Arab International Journal of Environmental Sciences (AIJES) Vol. 2, No. 1 (August), 2023, PP. 1-22

Ecological studies of *Helianthemum* plants associated with Desert Truffles in the Mediterranean North Coastal area, Egypt

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Abstract:

The present study reports on the ecology of desert truffles and their host *Helianthemum* plants collected from the Mediterranean North Coastal area. It focused on identification of desert truffle species, determination of their geographical distribution, and description of vegetation, edaphic and geomorphological characteristics of their natural habitat. The present study evaluates the effect of environmental variables on the diversity of vegetation and ecological characteristics. Truffles and their host plants were collected from six different locations in North Coast area resulted in the identification of two species of the family Pezizaceae: *Terfezia claveryi* and *Tirmania nivea*. These hypogeous ascomycetes live in mycorrhizal association with *Helianthemum aegyptiacum* and *Helianthemum lippii* belongs to family Cistaceae. Desert truffles grow in heterogeneous soils of sandy texture, slightly alkaline (7.00 ± 8.01), slightly salinity (38.70 ± 75.70), conductivity (0.31 ± 0.47), moderately Bicarbonate contents (4.1 ± 5.3), moderately Sulphates contents (32.8 ± 59.80), moderately Chlorides contents (22.87 ± 33.00), moderately calcareous (25.30 ± 36.70%), with moderately percentage of organic matter (1.4 ± 10.3), and little contents of Magnesium, Sodium and Potassium. Desert truffle growth is strongly associated with high rainfall. The geomorphological zones which accumulate rainwater promote the growth of both truffles and its host plant.

Key words: Ecology, Desert truffles, Host *Helianthemum* plants, Mediterranean North Coastal area, Egypt.

I. Introduction

Helianthemum aegyptiacum and *Helianthemum lippii* grow in arid or semi-arid climates when water is available during the rainy season. *H. aegyptiacum* and *H. lippii* grow on very high density but sandy soils with high gypsum slope landscapes. *H. aegyptiacum* and *H. lippii* can penetrate hard soils but grow in less restrictive soils **(Escudero *et al*., 1999)**.

Helianthemum aegyptiacum and *Helianthemum lippii* grow in warm summer and cold autumn in suitable soil conditions and a climate and weather fluctuations, rainfall and moisture, that as host plants of truffles. The truffle–host *Helianthemum* spp symbiosis and associated carbohydrate metabolism, however, complicate tracking climate responses; truffle must compete with *Helianthemum* spp the host plant's water and carbon demands. Truffles are hypogeous fruiting body or belowground in ectomycorrhizal with host plant *Helianthemum* spp **(Büntgen *et al*., 2011)**.

Helianthemum aegyptiacum and *Helianthemum lippii* are small shrubs that grow at low elevation on desert regions as in the Mediterranean Basin. Despite the ecological importance of the Cistaceae in the Mediterranean Basin very few studies have been carried out on the reproductive biology of this family, and partial studies have been carried out on the *H. aegyptiacum* and *H. lippii* (**Escudero *et al*., 1999**).

Helianthemum aegyptiacum and *Helianthemum lippii* are annual and perennial vascular hosts have been suggested for these truffles on the basis of field observations. *Terfezia* and *Tirmania* spp were confirmed to form special types of mycorrhizae with *Helianthemum ledifolium* and *H. salicifolium* (**Hussain and Al-Ruqaie, 1999).**

Helianthemum aegyptiacum and *Helianthemum lippii* host plants have been experimentally confirmed as mycorrhiza- formers with desert truffles. These truffles appear after 3-4 months of adequate autumn and winter rainfall. This is the same time period required for the annual host plants to complete their life cycle. Many individual host plants combine to support the production of one fruiting-body. Sometimes in some cases, many ascomata of forest truffles are produced annually in association with a single host shrub *H. aegyptiacum* and *H. lippii* over many decades (**Awameh, 1981**).

The desert truffles of the genera *Terfezia* spp and *Tirmania* spp are hypogeal ascomycete that naturally inhibits the Mediterranean region countries (**Trappe, 1979; Kovács and Trappe, 2014**), in the form of mycorrhizal associations on the roots of different species of the genus *Helianthemum* (**Dexheimer *et al*., 1985; Gücin and Dülger, 1997**).

These truffles grow in various types of soil of different characteristics, particularly in association with plant species which adapted with their soil as the family Cistaceae, mainly the genus *Helianthemum* **(Alsheikh and Trappe, 1983; Alsheikh, 1985; Kagan-Zur *et al*., 1994, 1999; Slama *et al*., 2006; Kovács *et al*., 2007).**

Among the mycorrhizal desert truffles fungi, the well-known edible ones are the white color and dark brown color belonging to the genus *Terfezia* (**Al-Rahmah, 2001)**, that usually inhibits the annual or perennial herbaceous *Helianthemum* spp (**Kagan-Zur *et al*., 1994; Morte *et al*., 1994; Khabar *et al*., 1999)**

As well as, several species of the plants are *Helianthemum aegyptiacum*, *H. lipii. H. tuberaria*, *H. guttatum* (L. Foureau), *H. salicifolium* (L). Mill., *H. ledifolium* (L). Mill., *H. salicifolium*, *H. almeriense*, and *H. sessiliflorum*, were reported as the host of desert truffles (**Morte and Honrubia, 1997**).

The aim of this study was to provide information about species ecology including the geographical distribution, habitat description, species occurrence frequency, main edaphic and climatic factors controlling their distribution and occurrence in the Mediterranean North Coastal area.

II. Material and Methods

Study Area

The study area is located in northern part of Western Desert, Egypt, between latitude 30. 1519 ° to 31.2116 ° north and longitude 27.1415 ° to 30.2613° east; with altitude of 5 to 121 meter above mean sea level. The study was conducted during January to March of 2020 to 2022.

The study area is generally characterized by a mild semi-arid climate with relatively high temperatures in summer during the months of June, July and August, and relatively low temperatures during the months of December, January and February. Maximum temperatures in study area range between 18.5^{o}C and 29.5^{o}C. The average of minimum temperatures ranged between 9.5^{o}C and 22.5^{o}C (**Cos *et al*., 2022)**.

The relative humidity is high in July (73%) and moderate in March (63%). Evaporation intensity varies from 162 mm in summer and 28 mm in winter. Air temperature is relatively mild in summer (26.8 °c) and low in winter (12.8 °c) (**EL-Sabri *et al*., 2011**).

The study area is an increase in winter precipitation of 10% and a decrease in summer precipitation. The increase may be of up to 10% in winter precipitation and a decrease in summer precipitation (**Chebli *et al*., 2023**).

Sampling sites selection

The present study is represented by six sampling sites that cover different habitats of study area for the collection of Desert Truffles and their host *Helianthemum* plants. The selection of study area ensures sampling of wide range of vegetation variation. The rope was determined on the selected section of transects which include vegetation survey, along the stand which divided into five quadrats, 5 x 5 m; twenty five meter, the rope was alternated on the sides along the stand. Desert truffles are found around plants of the *Helianthemum* genus by observing the fissures and ridges formed by the ascocarps (**Alsheikh, 1985**).

Soil sampling and analysis

At each *Helianthemum* plant habitat, three soil samples were collected at depth of 0–20 cm, for determination of physical and chemical characteristics. Most of the soil samples were collected from spots very close to truffles and *Helianthemum* plant. Soil samples are placed in locked plastic bags, and then these samples have been spread on paper for drying in air. After mixed it, sift it with a sieve with a 2 mm to bring out debris and gravels, lastly mobilized them in plastic bags in order to identify its chemical and physical properties through analysis.

The analysis of soil parameters were particle size, determined by Robison's pipette method and pH was determined with a pH meter with glass electrode on a soil extract (1:5) but electrical conductivity was measured with conductivity meter on a soil extract (1:5) at 25°C (**Allen *et al*., 1986**). Sieves method has used for determination of soil texture (**Piper, 1950**). Also, the titration method against 1.0 N HCl was being conducted for determination $CaCO_3$ (**Allen *et al*., 1986**) and too organic matter (**Black, 1965**). Soil extract (1:5) were set for assign of calcium, chlorides, bicarbonates, sulphates and magnesium (**Allen *et al*., 1986**).

Data Analysis

The data of soil and vegetation were treatment statistically by one-way ANOVA, and estimation of the relationships among the spatial variations with the soil variables by **SPSS (2006**).

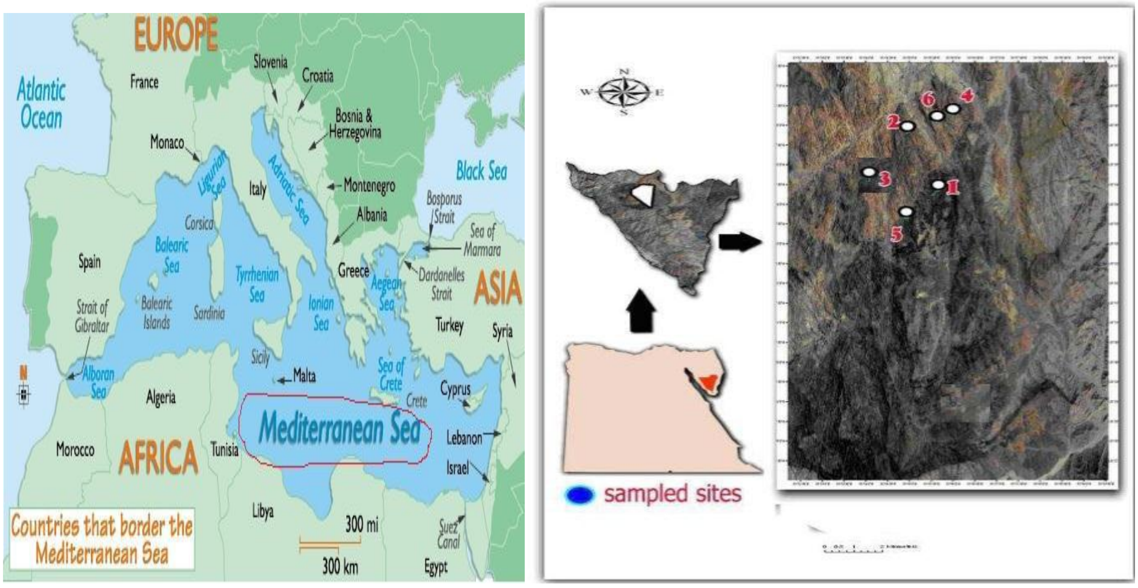

Fig. 1. Map of study area, habitats of truffles and *Helianthemum* host plants on the Mediterranean North Coastal area, Egypt.

III. Result

Ecology of desert truffles and *Helianthemum* host plants

Spatial distribution of plant species and communities over a small geographic area in desert ecosystems is related to heterogeneous topography and landform pattern. The heterogeneity of local topography, edaphic factors, microclimatic conditions lead to variation of the distribution behavior of the plant associations of the study habitats. In terms of classification, the vegetation that characterizes the study area can be divided into vegetation groups.

The importance of the study area from a phyto-geographical point of view may be due to its position on Mediterranean North Coastal area. These reflect that Mediterranean North

Coastal area is one of the richest and highly diverse in its flora. It's clear now that understanding organisms and their distributions within ecosystem or landscapes is the first step in any applied or basic ecological research. Such information is critical for explaining dynamic of the system. The convention on biodiversity makes clear that access to good information about biological diversity is Key to mobilizing resources.

Soil characteristics profoundly influence growth behavior, chemical composition and distribution pattern of plants. Physical and chemical properties of soil are changed with climate and type of vegetation which develops on it. The vegetation plays remarkable role in the formation of soil in which plants are fixed and from which they obtained their water and nutrients.

Figure 2. General view of the collection points of desert truffles and their host *Helianthemum* plants.

Vegetation and edaphic parameters

Results showed that habitat 1(at elevation 5- 6 m a.s.l.), habitat 5 (at elevation 31- 32 m a.s.l.) and habitat 6 (at elevation 120- 121 m a.s.l.) are located at North East (NE) aspect. Also the habitat 2 (at elevation 6- 7 m a.s.l.), habitat 3(at elevation 7- 9 m a.s.l.) and habitat 4(at elevation 25- 27 m a.s.l.) are located at North West (NW) aspect (Table 1).

In order to assess the correlates between community structure and the environmental factors which might affect the community, there is variation in the vegetation characteristics in the six studied habitats on Mediterranean North Coastal area.

The highest density, frequency, abundance and important value index (I.V.) were recorded at habitat 3 (at elevation 7- 9 m a.s.l.), while the lowest density, frequency, abundance and important value index (I.V.) were recorded at habitat 2 (at elevation 6- 7 m a.s.l.). Generally, this variation may come from the variation in individual species numbers and the way that species was distribute within the studied habitats on Mediterranean North Coastal area.

The results showed that *Helianthemum aegyptiacum* is the major plant community in the studied habitat 2 (at elevation 6- 7 m a.s.l.) and habitat 3 (at elevation 7- 9 m a.s.l.). *Artemisia monosperma* is the major plant community in the studied habitat 1(at elevation 5- 6 m a.s.l.). *Cistus monspeliensis* is the major plant community in the habitat 4 (at elevation 25- 27 m a.s.l.); *Plantago albicans* is the major plant community in the habitat 5 (at elevation 31- 32 m a.s.l.). *Globularia Arabica* is the major plant community in the studied stands of habitat 6 (at elevation 120- 121 m a.s.l.).

The highest number of families (19) was recorded in habitat 2 at elevation rank of 6- 7 m a.s.l., while the lowest number of families (5) found in habitat 3 at elevation of 7- 9 m. (a.s.l.). Species number gives an indication of the diversity (or richness) of any community. Habitat 2 (at elevation rank of 6- 7 m a.s.l.) recorded the highest species richness (58 species), while habitat 3 (at elevation 7- 9 m a.s.l.) showed the lowest species richness (12 species).

Result of soil analysis reveal great variation in the value of average physical and chemical parameters of soil collected from six habitats on Mediterranean North Coastal area. habitat 1 at elevation 5- 6 m (a.s.l.) had the highest value of sand, Organic matter, Cl^- and Mg^{++} and the lowest value of silt $K^+$and Ca^{++} (Table 1). Habitat 2 at elevation 6- 7 m (a.s.l.) had the highest value of pH, HCO_3^- and $CaCO_3$ and the lowest value of clay, TDS, Organic matter.

Habitat 3 at elevation 7- 9 m (a.s.l.) had the highest value of Water content, TDS and K^+ and the lowest value of Silt, EC, HCO_3^- and Mg^{++} . Habitat 4 at elevation 25- 27 m (a.s.l.) had the highest value of Ca^{++} and Na^+ and the lowest value of SO_4^{--}. Habitat 5 at elevation 31- 32 m (a.s.l.) had the highest value of sand and the lowest value of pH, Cl^- and Ca^{++}. Habitat 6 at elevation 120- 121 m (a.s.l.) had the highest value of EC and SO_4^{--} and the lowest value of Water content, Ca^{++} and Na^+.

Statistical analysis of soil results indicated significant differences among the different locations regarding in soil chemical properties (such as pH, TDS, EC, HCO_3^-, SO_4^{--}, Cl^-, $CaCO_3$, organic matter, Ca^{++}, Mg^{++}, Na^+ and K^+). Meanwhile, the results showed non-significant differences among in soil physical properties (soil content of moisture, sand, clay, silt) among the six habitats in study area (Table 1).

Table 1. Physical and chemical properties of soil collected from six habitats belonging to different altitude ranks in study area.

	Variable	**1**	**2**	**3**	**4**	**5**	**6**
		5- 6 m (a.s.l.)	**6- 7 m (a.s.l.)**	**7- 9 m (a.s.l.)**	**25- 27 m (a.s.l.)**	**31- 32 m (a.s.l.)**	**120- 121 m (a.s.l.)**
		Vegetation characteristics					
Vegetation analysis	Density	3.03	3.34	8.32	4.63	6.54	4.52
	Frequency	41.14	40	48.15	40.95	42.35	46.89
	Abundance	3.63	1.74	4.47	3.67	3.07	3.75
	I.V.I.	25.71	20.68	50	28.57	35.29	33.33
	No. of families	13	19	5	9	8	10
	Sp. Richness	35	58	12	21	17	27
	Dominant community	*Artemisia monosperma*	*Helianthemum aegyptiacum*	*Helianthemum aegyptiacum*	*Cistus monspeliensis*	*Plantago albicans*	*Globularia arabica*
Environmental Factors - Soil characteristics							
Soil chemical properties	pH	7.8	8.1	7.8	7.4	7.6	7.9
	TDS (ppm)	58	38.7	75.00	46	71.7	62
	EC (µS/cm)	0.14	0.34	0.13	0.42	0.39	0.45
	HCO_3^-(mg/kg)	5.10	5.70	4.10	4.70	4.70	4.90
	SO_4^{--} (mg/kg)	45.08	41.3	34.97	32.8	38.3	48.2
	Cl^- (mg/kg)	32.87	24.77	27.33	32.17	23.97	29.83
	$CaCO_3$ %	23.3	37.7	34.7	32	26.7	30.3
	Organic matter %	1.1	0.3	0.3	0.6	1.0	0.8
	Ca^{++} (mg/kg)	1	1.2	3.77	6.35	1.0	1.0
	Mg^{++} (mg/kg)	9.00	8.8	3.3	3.8	5.8	5.5
	Na^+(ppm)	8.4	8.4	8.9	10	9.1	5
	K^+(ppm)	9.4	12.3	31.7	15.6	15.6	17.7
Topography	altitude Mean (m. a.s.l)	±5	±7	±9	±27	±32	±121
	Aspect	NE	NW	NW	NW	NE	NE

Results showed that the studied habitats on Mediterranean North Coastal area are located at North East (50 %), North West (50 %), showed in table 2.

Table 2. Variation in soil properties among different habitats aspects in study area.

	NE	**NW**
Soil physical properities		
Water content %	2.03	1.02
Sand%	71.4	72.14
Silt%	18.1	17.7
clay%	12.4	10.5
Soil chemical properities		
pH	7.8	7.8
TDS (ppm)	63.9	53.2
EC (µS/cm)	0.3	0.29
HCO_3^- (mg/kg)	4.9	4.8
SO_4^{--} (mg/kg)	43.9	36.4
Cl^- (mg/kg)	28.9	28.1
$CaCO_3$ %	26.8	34.8
Organic matter %	0.9	0.4
Ca^{++} (mg/kg)	1.2	1.9
Mg^{++} (mg/kg)	6.7	5.3
Na^+ (ppm)	7.5	9.1
K^+ (ppm)	14.2	19.8

Results also showed that topography is a principal controlling factor in vegetation growth and the type of soils. Elevation and aspect are the main topographic factors that control the distribution and patterns of vegetation in studied areas. Aspect along with elevation in many respects determines the microclimate and thus large-scale spatial distribution and patterns of vegetation (Fig. 3).

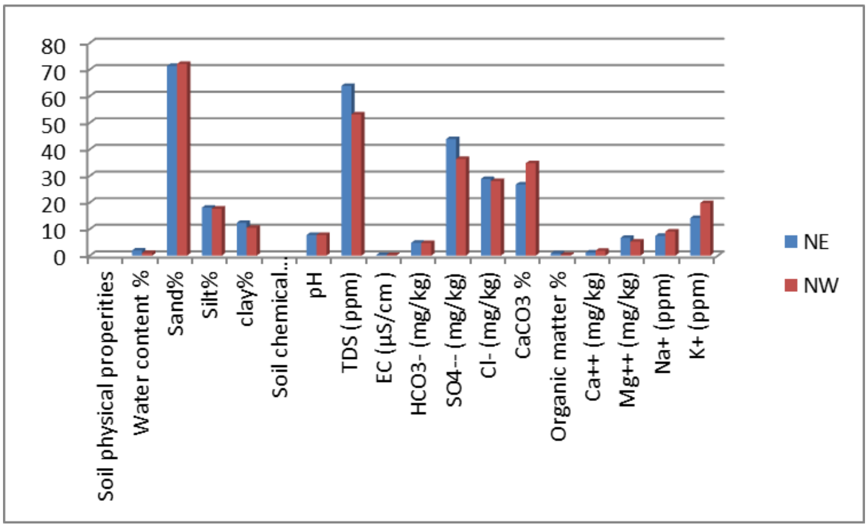

Figure 3. Physical and chemical properties of soil belonging to different aspect.

Soil sample collected from the different six habitats in study area on the Mediterranean North Coastal area, showed great variation in texture, the most frequent types were sandy and sandy loam. Results clearly showed that the soil texture of study area ranged between 31.25% in two habitats to 68.75% in sandy loam in four habitats showed in figure 4.

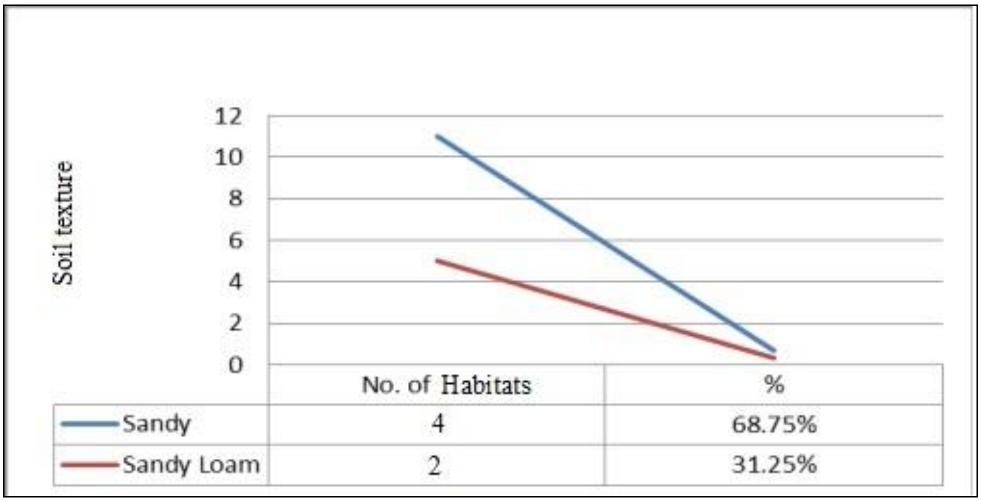

Figure 4. Soil texture type percentages recorded in studied habitats of study area.

Canonical Correspondence Analysis (CCA)

Directly extract the variation is explainable by the measured environmental variables (Table 3, Fig. 5). This pattern also appears in the summary table, where the first axis explains more than the second, third and fourth axes do together.

Table 3. Enviromental parameters used in the CCA and their eigenvalues.

Axes	1	2	3	4	Total inertia
Eigenvalues :	0.725	0.700	0.647	0.552	6.556
Species-environment correlations:	0.975	0.999	0.996	0.992	
Cumulative percentage variance					
of species data :	11.1	21.7	31.6	40.0	
of species-environment relation:	13.9	27.4	39.8	50.4	
Sum of all eigenvalues					6.556
Sum of all canonical eigenvalues					5.208

It will be noticed (Table 3) that the percentage variance explained by the first axis about 11.1 %, and also that the species-environment correlation is only slightly higher. This suggests that the measured environmental variables are those responsible for species composition variation.

CCA ordination diagram of six different habitats data (Fig. 5) tended to explanation of the most influential environmental factors on vegetation, depending on the length of the arrow. The Length of arrow is due to the strength effect of environmental variables on vegetation. Anion magnesium is the most influential, followed by Potassium, PH gradients, Organic matter, electrical conductively, bicarbonate, Calcium Carbonate, Sodium, chloride, total dissolved salts, calcium, and sulphate.

The number of axis scores calculated for a species-environmental variables biplot is restricted in a CCA, by default, to two. This is why the explained variability for the third and fourth axis is shown as 0. It was observed that there are correlations between different environmental variables positive as well as negatively.

It was showed that the first axis (Horizontal) is positively correlated with the increasing concentration of cations Calcium, and with the increasing pH gradients; and negatively correlated with the increasing concentration of cation (Potassium, Sodium), with the increasing concentration of Calcium Carbonate, with increasing concentration of total dissolved salts, with electrical conductively, and as well with soil organic matter gradient;

with the increasing concentration of bicarbonate with the increasing concentration of chloride, with the increasing concentration of anion Sulphate, with the increasing cation Magnesium.

The positions of arrows for environmental variables suggested that there is a group of variables that are mutually highly positively correlated with (Ca^{++} , pH) and negatively correlated with others (Cl^-, $CaCO_3$, Na^+, K^+, So_4^{--}, Mg^{++} TDS, Ec, and organic matter). A closer inspection of the correlated matrix in the CANOCO Log View shows that variables are indeed correlated, but in some cases the correlation is not very great. The correlation matrix confirms that the correlation of all the measured variables with the second axis (Vertical) is rather weak (Fig. 5).

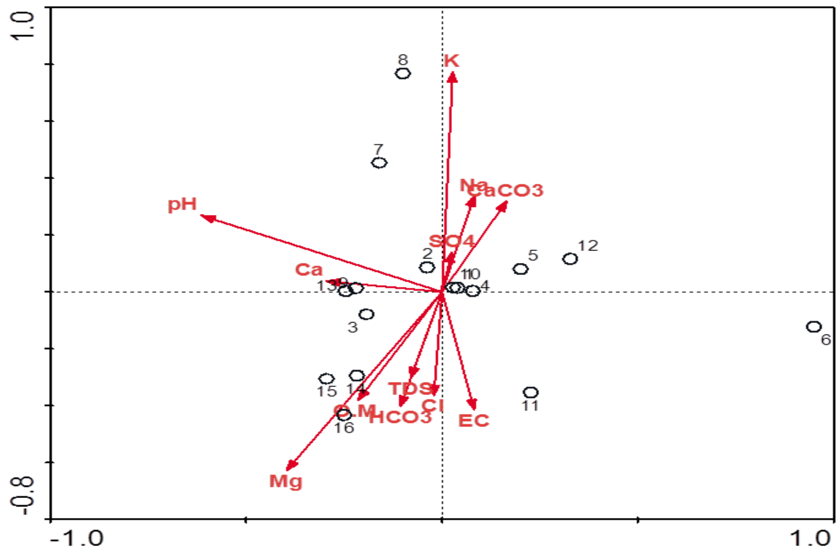

Figure 5. The samples-enviromental variables biplots of CCA with the environmental variables selected by the forward selection procedure.

Detrended Correspondence Analysis (DCA)

Detrended Correspondence Analysis (DCA) was used to detect the length of the environmental gradient. After DCA, Canonical Correspondence Analysis (CCA) was applied because the data set was relatively heterogeneous and therefore, the length of ordination axes in DCA was relatively long.

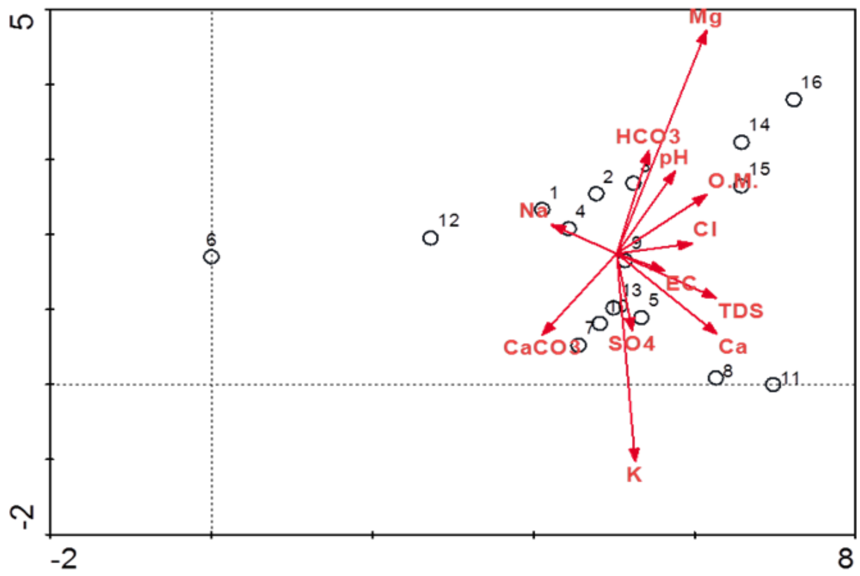

Figure 6. Environmental variables- sample and environmental variables biplot of the DCA.

DCA, first extract the axes of maximum variation in species composition, and only then fit the environmental variables, now we directly extract the variation that is explainable by the measured environmental variables.

The percentage variance of the species–environment relationship values represents percentages of this value. The number of axis scores calculated for a species– environmental variable biplot is restricted in a DCA, by default, to two. This is why the explained variability for the third and fourth axis is shown as 0. It was observed that there are correlations between different environmental variables positive as well as negatively (Fig. 6).

It was showed that pH value correlated positively with cations Calcium, while showed negative correlated with cation (Potassium, Sodium, Magnesium) and anion Sulphate.

IV. Discussion

The geographical distribution of desert truffles is limited to arid and semiarid lands, mostly in countries around the Mediterranean Sea such as central and southern Spain, Portugal, Italy, France, Hungary, Turkey, extending from Morocco to Egypt, the Arabian Peninsula, Iran, Iraq, Syria and Kuwait, also some desert truffle species have been found in South Africa (**Marasas and Trappe, 1973**).

Generally, the regions where desert truffles grow have an annual rainfall ranging from 50 to 380 mm. The truffle season produces good yields if rainfall ranges from 70 to 120 mm in North African countries (**Morte *et al*., 2008**), and this agree with our results, but in countries of southern Europe rainfall ranges from 100 to 350 mm, this disagree with the present results.

Most desert truffles establish mycorrhizal symbiosis with species of the *Helianthemum* genus of the Cistaceae family. Thus, the distribution and ecology of desert truffles are related to those of their host plants (**Morte *et al*., 2008**), this agree with the present results.

Terfezia claveryi is widely distributed around the Mediterranean region, from countries of North Africa to Asia. Truffles found always in soils that are basic, carbonated and clayey, or in sandy soils on the coast, and associated with species of the genus *Helianthemum* (**Morte *et al*., 2008**), this agree with the present results.

Mediterranean countries and Southern European have a high diversity of Cistaceae species associated with a large number of mycorrhizal species (**Bordallo *et al*., 2013**). Most geographic and evolutionary studies of Cistercaceae colonization in the Mediterranean (**Civeyrel *et al*., 2011**) have addressed possible interactions between the mycorrhizal characteristics of these Cistercaceae species and their distribution patterns. A high mycorrhizal dependence has been observed in some Cistaceae species (**Morte *et al*. 2010, Honrubia *et al*., 2014**), which depend on the presence of a fungal symbiotic in their root for survival.

Phylogenetic studies of mycorrhizal fungi with host plants are therefore needed and may help explain the success of new species in different Mediterranean regions. It is worth mentioning, Ascomycetes especially Tuberaceae and Pezizales were found in significant abundance in sampling from burned areas after fires in Mediterranean forests in which Pinaceae, Fagaceae and Cistaceae species are abundant (**Rincón *et al*., 2021**).

Characterization of the mycorrhiza formed by the *Helianthemum* plants with these desert truffles is extremely important to ensure high-quality mycorrhizal plants. For this reason, a morphological and molecular characterization of the desert truffle mycorrhiza was carried out (**Gutiérrez *et al.* 2003**), and characterization is also important to evaluate the permanence of the mycorrhiza in field conditions.

Desert truffles surveyed in the Northern Sahara of Algeria establish symbioses with plant roots of the family Cistaceae, especially with *Helianthemum lippii*, and this agree with the present results. Desert truffles are harvested in habitats characterized by a high density of the host plant (*Helianthemum* spp.). The genus *Helianthemum* is well known in literature for the establishment of associations with truffles in several regions in the world (**Díez *et al*., 2002; Mandeel and Al-Laith, 2007**).

The species *Helianthemum lippii* is a small plant, very branched, of stiff stems and partially lignified, that measures up to 30 cm of height in good rainfall conditions. The leaves are opposite, oblong, covered with very short hair, which gives them a whitish green color. Tiny yellow flowers of five petals, sessile as leaves, are visible in clusters (**Ozenda, 2004**).

Truffles are hypogeous fruiting bodies of the ascomycetous fungi living symbiotically with soil plant roots; truffle species have a wide range of host plant species, require a calcareous soil, and have different geographical distribution (**Trappe and Claridge, 2010).**

Truffles and their host plants have developed adaptations to take advantage of different soil types with different characteristics, especially in the species of the plant family Cistaceae, principally the genus *Helianthemum*. Most desert truffles form a symbiotic relationship with *Helianthemum* species in the Cistaceae family and fungi. Therefore the distribution and ecology of desert truffles are related to the host plants (**Khabar *et al*., 2001; Slama *et al*., 2006; Kovács *et al*., 2007**), these results agree with the present results.

The host plants of the genus *Helianthemum* are able to form ectomycorrhiza with truffles by mycorrhizal roots of different *Helianthemum* species with different *Terfezia* species (**Kovacs and Jakucs, 2001**). *Helianthemum almeriense* was able to form a sheathing ectomycorrhiza with both *T. claveryi* and *P. lefebvrei*. This is a clue the presence of endomycorrhiza or a sheath in *Helianthemum*-desert truffle mycorrhizal associations.

This support results of **Fortas and Chevalier (1992)** for *Helianthemum guttatum* and *Terfezia* and *Tirmania* species that substrate fertility affects mycorrhiza morphology, and also supports the present results.

According to **Morte *et al*. (2009)** variations in the content of carbonate and pH affect the presence of truffle species. Truffles grow in sandy structure soil with very low contents of organic matter, alkaline pH and very low levels of nitrogen and phosphorus the potassium and calcium contents were high (**Bermaki *et al*., 2017**) and this agree with the present results, and agree with **Bonifacio and Morte (2014)** where truffles appear in soils with a low organic matter and the low P availability.

Soil analysis of desert truffle revealed wide variation in soil properties (**Eswaran *et al*., 2010**) where all habitats of truffles in the Northern Sahara have soils of sandy texture, and this agree with the present results. Chemically, the habitats of desert truffles were characterized by soils having slightly alkaline pH ranging from 7.60 and 8.05 (**Baize, 2000**), and this agree with the present results.

In addition to, the soils have slightly electrical conductivity, this indicate non-saline soils, also have a high deficient in soil organic matter soils were moderately calcareous following the scale of total $CaCO_3$, and are poor in phosphorus (**Baize, 2000**), this agree with the present results.

The present results agree with (**Bradai *et al*., 2013**) where truffles as *T. claveryi* and *T. nivea* were reported occurring in semiarid and arid areas of Algeria on calcareous soils that have sandy texture and very slight organic matter values. In general, soil properties of truffles biota in Mediterranean North Coastal area are very similar to those reported in some truffle autoecological studies, whether in Northern Algerian Sahara (**Bradi *et al*., 2014**), in the North Africa (**Slama *et al*., 2006**) or in the Middle East (**Mandeel and Al-Laith, 2007**).

The present results are different from those observed in the Kalahari Desert, where the soil of truffle habitats had a low pH values ranging from 5.5 to 6.5; as well low total $CaCo_3$ content ranging between 0.3 and 3.1% (**Taylor *et al*., 1995).** This variability is probably due to influenced by local landscape type (territorial hydrologic habitat types) climate patterns (temperature precipitation seasonality) soil characteristics (soil types and growth) and host plant types **(Díez *et al*. 2002).**

The geomorphological zones of desert truffles is not random, that occur according to characterized by their ability to accumulate rainwater, which promotes the development of truffles as well as its host plant species. That occur especially in depressions and beds of temporal wadis, which the most favorable biotopes for vegetation which is among medicinal plants in the Saharan regions (**Ozenda, 2004**), this agree with the present results.

V. Conclusion

The present ecological study of desert truffles conducted for first time in Mediterranean North Coastal area has identified two species *T. claveryi* and *T. nivea*. These species living in association with *H. aegyptiacum* and *H. lippii* (Cistaceae) are few in number but have remarkable adaptations to the environment that is characterized by a severe aridity and rudimentary soil traits.

Truly ecologically harvested truffles grow in sandy moderately alkaline slightly calcareous soils that are moderately in organic matter and minerals. Climatically these truffles grow in hot and dry climates with intermittent rainfall in autumn and winter followed by periods of drought.

Acknowledgements

I would like to express my deepest sincerest gratitude and thanks to Dr. Osama Abd Ellatief, Environmental consultant at the Ministry of Environment.

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