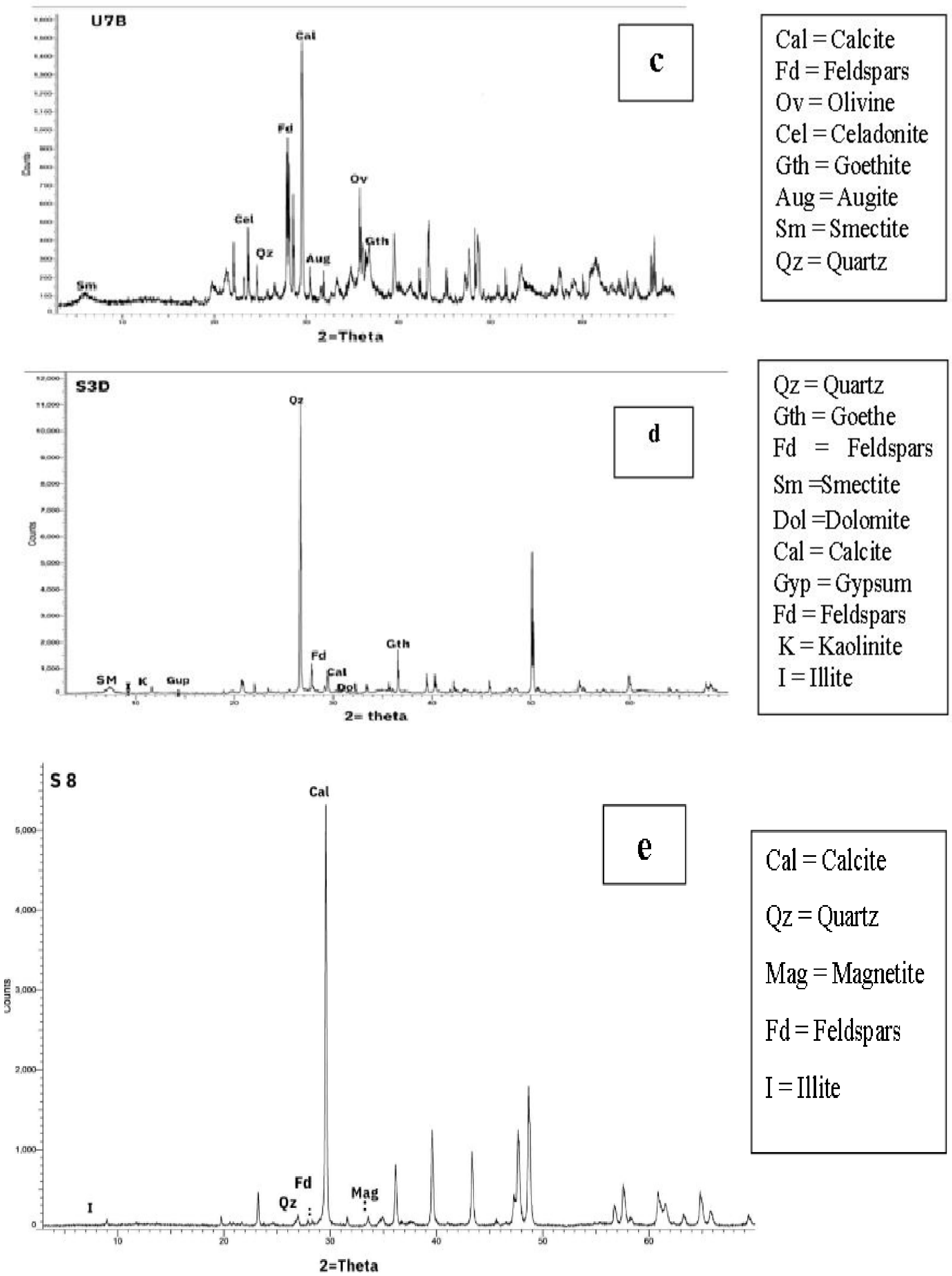

Fig. 5: X-ray diffraction (XRD) bulk samples of El-Hadaddin area

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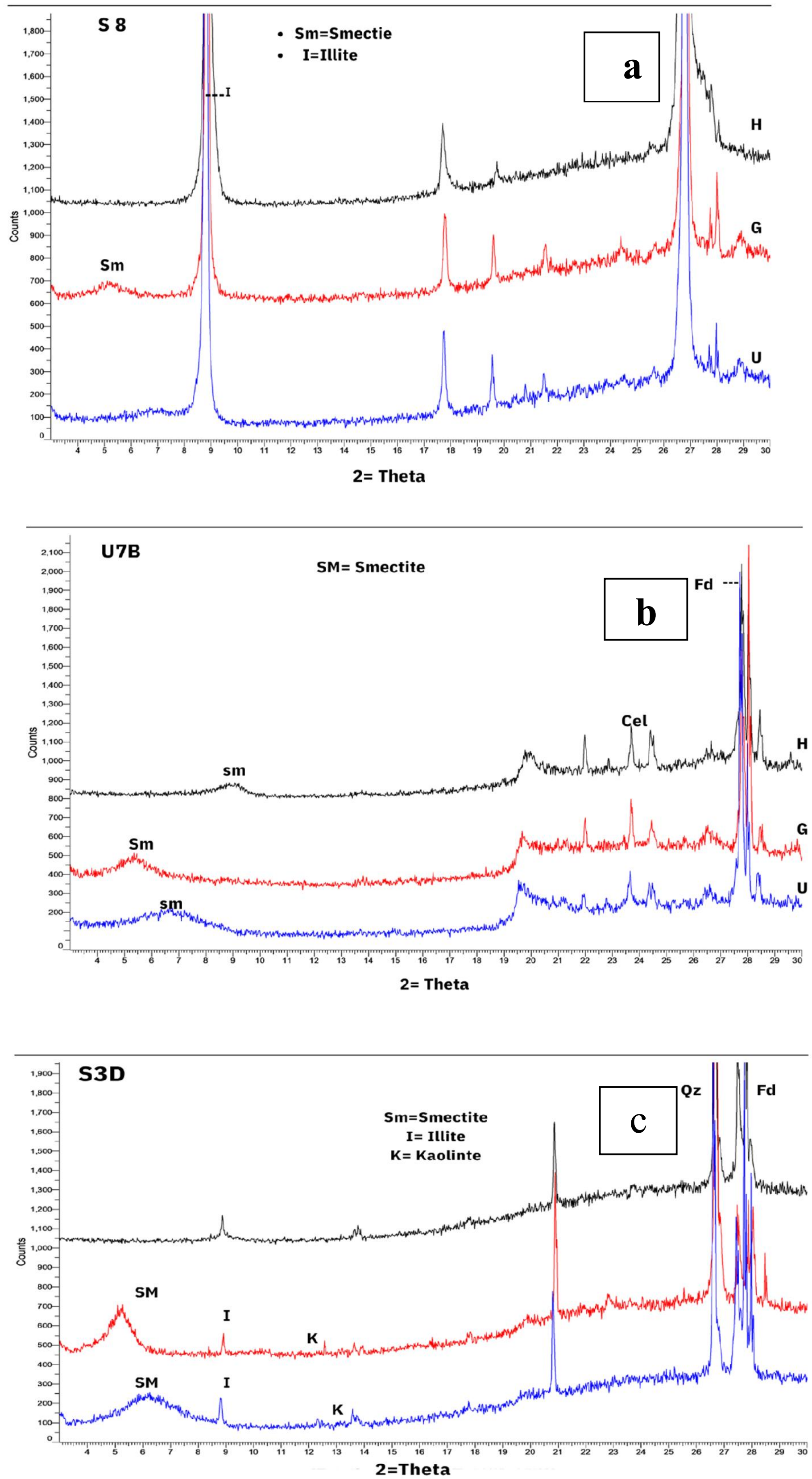

Fig. 6: XRD Charts of Clay Fraction in three samples (U7B, a) (S3D, b) (S 8, c) U: Untreated, G: Glycolated, and H: Heated oriented clay fraction

Table 1: Mineral composition of the basaltic media samples based on the XRD analysis. T, M, A and D represent the relative abundance of the identified minerals

The chemical formula of identified minerals	Moderately weathered			Highly weathered		Average composition of texture	Potential soluble cations
	VB	S3C	U7B	S3D	S8		
Augite (Aug) Mg 0.81 FeO. 15AlO	2.94A (T)	2.99A (A)	2.96A (M)	-	-	**M**	-
Olivine (Ov) (Mg,Fe)2Sio4	2.50A (M)	2.50A (M)	2.51 (M)	-	-	**M**	Mg
Feldspars (Fd) (Labradorite) Ca Si_3AlO_8	3.19A (D)	3.20A (A)	3.21A (A)	3.21A (M)	3.22A(T)	A	Ca,Na
Quartz (Qz) (Chalcedony) SiO_2	-	3.35A (T)	3.35A (T)	3.34A (D)	3.33A(T)	T	-
Calcite (Cal) Ca CO_3	3.02A (T)	3.02 (T)	3.04A (D)	3.07A (T)	3.04A (D)	A	-
Dolomite (Dol) Ca $Mg(CO3)_2$	2.88A (T)	2.88A (T)	-	2.88A (\T)	-	M	-
Goethite (Gth) $Fe+_3O$ (OH)	2.45A (M)	2.45 (T)	2.45A (M)	2.46A (M)	-	A	Fe
Magnetite (Mag) $Fe_2 O_3$	-	-	-	2.53A (T)	2.58A(T)	T	
Gypsum (Gyp) CaSO.$2H_2O$	-	-	-	7.63A (T)	-	M	Ca
Celadonite (Cel) K($MgFe_{3+}$)(Si_4O_{10}) $(OH)_2$	3.75A (T)	3.74A (A)	3.78A (M)	-	-	T	K
Smectite (Sm) $Al_2O_3.4SiO_2xH_2O$	14.64A (M)	14.75A (M)	15.36A (M)	12.05A (M)	-	T	-
Illite (I) $KA_{l2}.Si_3AlO_{10}(OH)$	-	9.91A (T)	-	10-0A (M)	10.13A (T)	M	K
Kaolinite (K) $A_{l2}Si_2O5(OH)_4$	-	-	-	7.2A(T)	-	M	-
Not detected	T =Trace <10%	M =Moderate 10-20%	A= Abundant 21-40%	(D)= Dommant>40%			

Table 2: Chemical analysis of saturated basaltic soil paste.

SP	EC dS/m	pH	Soluble Anions(Ml/L)				Soluble Catoins (Ml/L)			
			SO_{-4}	Cl	HCO_{-3}	CO_3	K^+	Na^+	Mg^{++}	Ca^{++}
25.0	2.48	8.20	14.40	19.0	3.30	-	0.10	26.96	3.65	6.0

The baseline soil properties are presented as preliminary and essential to establish a reference point for measuring the impact of basalt amendment on soil quality and plant performance over time. The basaltic soil significantly enhances the permeability of sandy soils, making it a valuable amendment for land reclamation by improving water retention and reducing irrigation requirements. In addition, basaltic soil enriches the soil solution with essential plant nutrients through the gradual release of dissolved ions such as calcium (Ca^2), magnesium (Mg^2), potassium (K^+), and sodium (Na^+), as shown in the chemical analysis of the saturated basalt paste (Table 2) and the elemental composition as shown in Table (3), which includes trace nutrients like Cu^{2+} and Zn^{2+}. These nutrients originate from the mineralogical composition of basalt, as identified by X-ray diffraction analysis (Table 1), which highlights nutrient-bearing minerals such as plagioclase feldspar (Na^+, Ca^{2+}, Al^{3+}), celadonite (K^+, Mg^{2+}, Fe^{2+}/Fe^{3+}), olivine (Mg^{2+}, Fe^{2+}), goethite (Fe^{3+}), calcite (Ca^{2+}), dolomite (Ca^{2+}, Mg^{2+}), and smectite (Na^+, Ca^{2+}, Mg^{2+}). The source of Cu and Zn is possibly the opaque minerals and their presence as trace elements in the silicate minerals. These minerals undergo weathering, gradually releasing nutrients into the soil solution and making them available for plant uptake. Therefore, basalt amendments serve a dual role in soil improvement: they enhance permeability through fine-grained particles, especially non-expansive clay-sized materials, and supply vital nutrients to nutrient-poor sandy soils through the release of soluble elements from weathered secondary minerals, in the amygdules formed during basalt alteration.

Table 3: Some elements content in saturated basaltic soil sample.

Concentration (Mg/Kg)						
N	**K**	**P**	**Cu**	**Fe**	**Mn**	**Zn**
104.0	203.0	7.92	0.03	11.22	0.47	0.31

3.3. Growth parameters

The acquired data of plant growth parameters as shown in Table (4) and Figure (7) divulged that the lowest growth parameters were recorded with pure media, whether sand (100%) or basalt (100%). On the other side, a combination of basalt and sand at a ratio of 25:75% had a profound consequence on Basil (*Ocimum basilicum*) plants since it significantly enhanced plant height by 97% compared to sand media only (100% sand) and 46% compared to basalt media only (100% basalt).

Table 4: Effect of basalt (B) and sand (S) media on Basil plants (*Ocimum basilicum*) morphology.

Treatments	Plant height (cm)	branches No.	Leaf area (cm)²	Root length (cm)	Shoot fresh weight (g)	Shoot dry weight (g)
S 100%	17.5d	0	13.09d	6.8c	9.6d	2.8c
S75,B 25%	34.5a	4a	56.17a	17.3a	37.3a	10.1a
S50,B 50%	30.8b	3a	51.26b	16.7a	34.2a	8.2a
B75,S 25%	31.4b	3a	50.11b	14.5b	28.8b	7.8a
B 100%	23.5c	1b	23.20c	10.6c	16.5c	5.2b

Means with the same letter in a column are not significantly different by DMRT

Fig.7: The growth plants (*Ocimum basilicum*)

The branch numbers of plants that grew in sand media (100%) did not record any side branches and only one side branch with those that grew in basalt media (100% basalt). Meanwhile there were insignificant differences among media of sand 75: basalt 25%, sand 50: basalt 50%, and basalt 75: sand 25% regarding side branches. Considering leaf area, the same trend was found where a combination of basalt and sand ratio of 75: 25 % media recorded a significant increase in leaves area by 329% over those plants that grew in sand media (100%) and 142% compared to basalt media (100% basalt). Simultaneously, there were insignificant differences between both sand 50: basalt 50% and basalt 75: sand 25% for leaf area. Root length also significantly donated the highest value, 154%, with basalt and sand ratio of 75:25% media in contrast to sand media only (100% sand) and 63% compared to basalt media (100% basalt). Moreover, both media of sand 50: basalt 50% and basalt 75: sand 25% recorded insignificant differences between each other regarding root length. Focusing on the fresh weight of Basil plants (*Ocimum basilicum*), the media of sand 75: basalt 25% confirmed significant increases by 298% compared to sand media (100%) and 132% compared to basalt media (100% basalt). Concurrently, it was distinguished that there were insignificant differences between both media of sand 75: basalt 25% and sand 50: basalt 50% regarding fresh weight. In connection with dry weight the same way was observed since sand 75: basalt 25% media verifies the highest value (260%) of dry weight balanced with sand media (100% sand) and 94% compared to basalt media (100% basalt). However, insignificant differences were recorded between three media of sand 75: basalt 25%, sand 50: basalt 50% and basalt 75: sand 25% concerning the dry weight of Basil plants (*Ocimum basilicum*).

3.4. B-Biochemical analysis

3.4.1. Nutrients concentration

Data associated with macro- and micro nutrients concentrations, as clarified in Table (5), revealed that the use of sand 75: basalt 25% media had suitable nutrients concentrations within Basil plant tissue (*Ocimum basilicum*). Since nitrogen significantly increased by 80% compared to plants grown in sand media (100% sand) and 50% compared to basalt media (100% basalt). At the same time, there were insignificant differences among plants grown in media of sand 75: basalt 25%, sand 50: basalt 50% and basalt 75: sand 25% regarding nitrogen concentration.

Table 5: Effect of basalt and sand media on Basil plants (*Ocimum basilicum*) and nutrients content

Treatments	N%	P%	K%	Zn ppm	Mn ppm	Fe ppm
S 100%	0.84c	0.29d	1.02c	11.02c	14.02b	11.16c
S75, B25%	1.52a	0.76a	1.84a	25.23a	35.16a	38.13a
S50, B50%	1.11a	0.70b	1.81a	24.85a	34.10a	37.01a
B75, S25%	1.10a	0.71b	1.82a	25.01a	34.72a	36.82a
B 100%	1.01b	0.52c	1.35b	18.06b	28.18b	32.35b

Means with the same letter in a column are insignificantly different by DMRT 5%

Also, phosphorus concentration was affected as a result of sand 75: basalt 25% media application since a significant increase in phosphorus concentration (162%) was recorded when plants grown in sand media (100% sand) and 46% compared to basalt media (100% basalt). Moreover, potassium concentration significantly boosted by 80% with sand 75: basalt 25% media in contrast to sand media (100% sand) and 36% compared to basalt media (100% basalt). It was notable that insignificant differences were recorded between three media of sand 75: basalt 25%, sand 50: basalt 50% and basalt75: sand 25% concerning potassium concentration. Regarding the micro-elements content, as shown in Table (5), zinc concentration was significantly elevated by 128% in plants tissue grown in sand 75: basalt 25% media compared to plants grown in sand media (100% sand) and 28% compared to basalt media (100% basalt). Concerning the manganese and iron, the same way was followed since sand 75: basalt 25% media recorded the highest amount of manganese and iron concentrations by 150 and 241%, respectively compared to 100% sand media (25%) and 100% basalt media (17%), respectively. It is worth to mention that insignificant variations were recorded between three media of sand 75: basalt 25%, sand 50: basalt 50% and basalt75: sand 25% concerning nitrogen, potassium, zinc, manganese, and iron concentrations.

3.4.2. Chemicals constituents

Giving attention to data in Table (6), it was clear that a mixture of sand and basalt (sand 75: basalt 25%) resulted in significant increases in biochemical compounds within plants tissue represented in total chlorophylls by 211% compared to plants grown in sand media (100% sand) and 118% contrast to plants grown in basalt media (100% basalt). Also, it was remarkable that there were insignificant differences between sand 75: basalt 25% and sand 50: basalt 50 media concerning the total chlorophylls. Considerable increases were also recorded with total carbohydrates within plants grown in sand 75: basalt 25% media; the augmentation was 163% balanced with sand media (100% sand) and 71% balanced to basalt media (100% basalt). Moreover, total phenol compounds were significantly elevated within plants tissue grown in sand 75: basalt 25% media by 26% judged against sand media (100% sand) and 58% judged against basalt media (100% basalt). As for tannins, there were insignificant escalations between plant tissues grown in the three media of sand 75: basalt 25%, sand 50: basalt 50% and basalt75: sand 25%. In the meantime, the previous three media recorded significant increases over both sand media (100% sand) and basalt media (100% basalt).

Table 6: Effect of basalt and sand media on chemical constituents of Basil plants (*Ocimum basilicum*)

Treatments	Total Chl. mg\g F.W	Total carbohydrates %	Total phenols (µg CE/g)	Total Tannin (µg CE/g)	Total Flavonoids (µg CE/g)
S 100%	7.12c	5.41b	30.03b	9.4b	12.06c
S75,B25%	22.17a	14.28a	38.10a	16.5a	28.14a
S50,B50%	19.06a	11.60a	37.04a	16.3a	26.69a
B75,S25%	16.24b	11.02a	30.21b	16.5a	22.15b
B 100%	10.13c	8.31b	24.11c	10.3b	16.27c

Means with the same letter in a column are insignificantly different by DMRT 5%

In addition, tissues analysis of plants grown in sand 75: basalt 25% media found that total flavonoids significantly increased by 133% contrast to sand media (100% sand) and 72% contrast to basalt media (100% basalt); however, insignificant variations were recorded between sand 75: basalt 25% and sand 50: basalt 50% pertaining to total flavonoids.

The positive effect of combined basalt and sand over pure media, whether sand 100% or basalt 100% in both morphological and biochemical ingredients, may be due to the availability of some released elements as shown in tables (2 and 3) represented in macro elements N, K, Ca, Mg and micro-elements Cu, Fe, Mn, Zn. Although it exists in trace amounts but are considered an essential elements (Tisdale *et al.,* 1985) besides some beneficial elements represented in Na and Al (Zhu *et al.* 2009), which together led to increase plant growth parameters, this raised spring from their beneficial effects on seedlings represented in nutrient availability and improvement of soil physical and chemical properties resulted in more water retention simultaneously its insightful effect on the physiological processes. It's worth mentioning that, even existence of declared elements but not in enough amounts required for plant growth and development (complete life cycle), since essential elements conditions required for plant are not available (Tisdale *et al.,* 1985). As a result, the growth of seedlings was temporary, but as a future point, basalt could mix with some other soil amendments (zeolite, organic matter, biochar vermicompost, etc.) and could be applied to soil after a simple size reduction through mechanical processes, serving as alternative nutrient sources in agriculture in order to provide all essential and beneficial elements for plant growth and development in adequate quantities consequently apply in desert reclamation plan. The aforementioned data are in trustworthiness with Abdelwahab *et al.* (2021) on barley (*Hordeum vulgare)* L, Ayman *et al.* (2020) on sandy soil and Hassan and Mahmoud (2016) on zeolite, Mariana *et al.* (2025) on basalt, Hend *et al.* (2024) on (*Spathiphyllum wallisii*).

4. Conclusion and Recommendation

This study highlights the promising role of weathered basalt as a sustainable growth media to enhance plant performance under arid and semi-arid conditions. The incorporation of basalt into sandy soils significantly enhanced the morphological traits and biochemical properties of *Ocimum basilicum* L. (Basil), particularly when applied at a 75% sand to 25% basalt ratio. This mixture outperformed both pure sand and pure basalt in terms of branch development, leaf area, root length, and biomass accumulation. From a soil conservation perspective, basalts capacity to retain water and improve soil structure that keeping all elements available to plants was evident in the improved physiological performance of Basil plants. The enhanced water-holding capacity of basalt-amended soils directly contributed to improved growth metrics, demonstrating basalts value in supporting sustainable agriculture in water-scarce regions. The weathering products and the associated secondary minerals that filling amygdules and voids of the basalt media ensures a sustained release of essential ions, enhancing soil fertility and supporting plant nutrition. Meanwhile, biochemical assessments revealed that basalt-enriched media led to increased concentrations of essential nutrients such as phosphorus, potassium, zinc, manganese, and iron, indicating enhanced nutrient availability and uptake by plant roots.

The results confirmed that the 75:25 sand-to-basalt mixture is recommended as the most effective medium to enhance Basil plants growth and biochemical performance under arid conditions. Fine grinding of basalt to nano scale is advised to increase its reactivity and effectiveness. Future studies should utilize sand from challenging desert environments with varying textures (fine, coarse, and local sands) to simulate field conditions. Expanding trials to other crops and conducting field-based studies will further validate the potential of basalt as a sustainable soil amendment in arid and semi-arid regions.

5. References

Abdel Wahab M. Mahmoud and Hend M. Swaefy, 2020. Comparison between Commercial and Nano NPK in Presence of Nano Zeolite on Sage Plant Yield and its Components under Water Stress. Agriculture (Pol'nohospodárstvo), 66(1):24-39. https://doi.org/10.2478/agri-2020-0003

Abdel Wahab M. Mahmoud, Hassan M. Rashad, Sanaa E. A. Esmail, Hameed Alsamadany and Emad A. Abdeldaym, 2023. Application of Silicon, Zinc, and Zeolite Nanoparticles- A Tool to Enhance Drought Stress Tolerance in Coriander Plants for Better Growth Performance and Productivity. Plants 2023, 12(15), 2838. https://doi.org/10.3390/plants12152838

Abdel Wahab M. Mahmoud, A.Z.A Hassan, S. Abdel Mottaleb, M. M. Rowezak and A.M. Salama, 2021. The role of nano-silicon and other soil conditioners in improving physiology and yield of drought stressed barley crop. Agriculture (Poľnohospodárstvo), 67(3): 124 – 143. https://doi.org/10.2478/agri-2021-0012

Ahmed, Z.A.H., M.M. Abdel Wahab, M.T. Gamal and S. Gehan, 2020. Rice husk derived biochar as smart material loading nano nutrients and microorganisms, Bulgarian Journal of Agricultural Science, 26 (2): 309–322

Anda, M., J. Shamshuddin, and C.I. Fauziah, 2015. Improving chemical properties of a highly weathered soil using finely ground basalt rocks. Catena, 124: 147-161.

Ayman, A., A.Z.A. Hassan, Rania A. El-bialy, and M.M. Abdel Wahab, 2020. Fate of Nano Soil Particles and Their Influence on Geotechnical and Physiochemical Properties of Sandy Soil. American Journal of Nanomaterials, 8(1): 48-57

Chahardehi, A.M., D.S. Ibrahim, and F. Sulaiman, 2009. Antioxidant activity and total phenolic content of some medicinal plants in Urticaceae family. Journal of Applied Biological Sciences, 3(2): 27–31.

Conoco, 1987. Geological map of Egypt of scale: 1:500,000(1987)

Darmawan, D., 2020. Effect of basalt rock application on soil fertility and plant growth. IOP Conference Series: Earth and Environmental Science, 484: 012046.

El-Alfy, Z., and M El-Sharkawi, 2015. [Conference presentation]. 53rd Annual Scientific Meeting, Egyptian Geological Society, Cairo, Egypt, 29–30.

Hassan, A.Z.A. and A.M. Mahmoud, 2016. Strategy for Boosting Rock Phosphate Efficiency and Conversion into Nano Zeolite. American Journal of Nanomaterials, 4(2): 27-38. DOI:10.12691/ajn-4-2-1

Hassan, A.Z.A., and A.W.M. Mahmoud, 2015. Hydrothermal synthesis of nano crystals (AM) zeolite using variable temperature programs. J. Nanomater. Mol. Nanotechnol., 4. doi:10.4172/2324-8777.1000168 732 37.

Helrich, K., 1990. Official Methods of Analysis, 15th ed.; Association of Official Agricultural Chemist: Arlington, VA, USA, *1*(673): 749 750 42.

Hend M. S. Ibrahim, A.M. Mahmoud, M. M. Soliman, and S. Abdel Mottaleb, 2024. Assessing biochar, clinoptilolite zeolite and zeo-char loaded nano-nitrogen for boosting growth performance and biochemical ingredients of peace lily (*Spathiphyllum wallisii*) plant under water shortage. BMC Plant Biology, 24:924. https://doi.org/10.1186/s12870-024-05592-6

Jackson, M.L. 1973. Soil Chemical Analysis. New Delhi: Printice-Hall of India. Privat Limited, New Delhi. Text book., 381:144-197.

Li, J., Y. Li, and Q. Meng, 2010. Removal of nitrate by zero-valent iron and pillared bentonite. Journal of Hazardous Materials, 174(1–3), 188 – 193. DOI:10.1016/j.jhazmat.2009.09.035.

Manning, D. A. 2010. Mineral sources of potassium for plant nutrition. A review. Agronomy for sustainable development, 30: 281-294. Agriculture (Poľnohospodárstvo), 66(1): 24 – 39.

Mariana, de C.R., R.M. Aline, S.A. Rodrigo, G.F.L. Luís, S.P. Hamilton, Sh.G. Fernando, C.M.T.F. Marcelo, H.A.–J. Cassio, D.J. Arun, F.C. Gian, G. Antonio and A.R.N. Thiago, 2025. Basalt rock dust as a soil remineralizer in upland rice grown in tropical soils: residual effects on soil fertility, Si availability, and leaf anatomy. Journal of Cleaner Production, 520.

Meda, A., C.E. Lamien, M. Romito, J. Millogo, and O.G. Nacoulma, 2005. Determination of the total phenolic, flavonoid and proline contents in Burkina Fasan honey, as well as their radical scavenging activity. Food Chemistry, 91: 571-577.

Moran, R., 1982. Formulae for determination of chlorophyllous pigments extracted with N, N-dimethylformamide. Plant Physiology, *69*(6): 1376-1381.

Pierce, J.W., and F.R. Siegel, 1969. Quantification in clay mineral studies of sediments and sedimentary rocks. Journal of Sedimentary Research, 39(1).

Schultz, L.G., 1964. Quantitative interpretation of mineralogical composition from X-ray and chemical data for the Pierre Shale (No. 391-C).

Sen, T.K. and D. Gomez, 2011. Adsorption of zinc (Zn2+) from aqueous solution on natural bentonite. Desalination, 267(2 –3), 286 –294. DOI:10.1016/j.desal.2010.09.041.

Shallaly, N.A., 1998. Geology and tectonic setting of the basalts and associated rocks in El Fayoum - 6th. October city area, Western Desert, Egypt. M.Sc. Thesis, Cairo University, 126.

Singleton, V.L. and J.A. Rossi, 1965. Colorimetry of total phenolics with phosphmolybdic phosphotungstic acid reagents. Am. J. Enol. Vitic. 16: 144-158.

Tisdale, S. L., W. L. Nelson, J. D. Beaton and J. L. Havlin, 1985. Soil and fertilizer potassium. Soil fertility and fertilizers, 4, 249-291.

Xie, Y., B. Li, G. Tao, Q. Zhang and C. Zhang, 2012. Effects of nano-silicon dioxide on photosynthetic fluorescence characteristics of Indocalamus barbatus McClure. Journal of Nanjing Forestry University (Natural Sciences Edition), 36(2): 59-63.

Zhu, Y.G., E.A.H. Pilon-Smits, F.J. Zhao, P. N. Williams, A. A. Meharg, 2009. Selenium in higher plants: understanding mechanisms for biofortification and phytoremediation. Trends in Plant Science, 14(8) 436-442. DOI: 10.1016/j.tplants.2009.06.006