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Truffle production in the Kingdom of Saudi Arabia – potential and limitation

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Summary

In Saudi Arabia desert truffles are much appreciated for culinary despite high prices. This is attributed to high demand throughout the year and a limited offer. So far, only naturally occurring truffles have been traded on local markets. The aim of the present investigation was to find out whether it is possible to establish and propagate truffles under semi arid conditions in Saudi Arabia using olive plants as host. The field experiment was installed at Al-Khalidiah Farm-Tebrak situated in the vicinity of Riyadh and comprised an area of 150 ha. Previously raised olive cuttings were inoculated with *Termania nivea* and *Tirmania pinoyi* and kept under controlled greenhouse conditions prior to be transplanted into the field. Although olive plants developed well, yields of truffles was very weak after four years. The incorporation of a suitable soil on separated areas modified the situation and truffles started to develop well, and up to 14 kg/ha were yielded. Unusual heavy rainfalls, however, inhibited the development of the fruit bodies of truffles resulting in a sharp decrease of the yields. Based on the promising results obtained during a four-year period, it was decided to continue to produce desert truffles taking into account the experiences gained in the past years.

1. Introduction

Truffles are rich-flavoured fruit bodies of a subterranean mushroom. They develop only in symbiosis with the root system of certain hardwood trees. Under ideal soil conditions, the roots of these trees are infected with fungal spores of spreading mycelium and the truffles start to grow.

Since time immemorial, this most precious of all edible mushrooms has exhibited a mystical aura. The mystery of its formation seemed impossible to solve and this unique treasure of nature could be reaped only after laborious searching and with great fortune. Although highly valued by gourmets, truffles remained a well-protected secret of nature.

The southern French truffle, a jewel of gastronomy since Roman times, is now almost extinct. This aromatic fungus has become so rare and so expensive that it is barely worth looking for. This lack has prompted both a minor economic eruption and a real social crisis in some parts of Europe where truffle hunting was once an important source of income and a popular pastime. Many rural people who used to collect truffles to supplement agricultural incomes are now facing a significant challenge due to the gradual extinction of wild truffles. At the turn of the century the southern plateau in France, known as „Le Causse“ was producing 500 tons of the black truffle which played a key role in the development of French cuisine and, even in 1960, eighty (80) tons were still being exported annually. During 1998-1999 the harvest for truffles had dropped to (6) tons and the truffle season produced a minuscule haul.

In contrast to the European forest truffles, the so-called desert truffles are found in arid and semi arid zones of the Mediterranean basin, in Iraq and Kuwait, the Sahara, Saudi Arabia and part of the Maghreb. For centuries, people from the Middle East have also appreciated the highly prized desert truffle. It is being recognized as beneficial for many medical problems including the treatment of gout, muscular and arthritic pains, and high cholesterol levels. With regard to their nutritional value literature reveals the following information: Of approximately 20% dry matter, 20-27% consists of proteins (of which about 85% is digestible by humans, 3-7.5% of fat (including unsaturated as well as saturated fatty acids), 7-13% of crude fibre and close to 60% of carbohydrates (ACKERMAN et al., 1975; AL-DELAIMY, 1977; AL-SHABIBI et al., 1982; SAWAYA et al., 1985; BOKHARI et al., 1989).

In Arab countries, desert truffles have long been prized for culinary. During their relative short fruiting season in years of abundance, they are marketed at prices comparable to those of meat, and indeed, served also instead of meat. In years of scarcity, they command even very high prices. According to investigations of the author at various markets in Saudi Arabia the demand for truffles exceeds by far the offer. Only in Riyadh the annual offer varies between **1-1.2 t** whereas the demand is much higher. For the whole country it is estimated to be more than **50 t per year.** Consequently, the price for one kilogram truffle remains high and may attain 200 US$ per kg.

To collect desert truffles, one needs not resort to trained dogs or pigs, as is the case with European forest truffles. The fruit bodies form close to the soil surface, and as they swell, they lift up the soil to form little cracked mounds recognizable to trained eye (AWAMEH and ALSHEIHK, 1979a). In some areas of the Arabian Gulf region, royal families claim the truffle crop during seasons of abundance and have truffle lands patrolled until most of the crop is harvested.

The objective of the present research was to investigate the possibility to produce naturally occurring truffles and to determine whether agricultural practices exert an impact on the development of desert truffles under semi-arid conditions in Saudi Arabia using *Olea europea* as host plant. In the following the term truffle is used for *Termania* spp. which is found in association with *Helianthemum* spp. in desert habitats.

2. Materials and methods

2.1. Location and conditions

The present research activities were carried out at Al-Khalidiah Farm-Tebrak situated in the vicinity of Riyadh. The soil in this farm is a sandy soil (Tab. 3) and was not considered by the author to be very suitable for truffle production. However, the owner of the farm insisted to carry out the investigations on his farm.

The climate in this area is semi-arid with a distinct moderate rainy season from January to March showing a very irregular distribution. Temperatures are highest in the dry season (June-October) and relative humidity is very low (Tab. 1).

According to taxonomic identification carried out by Dr. Giovanni Pacioni in 2004 at the Dipartimento di Scienze Ambientali, Università L´Aquila, Italy, it was confirmed that the truffles species used in the

experiment were: *Tirmania nivea* (Fig. 1 and 3) and *Tirmania pinoyi* (Fig. 2 and 4) often used under the same name of „Zubaidi“ (that is buttery) in Arab countries.

Tab. 1: Weather statistics from Al-Khalidiah Farm-Tebrak

Months	Temperature (°C)		Precipitation (mm)	Humidity (%)
	Mean daily minimum	Mean daily maximum		
June	22.8	42.1	0.0	14
July	23.4	43.0	0.0	15
August	23.3	42.2	0.0	14
September	20.2	40.5	0.0	18
October	15.3	34.8	2.5	24
November	11.0	28.4	2.9	37
December	7.7	22.5	8.0	46
January	6.5	21.5	18.0	56
February	8.5	24.4	27.0	50
March	12.5	27.7	24.4	35
April	17.1	33.3	16.0	33
May	21.0	38.7	7.3	22

Fig. 1: Naturally occuring „Zubaidi“ Truffel; *Tirmania nivea*

Fig. 2: Khanaqa's „Zubaidi“ Truffel; *Tirmania pinoyi*

The identification was carried out on the basis of morphological characteristics (see Tab. 2) and by allozyme analysis (PACIONI et al., 1997). According to Pacioni (personal communication), *Tirmania nivea* genes seem to be fixed in homozygosis, whereas *Tirmania pinoyi* shows a remarkable level of heterozygosis.

Tab. 2: Characteristics of *Tirmania nivea* and *Tirmania pinoyi*

Morphological characteristics	Tirmania nivea (Natural Zubaidi Truffel)	Tirmania pinoyi (Khanaqa's Zubaidi Truffel)
Asci	Spontaneously blushing with iodine reactive	Blushing after treatment with alcohol
Spores	Smooth broadly ellipsoids	Wrinkled and round
Peridium	White almost without sticking sand	Whitish with sticking sand

2.2. Ecology of Tirmania

Tirmania nivea and *Tirmania pinoyi* have been demonstrated to form a unique type of mycorrhizae with desert annuals belonging to the family Cistaceae. *Helianthemum ledifolium* (L.) Mill and *H. salicifolium* (L.) Mill (AWAMEH and ALSHEIK, 1979a; AWAMEH and ALSHEIK, 1979b). The habitat and ecology of *Termania* spp. have been studied in Kuwait (AWAMEH and ALSHEIKH, 1979a). *Terminia* spp. develops well in high pH calcareous soils (FORTAS and CHEVALIER, 1992; GIOVANNTTI et al., 1994). They occur in gravely gypsiferous, gypsiferous-saline, or saline deserts as described by HALWAGY and HALWAGY (1974a).

Sporocarp production is correlated with amount and seasonal distribution of rainfall, an important factor for the development of the host plant. According to ALSHEIKH and TRAPPE (1983) under semi-arid conditions in Kuwait, a minimum of 180 mm precipitation well-distributed from October through March, produces a rich development of annuals, including *Helianthemum* spp. Sporocarps of *Tirmania* form in the soil at depths of 1-6 cm among roots of annuals. As the sporocarps enlarge, they raise a mound of soil that cracks as it dries.

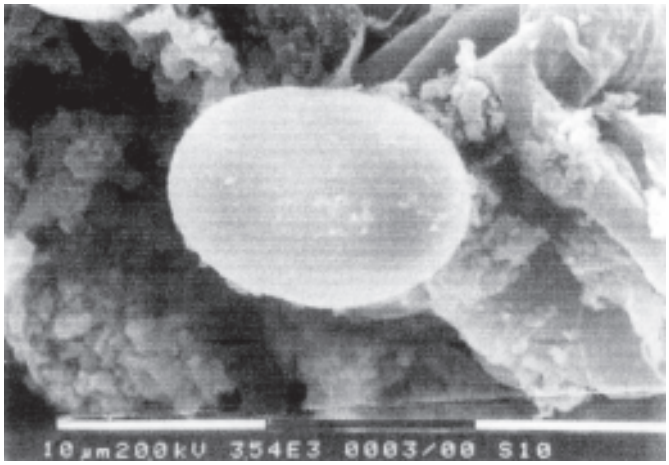

Fig. 3: Characteristic spore of Tirmania nivea, (PACIONI and EL-KHOLY, 1994), bar = 10µm

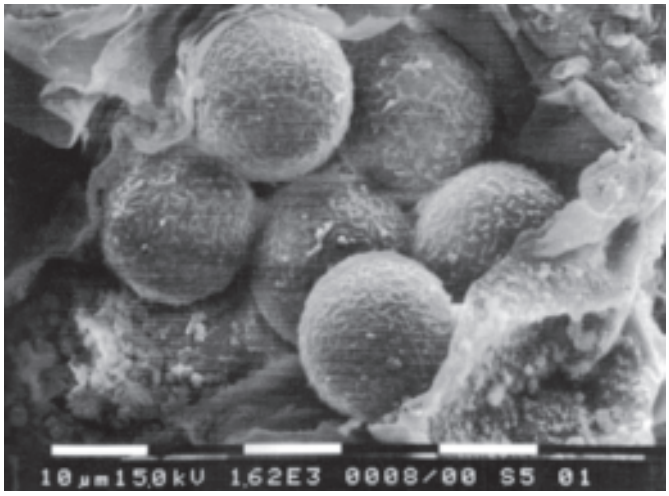

Fig. 4: Characteristic spores of *Tirminia pinoyi*

2.3. Soil analysis

Chemical and grain size analysis of the soils (Tab. 3) were carried by the Inspection Diagnostics Analysis Consultation Laboratories (IDAC) in Riyadh. Original soil **(S1)** designates the soil at Al-Khalidiah Farm whereas introduced soil **(S2)** refers to soil from an area about 30 km North of Riyadh and which was later incorporated at the experimental site. This area is known for its desert truffles which can be found in association with *Helianthemum* spp.

Tab. 3: Chemical and grain size analysis of the soils

Description and units	Original Soil **(S1)** (Sand)	Introduced Soil **(S2)** (Loamy Sand)
Sand + Gravel (%)	98.0	77.1
Silt (%)	1.0	14.0
Clay (%)	1.0	8.9
Water Content (%)	2.2	9.1
pH	7.69	8.1
EC (ms/cm)	4.5	1.05
Total Chloride, (mg/kg)	629	270
Sulphate, (mg/kg)	3095	850
Bicarbonate, (mg/kg)	267	150
Calcium, (mg/kg)	671	957
Magnesium, (mg/kg)	103	70
Sodium, (mg/kg)	380	130
Phosphorus, (mg/kg)	14.53	17.1
Potassium, (mg/kg)	121	104
Copper, (mg/kg)	0.07	0.08
Iron, (mg/kg)	0.56	0.41
Manganese, (mg/kg)	0.11	0.36
Zinc, (mg/kg)	0.08	0.1
Calcium Carbonate, (%)	27.08	38.22

2.4. Preparation of cuttings for truffle inoculation

In Saudi Arabia end of December is the most suitable time to take cuttings from a variety of trees (e.g. Olive trees) for truffle inoculation. Selected healthy mother trees were used for the production of cuttings. Each cutting had about 3-4 buds and was dipped into a hormone powder (Naphthalene acetic acid 0.80 gm + Vitamin B1 – hydrochloride 0.30gm) to activate root growth prior to be transplanted into the nursery of a greenhouse with automatic temperature regulation. Mean temperature was kept at 25ºc and cuttings were sprayed with water 5 times a day. At a root length of 5-7 cm cuttings were transplanted into plastic bags (3 litres) containing a pear light/peat moss mixture (50/50, v/v).

2.5. Inoculation with truffle spores

4-7 weeks after transplanting, cuttings were ready (root length > 10 cms) for inoculation. Locally occurring truffle species (*Tirmania nivea* and *Tirmania pinoyi*, see above taxonomic identification) were selected for the preparation of the inoculation media which consisted of truffle spores and hypheae and a specific truffle media previously produced and successfully tested in the laboratory of Dr. Khanaqa's Institute at Hannover/Germany (KHANAQA, 1994) . About 10 ml of truffle media were added to each plant in the plastic bag and kept in nursery under controlled greenhouse conditions. After six weeks 100 randomly selected samples of the inoculated plants were checked under the microscope for root infection. As soon as infection rate was higher than 80% olive plants were ready for transplantation on the land.

2.6. Plantation establishment, planting density and maintenance

The layout of the olive plantation (150 ha) was arranged on a grid where each plant is equidistant from its four neighbours. Distance between plants and between rows was 3 metres giving a total number of 1111 trees per hectare. In order to overcome insufficient rainfall during crucial periods of the year, a droplet irrigation system was installed and each olive plant was daily provided with 20 litres of water. No fertilizers or chemicals were applied. However, at the beginning of transplantation each plant received 3 kg of compost and again 3 months after transplantation with the following chemical composition (pH 7.7; Organic matter, 54.5%; Total Nitrogen, 2.1%; Calcium, 3.9%; Phosphorous, 0.9%; Potassium 2.3%; Magnesium, 0.5%).

2.7. Statistical analyses

Statistical analyses were carried out using Systat. Analysis of variance, was used to test the differences among the four harvests.

3. Results and discussion

The olive plantation was installed in 1997 and all plants began to take root and developed well (Fig. 5). The following description of the results and the observations made are based on a 4-year lasting development process and each year an additional treatment was evaluated. In February 2001, four years after implementation of the olive plantation, 250 plants randomly selected per hectare were checked for truffle infection. Development of truffles was very poor resulting in very modest yield. On the average less than 3 kg per ha were found (Tab. 4). These findings were very unsatisfying and we began to search for the reasons. We checked the soil (S1) where the olive plantation had been installed. The results of the soil analysis revealed a high percentage of sand and gravel (98%) and a very low percentage of silt (1%) indicating that this soil has an unfavourable granulation for truffle production. In addition the electrical conductivity (EC) was also high (4.5 ms/cm) which indicated the presence of salts in the soil. Further chemical analysis (Tab. 3) confirmed this assumption and chloride and sodium were found in

Fig. 5: Olive plantation, three years old

high concentration – 629 mg/kg and 380 mg/kg respectively. These findings clearly explained the weak development of truffles resulting in very low yields. In order to overcome this problem, we decided to incorporate a soil with better characteristics for truffle production. After intensive search a suitable soil (S2) was found which originated from a region about 30 km North of Riyadh. As we discovered later, this area is known for its desert truffles which can be found in association with *Helianthemum* spp. From the original olive plantation 4 ha were separated and each of the olive plants received 25 kg of soil (S2) which was thoroughly mixed and incorporated. In February 2002, again 250 plants per ha were randomly selected from the original plantation as well as from the previously separated area in order to examine the development of truffles. The results clearly showed the positive effect of the incorporated soil. In the original soil of the plantation truffle development was again very weak, however, in the separated area yield of truffle reached 10 kg/ha (Tab. 5, treatment 2 and 2a respectively). In order to confirm the results, an additional area (4 ha) was separated from the original plantation in 2002. This new area was also treated with (S2) as previously described. In the year 2003, plants were checked in the 3 treatments (3-3b). Again we obtained a very poor development of truffles in the area of the original plantation. In the two separated areas, however, the results were even significantly higher when compared to the yields in 2a of the previous year. Between the treatments 3a and 3b and between 2a and 3b significant differences were obtained. This finding clearly indicates a time course improvement of the development of truffles in the presence of (S2). The results in the year 2003 led to a yield of 75 kg. However, in order to follow this positive development we installed an additional area and repeated the same procedure as described above. In February 2004, the development of truffles was checked in the treatments 4-4c. Surprisingly, the development of truffles had dramatically decreased. In the original treatment (4) no truffles at all were found and even in the other treatments (4a-4c) only a reduced development was observed. In general, we found 50-60% less truffles when comparing the results of 3a/3b with 4a/4b. We assume that these poor yields are attributed to unexpected heavy rains which occurred during the months December 2003 and January 2004. Between the 10^{th} and 16^{th} of January 2004 about 200 mm rain were recorded and in some areas even temporary floods occurred. These heavy rain falls probably swept away many truffle spores and therefore the development of fruit bodies did not take place. In Mediterranean countries (France and Italy), this phenomenon occurs quite often after heavy rainfalls during the winter season (personal communication to the author). Considering the positive results of the second and third year, it was decided to continue with the experiment. Means were investigated on how (S2) could be transported in large quantities to Al-Khaladiah Farm to be incorporated into the local soil. We look forward to repeat these promising results which clearly revealed that the production of desert truffles is feasible.

Tab. 4: Results of yields (kg/ha) in the years 2001 - 2004. Average of treatments (1-4c, n = 250), s.e. in parentheses

Year of harvest and sequential treatments	Extrapolated yield kg/ha
1) 2001 (original plantation)	< 3
2) 2002 (original plantation)	< 2
2a) 2002 (4 ha separated in 2001 from original plantation + incorporated S2)	10.00 (1.4)
3) 2003 (original plantation)	< 2
3a) 2003 (4 ha separated in 2001 from original plantation + incorporated S2)	14.2 (2.2)
3b) 2003 (additional 4 ha, separated in 2002 from original plantation + incorporated S2)	11.1 (1.6)
4) 2004 (original plantation)	nil
4a) 2004 (4 ha separated in 2001 from original plantation + incorporated S2)	4.7 (1.2)
4b) 2004 (additional 4 ha, separated in 2002 from original plantation + incorporated S2)	5.8 (1.1)
4c) 2004 (additional 4 ha, separated in 2003 from original plantation + incorporated S2)	4.9 (1.4)

4. Conclusions

Desert truffles are so far known not cultivated anywhere in the world. In developed countries, where fertile soils can readily be worked by modern agriculture methods, cultivation of desert truffles based on perennial host plants transposed from their natural habitat is not likely to be a profitable venture at present. Introduction may be costly, and desert truffles fetch far lower prices than truffles from temperate regions. In desert regions, however, where the truffles are indigenous like in many Arabian countries, domestication of the truffle symbiosis may reasonably be expected to be successful. It would not involve new introductions and since an appreciative local market already exists, considerable returns could be expected.

Tirmania nivea and *T. pinoyi* are known for their economic value in the countries where they occur and provide a much-desired source of food. However, crops vary markedly from year to year because of variations in weather. Therefore, development of cultivation methods, e.g. through irrigation with drip irrigation in droughty years, could provide an important step in productive use of arid lands. As a result, cultivated imitation of nature would represent an advance over collection from the wild. Moreover, by using an appropriate perennial crop as host plant, such as *Olea europea,* a dual benefit from this association could be achieved i.e. the production of truffles and the

production of fruits from the trees. In addition, due to the presence of trees a microclimate will be established giving evidence to further benefits: 1) Soil formation will be promoted because the trees will prevent soil erosion 2) Water holding capacity will be improved in the planted area, 3) Decreased surface run-off due to an improved water retention by the trees resulting in enhancing the volume of underground water and, 4) trees will serve as windbreaks and sand-storm breakers.

Besides the annual costs for maintenance, the only investment to make is to purchase the truffle-infected seedlings and plant them in the designated areas. The experience gained with above described project are quite promising and will certainly have a great impact on the local and external market, where the cultivation of truffles on a large scale would allow more people to enjoy this exotic delicacy.

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