The Suitability of Ground Date (Phoenix dactylifera L.) Pits And Ghaf (Prosopis cineraria L.) Pods as Horticultural Growth Media or Soil Amendments

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M. Sc. in Horticulture

THE SUITABILITY OF GROUND DATE (Phoenix dactylifera L.) PITS AND GHAF (Prosopis cineraria L.) PODS AS HORTICULTURAL GROWTH MEDIA OR SOIL AMENDMENTS

By

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A thesis submitted to United Arab Emirates University
Faculty of Food and Agriculture
in partial fulfillment of the requirements
for the Degree of M. Sc. in Horticulture

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United Arab Emirates University, 2012
Table of Contents

1. General Introduction .......................................................... 1
   1.1. Ghaf pods and date pits: Two plant by-products available to farmers in
        the UAE .......................................................... 1
   1.2. The situation of the agricultural sector in the UAE, and opportunities
        for the use of alternative organic growth substrates and soil amendments... 2
   1.3. Aims of the present study, and potential significance of the results for
        plant production in the UAE ........................................ 3

2. Assessment of the Suitability of Ground Date Pits and Ghaf Pods as
   Growth Media .................................................................. 4
   2.1. Abstract ..................................................................... 4
   2.2. First experimental approach: Establishment of barley and maize
        seedlings on substrate constituting of ground date pits and ghaf pods ....... 5
   2.3. Second experimental approach: Barley seedling growth on ground
        date pits and ghaf pods substrates extracted by heated water ................... 14
   2.4. Third experimental approach: Examination of the suitability of
        fermented ground ghaf pods as a growth substrate for barley ................. 19
   2.5. Conclusions: Are date pits and ghaf pods suitable growth substrates
        for animal fodder production? .......................................................... 24

3. Test of the suitability of ground Date (*Phoenix dactylifera*) pits and
   Ghaf (*Prosopis cineraria*) pods as a soil amendment ....................... 26
   3.1. Abstract ..................................................................... 26
   3.2. Introduction ................................................................... 27
   3.3. Materials and methods .................................................. 28
   3.4. Result .......................................................................... 32
      3.4.1. Plant growth throughout the growth period ............................. 32
      3.4.2. Daily evapotranspiration from the planting pots .................... 39
      3.4.3. Water use efficiency and plant dry weight at the time of harvest .... 41
   3.5. Discussion and recommendation ........................................... 45

4. References ............................................................................. 48
Abbreviations used in the text:

_Prosopis cineraria_  
Ghaf
Ghaf pods  
G.pods
Date pits  
D.pits
Cocopeat  
C.peat

Keywords:

Growth media; Date pits; _Phoenix dactylifera_; _cineraria_; Plant by-product; Soil amendment; Organic fertilizer; United Arab Emirates
1. General Introduction:

1.1. Ghaf pods and date pits: two plant byproducts available to farmers in the UAE

Trees of the genus *Prosopis* are native to arid and semi-arid areas of the world and commonly grown in South America, Africa, South Asia and the Middle East. In the United Arab Emirates (UAE), ghaf is the predominant species grown in urban landscapes, man-made forest stands and farms of small-scale farmers. *Prosopis* trees belong to the family of the Fabaceae, and are characterized by the symbiotic association of their roots with nitrogen-fixing bacteria. The additional symbiotic nitrogen supply allows the *Prosopis* trees to accumulate relatively high contents of proteins and amino acids within their biomass even when grown on soils poor in available nutritional elements. In leaves and pods, the total protein concentration usually lies between 10 and 15% of the dry weight (Astudillo et al., 2000). This makes the biomass obtained from legume trees such as *Prosopis spp.* a valuable animal fodder and organic fertilizer. However, particularly pods produced by trees in urban landscapes are not collected and used, even though the demand for organic fertilizers and animal fodder in the UAE is continuously growing. Previous studies have demonstrated that pods of *Prosopis cineraria* (G.pods) are a valuable fodder for small ruminants, as long as they were mixed with other fodder and do not make up more than 20% of the total biomass consumed (Abdullah and Abddel Hafes, 2004; Mahgoub et al., 2005). The beneficial effect of *Prosopis* litter on soil properties has been demonstrated frequently by the creation of 'islands of fertility' around trees of this species. The use of G.pods as an organic fertilizer for horticultural growth substrates has not yet been investigated in detail. Ground seeds of e.g. Alfalfa (*Medicago sp.*) or castor bean (*Ricinus communis*) are already on the market as nitrogen and phosphorus fertilizers for organic farming systems. Concerning the use as animal fodder or soil amendment, however, a major drawback associated with the G.pods might lie in their relatively high tannin and phenolic content, which may be toxic at high concentrations for animals as well as plants. On the other hand, phenolic compounds have also been shown to have beneficial effects, e.g. by scavenging for oxygen radicals within live tissues. Similar with the G.pods, pits of date palms (*Phoenix cactylifera; D.pits*) constitutes a plant by-product that is not commonly used
in the UAE, even though it is produced in relatively high amounts. The yearly date fruit production of the UAE is around 760 thousand tons, with D.pits accounting for 6 – 12 % of this weight. The crude protein content of D.pits lie commonly around 4 to 6 %, making it a potentially suitable animal feed or fertilizer (Al-Hiti and Rous, 1978; Maṣoudi et al., 2010). Date pits also contain around 10 – 12 % of fat, with unsaturated fatty acids making up approximately 50 % of the total fatty acids (Besbes et al., 2004). Detailed studies on the tannin and total phenolic content in D.pits have not yet been performed. So far D.pits have mainly been tested for their use as an animal feed, e.g. in broiler production. They were shown to have beneficial effects on animal performance when making up between 5 and 30 % of their diet (Vandepopuliere et al., 1995; Masoudi et al., 2010). Whether ground D.pits could be used as a soil amendment or full growth substrate for plants, has not yet been investigated.

1.2. The situation of the agricultural sector in the UAE, and opportunities for the use of alternative organic growth substrates and soil amendments.

In total, there are 53 thousand farms in the UAE. Out of these, 72 % are focused on plant production. The most commonly grown plant in the UAE is the date palm, followed by fodder crops such as Rhodes grass and alfalfa. Field cultivation of fodder is known to consume particularly high amounts of irrigation water. Currently the total land area cultivated with forage accounts for 27,000 ha, corresponding to 13.1 % of the total farming land. Over-exploitation of groundwater resources has been significant in the UAE, and much of this can be assigned to the production of Rhodes grass and other animal fodder. In many areas of the UAE, groundwater tables have fallen dramatically, and out of the 90 thousand wells in the UAE, only 65 thousand are still in production. Scarcity of fresh water resources, and salt water intrusion into fresh water aquifers has promoted soil salinization in most agricultural areas of the UAE. In Abu Dhabi, 90% of the agricultural land around Al Ain is affected by salinity. Only 11 % of the agricultural soils in the UAE have an EC value below 4 dS/m, and are hence classified as non-saline (Abdelfattah, 2009). The annual recharge for groundwater in the UAE is 120 Mm³.
extraction is 880 Mm³. This has resulted in aquifer depletion, salt-water intrusion and water quality problems.

In an attempt to reduce water spent on animal fodder production, the government recently cut subsidies for Rhodes grass produced by UAE farmers. However, animal fodder of good quality is still required by farmers who keep camels, cows or small ruminants. The identification of water saving production practices for animal fodder is thus of great national interest.

Cultivation systems for animal fodder in the greenhouse have been tested by several research groups in the past, and have often been found to require much less water compared with field cultivation (Al-Karaki, 2012). Greenhouse cultivation of fodder is usually done in a multi-storey system, where growth substrates are placed in shallow trays, and planted with fast-growing grasses such as barley or maize. The fodder plants alone, or the plants together with the former growth substrate might subsequently be fed to the animals. Locally available growth substrates for such a system would still have to be identified within the UAE.

Worldwide the UAE ranks among the countries with the highest consumption of mineral fertilizers per unit farmland. Cultivated soils in the UAE are sandy and have a poor cation exchange capacity and organic matter content. Nutritional elements applied in mineral form may thus rapidly leach out of the rooting zone. Different from mineral fertilizers, organic soil amendments might not only release nutritional elements slower, but could also improve the physical and chemical soil traits. Currently residues from poultry farms, fisheries and slaughters are main components of organic fertilizers available to farmers in the UAE. Locally available plant by-products such as D.pits or G.pods have not yet been evaluated for their suitability as a soil amendment.

1.3. Aims of the present study and potential significance of the results for plant production in the UAE

The overall aim of this study is to assess the potential use of two different plant by-products, D.pits and G.pods, production. The experimental approaches aim at the following:
1. Evaluation of the suitability of ground D.pits and G.pods as growth media for production of animal fodder.
2. Test the suitability of ground G.pods and D.pits as organic amendments for soils of the UAE.

Information obtained from this study is supposed to help make use of otherwise unused plant by-products, and to replace currently imported growth substrates such as cocopeat or peat by locally available material.

2. Assessment of the Suitability of Ground Date Pits and Ghaf Pods as Growth Media

2.1. Abstract

The UAE and its neighboring countries are encountering scarcity of water resources and soil degradation due to salinization. The current over-exploitation of aquifers by the agricultural sector is a major concern for the government. Open field production of forage as a feed for camels, cows and small ruminants requires particularly high amounts of irrigation water. Greenhouse production of fodder might save water, but would require a suitable growth substrate that is readily available in the UAE, and ideally constitutes a palatable fodder itself. The objective of this study was to evaluate the suitability of ground D.pits and G.pods as growth substrates for greenhouse cultivation of barley (*Hordeum vulgare*) and maize (*Zea mays* L.) as fodder. A series of three experiments was conducted throughout 2011 by utilizing the laboratory and greenhouses of the Al-Foah Experimental Farm of the UAE University, Al-Ain, UAE. In a first experimental approach, freshly ground D.pits and G.pods were compared with the standard growth medium cocopeat (C.peat) for their ability to support growth of the target plants. This experiment revealed that both substrates severely impaired plant growth, and were not suitable as a growth medium. High concentrations of phenolic compounds commonly found in D.pits and G.pods might be a reason for this. A second experimental approach tested whether compounds that impaired plant growth on the fresh substrate could be removed by a hot water extraction. This experiment confirmed that at least some of the inhibitory compounds are soluble in hot water. However, even two cycles of hot water
extraction were not sufficient to render the D.pits or G.pods suitable growth media for barley. A third experimental approach tested whether microbial decomposition could improve the suitability of G.pods as growth substrate for barley. For this purpose, the ground G.pods were mixed with water, and then allowed to ferment either under anaerobic or aerobic conditions. When the material was subject to a combination of anaerobic and aerobic fermentation, it indeed lost its inhibitory compounds, and supported plant growth as good as C.peat. Anaerobic fermentation alone was not sufficient to remove inhibitory compounds. Whether the ground G.pods would still be accepted as a fodder by farm animals after fermentation, still needs to be tested by future experiments. Our results suggest that D.pits and G.pods could be used as growth substrates for greenhouse cultivation of fodder plants, under the prerequisite that future research identifies and further refines methods for extraction of plant growth inhibitory compounds.

2.2. First experimental approach: Establishment of barley and maize seedlings on substrate constituting of ground date pits and ghaf pods

2.2.1. Introduction

Ghaf pods as well as D.pits can be used as animal fodder in combination with other components such as hay or grain. Mahgoub (2005) confirmed that P. juliflora pods constitute a suitable animal fodder, in combination with date fiber. As the production of conventional animal fodder in the field consumes high amounts of water, alternative strategies for the production of animal feed are required for areas such as the UAE, where irrigation water is particularly scarce. Greenhouse cultivation of plants can save irrigation water, because a larger proportion of applied water is available to roots when plants are growing in containers instead of the open field. In addition, water draining from the bottom of the pots may be collected and recycled.

Greenhouse-based hydroponic systems by which animal fodder is grown in shallow trays supplied with a circulating nutrient solution have been proposed as a water-saving alternative to growing fodder under irrigation in the field (Bradley and Marulanda, 2000; Al-Karaki, 2011). In hydroponic systems, plants are either grown in absence of any growth substrate in liquid culture, substrate that is supplied with nutrient solution. Perlite, C.peat or rockwool are
commonly used substrates in hydroponic systems. Sometimes substrate based hydroponic cultures are termed 'semi-hydroponic', particularly when the growth medium also releases some nutritional elements in addition to what is supplied with the nutrient solution.

Hydroponic or semi-hydroponic systems have been shown to be particularly water use efficient. It has also been shown that plants growing in hydroponic systems can cope better with saline irrigation water compared with plants that grow in the soil (Raviv and Lieth, 2008).

For the production of fodder, rapidly growing grasses that produce a high biomass within a short time are particularly suitable. In hydroponic fodder production, barley or wheat are ready for harvest within less than two weeks (Cuddeford, 1989). Whether Ground G.pods or D.pits could be used as a growth substrate in hydroponic fodder production has not yet been tested. It is possible that after having served as a growth substrate for 10 to 14 days, the material could be used as an animal fodder, along with the barley or wheat plants that grew in it. However, it is known that both materials contain considerable amounts of phenolic compounds. On one hand, passing nutrient solution through the growth substrates might remove phenolic compounds and improve their nutritional value. On the other hand, the high phenolic concentration might also impair seed germination or plant growth. The first experimental approach tested the hypothesis that freshly ground D.pits and G.pods would support the growth of maize and barley, and that the biomass produced by these plants could then be used as animal fodder, along with the former growth substrate.

2.2.2. Materials and methods

Planting pots and growth media

Round plastic pots with a height of 7 cm and a diameter of 15 cm (total volume = 1238 ml) were used as growth substrate containers in this experiment. A hot pin was used to stitch nine holes into the bottom of each container at regular distance. These allowed for free drainage of irrigation water and nutrient solution from the growth substrate. As the containers were slightly transparent, they were wrapped with aluminum foil from outside to prevent exposure of plant roots to light. Liquid draining out of the growth substrate was collected in a pot that was placed beneath every substrate container.
Preparation of the growth substrate

G.pods were collected in August 2010 from Sharjah Emirate – Aldhaid highway road side. The trees were grown under irrigation, and their age was approximately 7 years. They were three to five meters high. The D.pits was brought from CONSEPT FZE (Jebel Ali Free Zone Dubai, United Arab Emirates). The origin of the dates were the local an Italian heavy-duty grinder. The ground D.pits were not subject to any other treatment before they were use in the experiment. The G.pods were ground into pieces of 0.5 to 5 mm using a small mill with 2.5 - 5 mm sieves (NUOVO ERCOLINO mill Art. 0518A). The C.peat substrate was obtained from Worms Wrangler-Retail, USA. Eight substrate containers were filled with the same type of substrate. Four of each of the eight replicates was subsequently sown with barley, and four with maize.

![Figure 1: Planting pots used in the first experimental approach at the time of sowing. Rows from top to bottom: D.pits, D.pits+G.pods 1:1, G.pods and C.peat.](image)

Plants used, and their cultivation

Seeds of the hybrid sweet corn (*Zea mays* L.) 'Merit' was obtained from ASGROW Vegetable Seeds (USA). Grade 1 barley seeds (*Hordeum vulgare* L.) of an unknown Australian cultivar were obtained from the Grand Mills for Flour and Feed Company (UAE). The germination percentage for the maize seeds was estimated to be 95 %, whereas that of the barley was 60 % according to a Petri-dish test performed in our laboratory. Both, barley and corn were sown at a density of 25 grams of dry seeds per
substrate container. The barley seeds were directly placed on top of the substrate, whereas the maize seeds were buried into the substrate at a depth of 1-2 cm. The substrate containers were covered with transparent plastic and kept in the laboratory at 25°C for four days, until most of the seeds had germinated. Thereafter they were transferred to a shade house at the UAE University / Al Jimi Campus, where they were kept from the 14th of March 2011 until the 14th of April 2011. During the first two weeks of growth, 100 ml of deionized water were added to each substrate container every day. Water draining from the bottom of the containers was added back into the growth substrate. Fourteen and twenty four days after transfer of the containers to the shade house, the growth substrate was flushed with a nutrient solution (Tab.1).

Table 1: Composition of the nutrient solution used for the flushing the growth substrate (Neumann et al, 2011)

<table>
<thead>
<tr>
<th>Element</th>
<th>Element concentration in the nutrient solution</th>
<th>Applied form</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>5.0 mM</td>
<td>Ca(NO₃)</td>
</tr>
<tr>
<td>P</td>
<td>0.5 mM</td>
<td>KH₂PO₄</td>
</tr>
<tr>
<td>K</td>
<td>1.5 mM</td>
<td>K₂</td>
</tr>
<tr>
<td>CA</td>
<td>3.1 mM</td>
<td>Ca(NO₃)₂ and CaSO₄*2H₂O</td>
</tr>
<tr>
<td>Mg</td>
<td>0.6 mM</td>
<td>MgCl₂*6H₂O</td>
</tr>
<tr>
<td>S</td>
<td>3.0 mM</td>
<td>CaSO₄*2H₂O and K₂ SO₄</td>
</tr>
<tr>
<td>B</td>
<td>56 µM</td>
<td>H₃BO₃</td>
</tr>
<tr>
<td>Fe</td>
<td>46 µM</td>
<td>Fe-EDTA</td>
</tr>
<tr>
<td>Mn</td>
<td>3.6 µM</td>
<td>MnSO₄</td>
</tr>
<tr>
<td>Zn</td>
<td>1.5 µM</td>
<td>ZnSO₄*H₂O</td>
</tr>
<tr>
<td>Cu</td>
<td>1.6 µM</td>
<td>CuSO₄</td>
</tr>
<tr>
<td>Mo</td>
<td>0.14 µM</td>
<td>(NH₄)₆Mo₇O₂₄</td>
</tr>
</tbody>
</table>

For the first flush, substrate, in order to replace the substrate solution by the nutrient solution. In the second flush, 700 ml of nutrient solution was passed through the substrate. Liquid drained out of the substrate was not added back to the pots. At the time of the first flush, the average length of the five shortest and the five tallest plants within each substrate container was measured using a regular 1 mm ruler. As no living seedlings
were observed in containers with D.pits and those with the D.pits / G.pods mixture planted with barley and sunflower included into the trial, and not subjected to any further analyses.

Harvest and analyses

The plants were harvested 30 days after germination. Shoots were cut off and dried in an oven at 65°C before the dry weight was estimated. The growth substrate remaining in the substrate containers was air-dried at 35 – 40°C before its weight was assessed. The substrate remaining in the pots for each treatment was mixed homogeneously, and a subsample was analyzed for its N, P and K concentration, along with a representative sample of the fresh D.pits and G.pods. After pulverization of the samples, N concentrations were analyzed according to Kjeldahl (1883). For this purpose, a subsample was digested with concentrated H₂SO₄ catalyst mixture to convert all N into ammonium. The latter was then released from the liquid sample and captured in saturated H₃BO₃. Thereafter, ammonium was quantified by titration. To assess the K and P concentrations, subsamples were digested in a boiling 8:1:1 mixture of HNO₃, H₂SO₄ and HClO₄. Concentrations of K in the liquid samples were analyzed by a flame photometer (BWB-1), determined photometrically with a spectrophotometer (Jenway 6320D) at 436 nm wavelength after staining with ammonium-molybdate-vanadate solution (Gericke and Kurmies, 1952).

2.2.3. Results

Appearance of the growth substrate, seed germination and plant growth

Except for the C.peat, bacterial colonies on their surface from five to seven days onward after set-up. Small insects were observed in the growth substrates during the second half of the growth period. Seed germination was initially relatively high in all treatments, but seedlings appeared to cease in growth and to die in all types of tested growth substrates, except for the C.peat. At two weeks after germination, only between 5 and 20 % of barley or maize seeds had turned into living plants when the growth substrate was G.pods (according to visual appraisal). This rate was even less (around 5 %) for maize seedlings establishing on a 1:1 mixture of G.pods / D.pits. Neither maize nor barley
seedlings survived on the ground D.pits substrate, and no barley seedling established on the G.pods / D.pits mixture. When C.peat was used as a growth substrate, however, a percentage of 60% for barley and 95% for maize. The length of the five smallest and the five largest plant shoots at two weeks after germination was indicative of a much better growth of seedlings when the substrate was C.peat instead of G.pods or a mixture of G.pods and D.pits (Fig. 2 and 3). Maize plants were generally larger compared with barley, but the growth responses to the different substrate treatments were very similar between both plant species (Fig. 2).

![Figure 2](image)

Figure 2: the averages shoot length of the five smallest and the five largest plants in each planting container in cm per plant. Shown are the mean values ± standard deviation.

Seedlings that survived on G.pods or the mixture between D.pits / G.pods showed a poorer growth compared with those established on C.peat. While plants on C.peat appeared healthy, those growing on the other substrates showed brown leaf tips and loss of older leaves. The total shoot biomass obtained from the containers by the end of the growth period was much more for plants grown on G.pods compared with C.peat, irrespective of the plant species (Fig. 4).
Figure 3: Appearance of substrate containers with barley and maize plants at fourteen days after germination. The photo was taken on 27/3/2011.

Figure 4: Shoot dry weight in g per container obtained at the time of harvest. Shown are the mean values ± standard deviations. The error bars shown above the columns represents the standard deviation.

In maize, very little biomass was obtained for plants growing on the substrate mixture, while barley did not produce any biomass when the growth substrate contained D.pits.
Changes in dry weight and composition of the growth substrate during plant cultivation

The dry weight of the ground G.pods and of the D.pits/G.pods mixture strongly decreased during the cultivation of both maize and barley plants (Fig. 5). The total biomass including the substrate, shoot and root biomass as well as the seeds was thus much lower after cultivation compared with the situation before. By the end of the growth period the shoot biomass made up less than 10% of the total biomass in every planting container.

![Graph showing biomass comparison](image)

**Figure 5**: Total biomass obtained from the substrate containers at the time of harvest in g per container. Shown are the mean values for the substrate biomass including roots and residues of seeds (white), as well as the shoot biomass (black). The error bars shown above the columns represent the standard deviation.

Nitrogen concentrations in the G.pods substrate seemed to slightly decrease during cultivation, whereas the phosphorus and potassium concentrations remained constant (Tab. 2). In the D.pits/G.pods mixture, $N$ during cultivation, whereas concentrations of $K$ remained unchanged compared with the original substrate.
Table 2: Nitrogen, phosphorus and potassium concentrations in the different growth substrates before they were used for cultivation, and afterwards in mg per g dry weight.

<table>
<thead>
<tr>
<th>Element</th>
<th>G.pods / D.pits mixture 1:1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before cultivation</td>
</tr>
<tr>
<td>N</td>
<td>15.91</td>
</tr>
<tr>
<td>P</td>
<td>1.86</td>
</tr>
<tr>
<td>K</td>
<td>10.29</td>
</tr>
</tbody>
</table>

2.2.4. Discussion and recommendation

Seed germination and / or the survival and growth of seedlings were poor on both substrates, the D.pits and the G. pods, compared with the C.peat. It is well possible that growth inhibitory compounds within the growth substrates were responsible for this. Legumes commonly contain significant quantities of phenolic compounds such as phenolic acids, flavonoids and tannins, which can be potentially growth inhibitory (Dabrowski & Sosulski, similar to those of soybean (0.18–0.41 g GAE per 100 g DW; Cardozo et al., 2010). In the present experiment, ground D.pits did not support any seedling establishment. A high phenol content has been found in date seed oil (Tuck and Hayball 2002). Total phenols, considered as the principal source of oil oxidation resistance, ranged from 520.81 for cultivar 'Deglet Nour' to 220.32 mg/kg for 'Allig' (In Practice.11.5.211 Besbes et al., 2004). The amount of phenols in D.pits seems to depend on the identity of the date palm cultivar (Al-Turki, 2008). It can not be excluded that D.pits of cultivars particularly poor in phenolic compounds would have supported plant growth better compared with the substrate tested within our study. Phenolic compounds are generally believed to be key components of the oxidative defenses of plants against pathogens and herbivores. (Barbehenn et al., 2005). Should further studies confirm that seedling growth inhibition observed within our study was indeed due to phenolic compounds within the substrates, it could be tested, whether the substrates themselves, or their extracts, might be used as herbicides. It is, however, also possible that fungi and bacteria that established on the D.pits and G.pods produced some compounds that were harmful to the seedlings. Fredrickson and Elliott (1984) mentioned that crop growth can be positively or negatively affected by rooting zone
colonization with microorganisms, remain largely unknown. Maize plants generally grew been the consequence of a lower germination of barley seeds compared with maize. In addition, maize seeds were coated with a fungicide, which might have better suppressed microbial development around the seedlings after sowing. Growth substrate biomass decreased considerably during the cultivation period. Most likely this was because the D.pits and G.pods material was rapidly decomposed by microorganisms, and carbon was released. There was a considerable loss in nutritional elements from the growth substrates (concentrations stayed the same, biomass decreased almost by 50%). It is expected that a small part might have been captured by the plants. The results suggest a quick release of nutrients and carbon from the growth substrates tested. Apparently the phenolic compounds within the substrates did not hamper microbial development much. Insects proliferating within the substrate during the second half of the growth period might also have contributed to its decomposition. The rapid decomposition of the material during plant cultivation suggests further that plant cultivation periods should be kept very short in fodder production that uses plant byproducts as substrates. Otherways, biomass losses from the substrate may be higher than biomass gains by fodder cultivation.

2.3. **Second experimental approach: Barley seedling growth on ground date pits and ghaf pods substrates extracted by heated water**

2.3.1. Introduction

The poor seedling establishment and plant growth observed in the first experimental approach might have been the result of inhibitory metabolites in the growth substrates tested. The objective of the second attempt was therefore to examine whether treatment of ground D.pits and G.pods with hot water would improve the ability of these substrates to support the establishment of barley seedlings. Phenolic compounds have been previously identified in D.pits and G.pods. Though the precise nature of these compounds is not known,
soluble in hot water. Treatment of the growth substrates with hot water would most likely not negatively affect their suitability as an animal food. Even small-scale farmers would be able to undertake such a pre-treatment. In this experimental approach we therefore tested the effect of hot-water extraction of D.pits and G.pods on their suitability as a substrate for cultivation of barley. In order to save energy and water, it would be important to know the minimum boiling time for sufficient removal of inhibitory compounds. Thus we compared the effect of two different boiling times on seed germination. The strong inhibitory effect of the growth substrates on seed germination observed in the first experiment might even suggest that the compounds responsible might be used as a herbicide. This experimental approach thus also tested the effect of external application of the hot water extract of D.pits and G.pods on germination of barley seeds on C.peat.

2.3.2. Materials and methods

Preparation of the different growth substrates

The original growth substrates and the barley seeds used in this approach were the same as the first attempt. Seven treatments with four replicates were set-up. For the hot water treatment, 200 g and 400 g of G.pods and D.pits respectively were placed into a laboratory beaker together with 1500 ml of water. The mixture was then boiled for 5 minutes before it was poured over a 500 μm sieve. The liquid draining out of the sieve was collected and allowed to cool. The growth substrate remaining on the sieve was rinsed with cold tap water for one minute before it was either used for the germination test, or subjected to a second round of hot water extraction. The latter was done in the same way as the first extraction.

Set-up of the germination test

Round styrofoam pots with a height of 3.5 cm and a diameter of 5.5 cm (total volume = 133 ml) were used as growth substrate containers. Two holes were stitched into the bottom of each pot, to allow free drainage of excessive water. As the containers were slightly transparent, the exterior was wrapped with aluminum foil to prevent exposure of plant roots to light (Fig. 6).
Figure 6: Styrofoam pots that were used as substrate containers in the second experimental approach.

Fifteen seeds were sown in the surface of each pot media. The pots were filled with 12, 30 or 40 grams of moist G. pods, D.pits and C. peat respectively. Before the seeds were sown, 35-40 ml of extract from the first boiling of G.pods or D.pits were applied to some of the pots filled with C. peat. Controls remained without extract and received only water. For pre-germination, barley seeds were soaked in tap water for twenty four hours before sowing. The experiment was conducted in the same shadehouse as the first experimental approach. The duration of this experiment was 13 days (from 30th of March to 12th of April 2011).

Harvest and analyses

When the plants were 13 days old, the number of germinated seeds in percent of the total seed number was recorded for each pot. At the same time, the length of the shoots of the germinated plants was measured using a regular 1 mm ruler. The data was subjected to one way ANOVA using SigmaStat-3.1, and significant differences at P < 0.05 among individual treatments were identified by Tukey's multiple comparison.

2.3.3. Results

The germination was decreased compared with the control treatments, when heat treated G.pods or D.pits were used as a growth substrate (Fig. 7). In G.pods but not in D.pits double extraction with hot water slightly improved the germination rate compared with the substrate that was treated only one time. Application of the liquid extract of D.pits and G.pods to C.peat substrate had no effect on germination of the barley seeds, but the development of the seedlings into plants was severely hampered by this treatment (Fig. 8). Similarly, seedling growth was strongly impaired on heat-
extracted G.pods or D.pits substrate. In the G. pods, two cycles of hot-water extraction allowed for a slightly better seedling development compared with only one cycle. However, the shoots of these plants grew only to less than 10% of the length of those of the control treatments. Different from the first experimental approach, the surface of the growth substrate did not show development of fungal or bacterial cultures within this attempt (Fig. 9).

Figure 7: Germinated seeds in percent of the total number of seeds that were sown into the different growth substrate treatments. Shown are the mean values of the four replicates per treatment with standard deviations.
Figure 8: The average length of shoots of barley seedlings in cm per plant at 13 days after sowing. Shown are the mean values ± standard deviation.

Figure 9: Appearance of substrate containers with barley seedlings at six days after sowing. Shown are the control treatments with C.peat substrate.

2.3.4. Discussion and recommendation

Some phenolic compounds in plant tissues are soluble in hot water, and this experiment tested whether a hot water extraction would remove some of the compounds that inhibited seedling establishment in the first experimental approach. The results confirm that some of the plant growth inhibiting components in D.pits and G.pods are soluble in hot water. However, even two consecutive hot water extractions cannot remove these compounds sufficiently to allow for satisfactory plant growth. The application of D.pits and G.pods extract to C.peat treatment reduced the
growth rate by more than 80%, suggests that relatively small amounts of the extract are sufficient to repress growth of grasses. Further experiments might focus on the investigation of the suitability of D.pits and G.pods extracts as herbicides. These extracts might be particularly suitable to decrease the viability of weed seeds in agricultural soils, as they mainly impair seedling growth, but not seed germination. In any case, the data obtained within this experimental approach suggest that hot water extraction cannot render D.pits or G.pods suitable growth substrates.

2.4. Third experimental approach: Examination of the suitability of fermented ground ghaf pods as a growth substrate for barley.

2.4.1. Introduction
Ground G.pods and D.pits are easily available to farms in the UAE, and they might constitute suitable substrates for animal fodder production by small-scale farmers. However, the first two experimental approaches conducted within this study have shown that they do not well support the establishment of fodder grasses when used fresh, or after a hot-water extraction.

Alternative treatments that might be applied to the substrates should be relatively easy to do by farmers, and should not render the substrates unpalatable by ruminants. Fermenting of the growth substrates might be a suitable tool to remove growth inhibitory compounds, as microbes are able to cleave these. Within this experimental approach, it was thus tested, whether a period of aerobic or anaerobic fermentation would render the plant by-products suitable growth substrates for barley. Fermentation takes less time than composting, and is commonly used in the preservation of fodder (e.g. silage). Different aerobic and anaerobic fermentation treatments were tested. Anaerobic fermentation promotes bacteria able to degrade organic substances rather incompletely in absence of oxygen. Aerobic fermentation promotes bacteria that oxidize organic molecules, and are able to decompose them more completely.
2.4.2. Materials and methods

Seeds and preparation of the different growth substrates

This experiment was done only on ground G.pods. The original material was the same as used in the other experimental approaches. However, different barley seeds were used. They were purchased from the 'Yemeni Market' (Global City, Dubai, UAE). Similar with the first approaches, the barley seeds were purchased as foodstuff, and not as planting material, in order to represent material that would be used by farmers for a similar purpose. The precise cultivar of the barley seeds thus remained unknown. To ferment the ground G.pods, 1000 grams of the material was placed into a light-impermeable, round plastic jar (diameter 50 cm; height 17 cm). Then 2000 ml of tap water was added, and the mixture was stirred for 2 minutes. To induce anaerobic fermentation, the material was left without aeration in the external weather condition (43°C). Aerobic fermentation was done by placing a plastic tube into each jar, which was connected to an aeration pump. All treated material was subject either to a period of 7 or 17 days anaerobic fermentation (7d-O / 17d-O), either or not followed by a period of aerobic fermentation for 7 days (7d+O). By the end of the respective fermentation treatment, the content of the jars was poured through a sieve, and the substrate remaining on the sieve was washed with tap water until the washing water remained clear. The substrate was air-dried for three days, and stored in a fridge (5 °C) until used in the experiment. It was assumed that the extraction of growth inhibitory compounds from ground G.pods might be particularly difficult for larger particles of the Ground material. Thus within this experiment, the effect of the particle size of the ground material was also tested. For this purpose, a portion of the ground material was passed first through a 4 mm mesh sieve, and all particles remaining on the sieve were eliminated. Thereafter, the material was passed through a 1.6 mm mesh sieve, (all big particles (> 4 mm) were eliminated, and the size of 4 - 1.6 mm was reduced by 38 %). The sieved substrate was subject to 17 days of anaerobic fermentation, and 7 days of aerobic fermentation. Similar with the first two experimental approaches, C.peat served as a control substrate. It was not fermented prior to its use in the experiment.
**Set-up of the germination test**

The same round styrofoam pots as used in the second experimental approach were used in this trial. Each pot was filled with 125 ml of fermented growth substrate. Control treatments received adequate amounts of the fresh material. The weight of the substrate was 70 g per pot for the moist C.peat (34 g dry weight), and 30 g dry weight for the other substrates. Four replicates were prepared for each treatment. Before the seeds were sown, 70 ml of tap water was applied to each pot. For pre-germination, barley seeds were soaked in tap water for twenty four hours. After sowing, the pots were kept at room temperature and were covered by black plastic foil to reduce evaporation. Three days after sowing, the foil was removed and pots were transferred to an air-conditioned greenhouse at the Al Foah experimental farm of the UAEU. The temperature in the greenhouse was on an average 32°C during the day, and around 28°C during the night. The experiment started on 7th of September 2011 until the 2th of September 2011.

**Harvest and analyses**

The germination percentage of the barley seeds was assessed one week after sowing. Germinated plants were allowed to grow for one week before they were cut for the first time. The cutting was meant to simulate animal grazing or harvest of biomass. The shoot biomass of the germinated plants was cut off 1 – 2 cm above the substrate surface. Before cutting, the length of the shoots of germinated plants was measured using a regular 1 mm ruler. One week after cutting, the length of the re-grown shoots was recorded. The plants length was measured two times on the seventeenth day and the fourteenth day.

**2.4.3 Results**

Similar with the first experimental approach, fresh ground G.pods did not support the establishment of barley seedlings in this trial (Fig. 10). Exposure of the material to a period of anaerobic fermentation that lasted either for 17 or for 7 days did not significantly improve barley seed germination compared with that on non-treated G.pods. The length of the seedlings grown on non-treated or anaerobically fermented G.pods was less than 10 % of that achieved by the control plants (Fig. 11).
However, when ground G. pods were subject to a combination of anaerobic and aerobic fermentation, barley germination and seedling development on the obtained substrate were not different from that on C.peat (Fig. 10 and 11).

**Figure 10:** The number of live seedlings seven days after sowing in percent of the number of seeds that were placed into each planting pot. Shown are the mean values of the four replicates per treatment. Error bars show the standard deviation. The G.pods were fermented for 7 or 17 days (d) either in absence (-O) or in presence (+O) of aeration.

**Figure 11:** Average leaf length in mm per plant measured at the time of the first cut (seven days after sowing), and after the plants had re-established (14 days after sowing). The figure shows the mean values of the four replicates of each treatment with standard deviation. For treatment abbreviations see Fig. 10.
After the plants were cut at seven days after sowing, seedlings growing on G.pods material that was subject to a combination of anaerobic and aerobic fermentation re-established as well as the controls. The growth of seedlings on non-treated or only anaerobically treated G.pods remained very poor until the end of the experiment.

2.4.3. Discussion and recommendation

This experiment tested whether exposure of ground G.pods to a period of microbial decomposition in aerated or non-aerated water would remove compounds that prevented barley and maize seeds from developing into healthy seedlings in the previous two experimental approaches. Results obtained indicate that anaerobic fermentation alone does not remove growth inhibiting substances sufficiently. However, when anaerobic fermentation was followed by a period of aeration of the liquid, the treated substrate allowed for growth of barley seedlings as well as the C.peat. It could be speculated that microbial or non-microbial oxidation of phenolic compounds was responsible for this. Whether aerobic fermentation alone would be sufficient to make a suitable growth substrate out of the ground G.pods requires further investigation.

The results obtained from this experiment indicate that fermented G.pods might be a suitable growth substrate for semi-hydroponic cultivation of fodder and eventually other greenhouse plants in the UAE. However, whether the fermented material would still be palatable by farm animals deserves further testing.

When G. pods were used as a growth substrate in the first experimental approach, considerable amounts of biomass and nutritional elements were lost after a period of only one month. It can not be excluded that similar losses occurred during fermentation. Whether shorter periods of fermentation might be sufficient to render the G.pods substrate suitable for plant growth should be investigated in further experiments. Shorter fermentation would most likely reduce biomass and nutrient losses. Some chemicals such as the surfactant Dynol 604 have been shown to increase microbial oxidation of phenolic compounds (Kulyš and Ivanec-Goranina, 2009), and it could be tested whether application of such compounds to the fermenting G.pods might speed up their conversion into a growth substrate that is free of inhibitory compounds.
It should also be assessed, whether the liquid that drains out of the fermented material could be used as a fertilizer. On one hand it is very likely that it contains significant amounts of nutritional elements, on the other hand it might also still contain some of the growth inhibitory compounds.

The observation that the barley shoots did not re-establish to their original height seven days after cutting may suggest that nutritional elements in the G.pods substrate became scarce, and that fertilization with readily available nutrients would be required in order to achieve optimal biomass production. Whether the fermentation liquid could be added back to the G.pods during plant cultivation to improve nutrient supply also deserves further investigation.

Elimination of coarse particles from the growth substrate prior to anaerobic and aerobic fermentation (17d – O / 7d + O), had no additional beneficial effect on barley seedling establishment. This suggests that coarse particles can remain in the substrate as long as the material is properly fermented.

2.5. Conclusions: Are date pits and ghaf pods suitable growth substrates for animal fodder production?

The results of the first three experimental approaches clearly indicate that non-treated G.pods and D. pits are not suitable as growth substrates for grasses and possibly other plants. The precise nature of the plant growth inhibitory compounds remains unknown. Our results indicate that they are at least partially soluble in hot water. The growth inhibitory compounds appeared to impair seedling development more than seed germination, which might make them a potentially powerful organic herbicide. It could be speculated that phenolic compounds are mainly responsible for the growth inhibition observed in plants growing on the fresh substances. Date pits contain particularly many phenolic compounds (3102–4430 mg of gallic acid equivalents/100 g fresh weight; antioxidant activity 580–929 μmol of Trolox equivalents/g fresh weight; Al-Farsia et al., 2007), and in our study, they impaired grass seedling establishment stronger than G.pods did.

Concerning the use of the two plant by-products as growth substrates, the most significant finding of the experimental approaches undertaken so far is that a combination of anaerobic and aerobic fermentation renders the G.pods substrate
suitable for the establishment of barley seedlings. Whether D.pits could be used for growing plants after being exposed to a similar treatment, still needs to be tested. Should further experiments confirm that fermented G.pods and possibly D.pits can potentially replace foreign materials such as C.peat or rockwool in semi-hydroponic cultivation systems in the UAE, an economic study should evaluate to which extent the production of this substrate is feasible for farmers or supplying industries. The first experimental approach indicated that when used as growth substrates, D. pits and G.pods may undergo rapid decomposition, leading to around 50 % of biomass and nutritional element loss after only one month. In case the material is meant to be used as an animal feed along with the fodder grasses that grew on it, care would have to be taken, in order to keep these losses small. Short cultivation cycles and a small amount of growth substrate per unit of seeds could help to reduce carbon volatilization from the substrates.
3. Test of the suitability of ground Date (*Phoenix dactylifera*) pits and Ghaf (*Prosopis cineraria*) pods as a soil amendment

3.1. Abstract

Adding plants byproduct as a fertilizer to the soil has been investigated all over the world in traditional and conventional production systems because it enhances soil fertility and the crop production. The objective of the present study was to investigate the effect of D.pits (*Phoenix Dactylifera*) and G.pods (*Prosopis cineraria*) as a local organic fertilizer in the UAE. The experimental units were subjected to three factors, fertilizer type, level of fertilization and salinity. The experiment includes sixteen treatments, and each treatment has four replicates. Levels of fertilization were identified as high, medium and low for a 300, 150 and 75 mg nitrogen per kg of dry soil respectively and the same levels were applied to D.pits and G.pods with response to the control treatments. The plants were allowed to grow for fifty eight days and fourteen parameters were investigated. Results showed that no significant differences were observed in shoot length increment depending on the fertilization level in organic treatments. When plants received mineral fertilizer, the shoot length was higher compared with plants that received the same amounts of nutritional elements either in form of D.pits or G.pods. The shoot length increment in D.pits control treatment has been highly affected when irrigated by saline water. The organic D.pits and G.pods treatments showed a stable growth by the application of saline water. The leaf number per plant in D.pits control treatment has been highly effected when irrigated by saline water, whereas in the opposite side the organic D.pits treatments had a stable growth by the application of saline water. The leaf number per plant in G.pods control treatments has a higher growth when irrigated by saline water, while the organic D.pods treatments had negative results for the same applications. No interactions were observed between the treatment's factors. Most of the treatments had significant ($P < 0.05$) differences through the experimental period. Total leaf increment, root dry weight, shoot/root ratio and evapotranspiration had a significant ($P < 0.05$) difference. The plant dry weight and its proportion had no significant ($P < 0.05$) difference. When considering the dry weight as a fundamental indicator of the plant production it is suggested that the D.pits and G.pods could be a promising local
organic fertilizers and it is recommended to apply them on a larger scale by using a production plants such as tomato, cucumber and lettuce.

3.2. Introduction

An organic fertilizer refers to a soil amendment derived from natural renewable sources that provides at least small amounts of nitrogen, phosphate, and/or potassium to agricultural plants. Examples include plant and animal by-products (Card et al, 2008). The beneficial effect of litter of ghaf trees, including G.pods, is known by many farmers of arid and semi-arid lands, who traditionally plant their vegetables under the Ghaf trees. For example, agroforestry systems where annual plants are grown beneath Ghaf trees are common in Rajasthan and Haryana regions in India (Puri et al, 1994). Singh (2009) concluded that his research indicated bio-economic benefits of optimum density of Ghaf trees over traditional practices of maintaining random trees in farming systems in arid zones. It is often suggested that the increase in productivity of plants grown under tree canopies is due to many beneficial effects their litter has on soil properties, such as plant nutrient availability, cation exchange and water holding capacities (Clary & Jameson, 1981; Dye & Spear, 1982; Walker et al., 1986). Adding plant byproducts as fertilizer to the soil has been investigated in a field trial in Akure, southwest Nigeria, where organic fertilization was tested as an alternative to the conventional fertilization practices. Plant residues applied at a rate of 6t/ha increased soil organic matter, and availability of N, P, K, Ca, and Mg to the crop. In consequence, higher yields were achieved (Folorunso et al, 2003). The litter of legume plants is particularly suitable to improve the nutritional status of crops. This is because roots of members of the legume family (Fabaceae) live in symbiosis with bacteria that fix atmospheric nitrogen. In most parts of the world legumes are a major source of organic nitrogen fertilizer, and an essential component of sustainable farming systems (Young al., 2003). The use of organic fertilizers may also improve the ability of plants to withstand adverse effects of soil salinity. As organic matter provides cation exchange capacity, it might adsorb sodium from the soil solution. Furthermore, organic material might counteract negative effects of NaCl on the soil structure, and improve plant Ca supply.

In the UAE, Ghaf trees are grown in large numbers in urban and peri-urban man-made forests and landscaping areas. In most of these areas it is not possible to grow annual crops directly under the trees. However, a part of the litter produced by Ghaf
tree plantations could be collected and used as an organic fertilizer elsewhere. Organic fertilizers are particularly scarce in the UAE, as any plant biomass production is associated with irrigation water expenditure. The use of plant by-products as organic fertilizers has a particularly high potential under these conditions. Date pits constitute a residue from the date fruit processing, which is produced in relatively large quantities in the UAE. Whether ground date pits could be used as a soil amendment has not yet been investigated in much detail. Date pits contain considerable amounts of nutritional elements, but other compounds they contain may impair plant growth, as indicated by the results obtained in Chapter 2 of this Thesis. Hence there is need to investigate the suitability of locally available materials in UAE such as D.pits and G.pods as organic fertilizers that may replace or complement the mineral fertilizers and imported organic soil improvers. In the present experiment the ability of G.pods and D.pits to support the growth of an ornamental plant was tested in a pot experiment. Dune sand from the UAE was used as a growth substrate, and was either mineraly fertilized or amended with P.pods or D.pits. We tested the hypothesis that plants growing on G.pods amended soil would achieve 70% of the dry weight of plants that received a corresponding mineral fertilization, due to the small C:N ratio of the G.pods. Date pits were expected to release nutritional elements slower, and thus to support plant growth less than G.pods in a short-term experiment. The present experiment further tested the hypothesis that amendment with organic matter would be superior compared with mineral fertilization when plants grow on a saline soil. All fertilization treatments involved into this experiment were thus established either in presence or absence of salinity.

3.3. Materials and methods

The experiment was of a three factorial design, testing the effects of the fertilizer type, level of fertilization, and presence of salinity on the growth of Sphagniticula trilobata (L.) Pruški plants. The experiment consisted of sixteen treatments, each with four replicates (Table 3). Prior to their use as soil amendment in this experiment, D.pits and G.pods were ground to powder (< 1 mm particle size). The planting pots were filled with 500 g of air-dried field soil plus the organic soil amendments. The soil was brought from the desert dune near the Faculty of Food and Agriculture Farm in Al Foah, which had not been fertilized before.
Table 3: Treatments involved into this experiment:

<table>
<thead>
<tr>
<th>Mineral fertilization</th>
<th>Organic fertilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium level</td>
<td>Low level</td>
</tr>
<tr>
<td>G.pods control</td>
<td>D.pits</td>
</tr>
<tr>
<td>D.pits control</td>
<td>G.pods</td>
</tr>
<tr>
<td></td>
<td>D.pits</td>
</tr>
<tr>
<td></td>
<td>G.pods</td>
</tr>
<tr>
<td></td>
<td>D.pits</td>
</tr>
</tbody>
</table>

The second row shows the fertilization levels, the third row the type of soil amendment. The 'G. pods control' and 'D. pits control' received nutritional elements in mineral form. The last row indicates the salinity treatments, with '-S' being treatments that grew in absence of NaCl, and '+S' those that received saline irrigation water.

Three levels of fertilization were set up based on the nitrogen (N) supply. Organic material mixed with the soil contained either 300, 150 and 75 mg N per kg of dry soil, corresponding to the high, medium and low fertilization level respectively (Table: 4). The N, P and K concentration in the fresh D.pits and G.pods was determined in the Food and Agriculture College Laboratory in Al-Ain at the UAE University / Al Jimi Campus as described in Chapter 2.2.2 (see Tab.2). The quantities of organic material supplied to establish the high, medium and low fertilization level were 34.01, 17.01 and 8.50 g D.pits, and 9.97, 5.4 and 2.49 g G.pods per kg dry soil, respectively. Control pots were supplied with amounts of N, P and K in mineral form that corresponded to those added with 17.01 g kg dry soil\(^{-1}\) D.pits (D.pits control) or 5.4 g kg dry soil\(^{-1}\) G.pods, respectively (G.pods control; medium fertilization level, Tab. 5).

Before the fertilization treatments were set up and the soil was supplied with the organic material, soil for all treatments received a basic fertilization (Tab. 6). Since concentrations of micronutrients in the organic material were not known, the basic fertilization made sure that plants were sufficiently supplied with Fe, Zn and Cu. In addition, the basic fertilization supplied a small amount of macronutrients, which were supposed to support initial plant growth until nutritional elements from the organic material were released by decomposition.
Table 4: Amounts of N, P and K (in mg per kg dry) supplied with the G.pods and D.pits material.

<table>
<thead>
<tr>
<th>Levels</th>
<th>G.pods</th>
<th>D.pits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>P</td>
</tr>
<tr>
<td>High</td>
<td>300</td>
<td>44</td>
</tr>
<tr>
<td>Medium</td>
<td>150</td>
<td>22</td>
</tr>
<tr>
<td>Low</td>
<td>75</td>
<td>11</td>
</tr>
</tbody>
</table>

Table 5: Amounts of N, P and K added to treatments of the medium fertilization level (mg per kg dry soil, first three rows), and amounts of nutrient salts added to the mineraly fertilized controls (in g per 2.5 kg dry soil, last three rows).

<table>
<thead>
<tr>
<th>Nutritional element/salt</th>
<th>G.pods</th>
<th>D.pits</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>150</td>
<td>150</td>
</tr>
<tr>
<td>P</td>
<td>21.98</td>
<td>9.86</td>
</tr>
<tr>
<td>K</td>
<td>82.65</td>
<td>121.6</td>
</tr>
<tr>
<td>NH₃ NH₃</td>
<td>2.14</td>
<td>2.14</td>
</tr>
<tr>
<td>KH₂ PO₄</td>
<td>0.48</td>
<td>0.22</td>
</tr>
<tr>
<td>K₂ SO₄</td>
<td>0.612</td>
<td>1.22</td>
</tr>
</tbody>
</table>

Table 6: Basic fertilization to enhance the desert soil nutrients. Basic fertilization was used for all pots which represents the minimum requirement for the plant.

<table>
<thead>
<tr>
<th>Nutrition element</th>
<th>Applied form</th>
<th>Element in mg per kg dry soil</th>
<th>Applied form in g per 10 kg of dry soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>NH₄ NO₃</td>
<td>50</td>
<td>2.86</td>
</tr>
<tr>
<td>P</td>
<td>KH₂ PO₄</td>
<td>60</td>
<td>2.65</td>
</tr>
<tr>
<td>K</td>
<td>K₂ SO₄</td>
<td>100</td>
<td>2.23</td>
</tr>
<tr>
<td>Mg</td>
<td>MgSO₄.7H₂O</td>
<td>100</td>
<td>10.38</td>
</tr>
<tr>
<td>Fe</td>
<td>Fe-EDITA</td>
<td>20</td>
<td>1.6</td>
</tr>
<tr>
<td>Zinc</td>
<td>ZnSO₄.7H₂O</td>
<td>10</td>
<td>0.45</td>
</tr>
<tr>
<td>Cu</td>
<td>CuSO₄.5H₂O</td>
<td>10</td>
<td>0.39</td>
</tr>
</tbody>
</table>

Chemicals were dissolved in 800 ml of water, and then mixed with 10 kg dry soil.

Round, brown plastic pots with a volume of 500 ml were used for this experiment. After they were filled with soil, they were set up completely randomized in an air-conditioned green house at the Al Foah Experimental Farm. The average temperature...
during the day and night was 36 and 29° C, respectively. The pots were planted with *Sphagnetica trilobata* two leaf stem cuttings (Fig.12). *Sphagnetica trilobata* is an ornamental groundcover that is commonly grown in the UAE. Plant shoots were cut from plants that grew in the area around the Food an Agriculture College in Al-Ain. The apical parts were not used as cuttings, and each cutting had two leaves, with two third of each leaf removed to enhance rooting and to reduce the transpiration. The leaf base was implanted in the soil to grow roots from it is node, a long stem was kept down for anchoring purpose, and the soil was watered before planting. During the first week after insertion of the cuttings, the pots were covered with a plastic bag to reduce transpiration.

**Figure 12:** Planting pots with *S. trilobata* cuttings in the greenhouse. The plants on this picture are two weeks old.

The plants were allowed to grow for fifty eight days, starting from 19th of June 2011 to 16th of August 2011. Each two to three days, amounts of water lost from each pot were assessed gravimetrically and replaced with deionized water. In addition, length of shoots and the number of leaves per plant were estimated every week during the second half of the growth period. Leaves lost throughout the growth period were collected for each plant, and their dry weight was assessed after drying at 65 °C in a drying oven. At 31, 35 and 49 days after planting, the +S treatments received saline irrigation water, supplying 500 mg NaCl. In total, all +S treatments received 1500 mg NaCl.

At the time of harvest, shoots were cut off above the ground, and the leaves were cut off the stem. The pots with the sand were allowed to dry in the open air (approx. 40° C), before their contents was passed through a 1 mm sieve, and roots were collected from the material that remained on the sieve using a forceps. The roots were
subsequently washed with tap water. All plant material was dried at 65° C in a drying oven for three days, until the dry weight was estimated.

### 3.4. Result

#### 3.4.1 Plant growth throughout the growth period

The shoot length increased in all treatments throughout the second half of the growth period (Fig. 13). No significant (P > 0.05) differences were observed in shoot length depending on the fertilization level in any of the treatments receiving organic material. When plants received mineral fertilizer, the shoot length was higher compared with plants that received the same amount of nutritional elements either in form of D.pits or G.pods (Fig. 13; Tab. 7). The shoot length increment in the D.pits control treatment appeared to be decreased when plants were irrigated with saline water, compared with the corresponding -S treatment. However, the ANOVA did not indicate a significant effect of salinity on shoot growth or the leaf numbers (Tab. 7). Similar with the shoot length, leaf numbers appeared to be largely unaffected by the salinity treatment. Only in the D.pits control treatment salinity appeared to decrease the number of leaves per plant. However, a significant effect of saline irrigation water was not detected by the ANOVA (Tab. 8).
Figure 13: Shoot length in cm per plant measured at different time points during the second half of the growth period. Shown are the mean values. The arrows indicate the time of salt application to the +S planting pots.
Figure 14: Leaf numbers per plant measured at different days points during the second half of the growth period. Only fully expanded leaves with a length greater than 1 cm were counted.
Table 7: Results of the Three Way ANOVA performed on data for shoot length and leaf numbers obtained for treatments fertilized either minerally or organically at an intermediate level. A black dot indicates a significant (P < 0.05) affect of either the type of organic material (D.pits vs. G.pods), the type of fertilization (organic vs. mineral), or the application of NaCl.

<table>
<thead>
<tr>
<th>Shoot length</th>
<th>Days after planting</th>
<th>25</th>
<th>31</th>
<th>38</th>
<th>47</th>
<th>58</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Organic vs. mineral</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Application of NaCl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaf numbers</th>
<th>Days after planting</th>
<th>25</th>
<th>31</th>
<th>38</th>
<th>47</th>
<th>58</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Organic vs. mineral</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Application of NaCl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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</tr>
</tbody>
</table>

Table 8: Results of the Three way ANOVA performed on data for shoot length and leaf numbers obtained for organically fertilized treatments. A black dot indicates a significant (P > 0.05) effect of either the type of organic material (D.pits vs. G.pods), the fertilization level, or the application of NaCl.

<table>
<thead>
<tr>
<th>Shoot length</th>
<th>Days after planting</th>
<th>25</th>
<th>31</th>
<th>38</th>
<th>47</th>
<th>58</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertilization level</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Application of NaCl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaf numbers</th>
<th>Days after planting</th>
<th>25</th>
<th>31</th>
<th>38</th>
<th>47</th>
<th>58</th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fertilization level</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Application of NaCl</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

The results of the Three Way ANOVA indicated that at an intermediate fertilization level, mineral fertilization resulted in longer shoots and more leaves per plant compared with organic fertilization. The type of organic material did not have any effect on shoot length or leaf numbers measured throughout the growth period (Tab. 8).

At the time of harvest, organically fertilized plants that received D.pits had more leaves compared to treatments that received G.pods (Tab. 8). However, no such
differences in growth were observed earlier between treatments receiving D.pits and G.pods during the second half of the growth period. The total shoot length increment since the first salt application showed a relatively large variability (Fig. 15, Tab. 9). Among the organically fertilized treatments the plants that were amended with small amounts of G.pods and received saline water had the smallest shoot length growth, and lost more leaves than they formed between the first salt application and the final harvest.

Figure 15: The shoot length (cm per plant) and leaf number increment between the first salt application 30 days after planting, and the harvest. Shown are the mean values with standard deviations for organically fertilized treatments of the three different fertilization levels.
Table 9: Results of the Three Way ANOVA performed on data obtained for the shoot length and leaf number increment of organically fertilized plants. Shown are the P values for the factor effects, as well as significant (P < 0.05) interactions. The P values indicating a significant factor effect are printed in bold.

<table>
<thead>
<tr>
<th>Results of the Three Way ANOVA</th>
<th>Growth increment since the first salt application</th>
<th>Leaf numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot length</td>
<td></td>
</tr>
<tr>
<td>D.pits vs. G.pods (T)</td>
<td>0.251</td>
<td>0.189</td>
</tr>
<tr>
<td>Fertilization level (L)</td>
<td>0.259</td>
<td>0.004</td>
</tr>
<tr>
<td>Application of NaCl (S)</td>
<td>0.060</td>
<td>0.005</td>
</tr>
<tr>
<td>Interactions</td>
<td>T x L x S</td>
<td>-none-</td>
</tr>
</tbody>
</table>

Generally the shoot length and leaf number increment appeared to be larger for plants amended with D.pits than G.pods. Salinity had a significantly negative effect on the development and/or the maintenance of leaves (Tab. 9). The leaf number increased with increasing fertilization level, and this effect was particularly pronounced in plants that grew in non-saline soil amended with D.pits.

The comparison between the mineral and the organic fertilization treatments at medium supply level revealed no difference in shoot length increment depending on the salinity level or type of fertilizer applied (Fig. 16, Tab. 10). The leaf number increment, however, was significantly higher for D.pits than for P.pods. Salinity had no effect on the leaf formation in the treatments of the medium fertilizer supply level.
Figure 16: The shoot length (cm per plant) and leaf number increment between the first salt application 30 days after planting, and the harvest. Shown are the mean values with standard deviations for organically and mineraly fertilized treatments of the medium supply level.

Table 10: Results of the Three Way ANOVA performed on data obtained for the shoot length and leaf number increment of plants of the medium fertilizer supply level. Shown are the P values for the factor effects, as well as significant (P < 0.05) interactions. The P values indicating a significant factor effect are printed in bold.

<table>
<thead>
<tr>
<th>Results of the Three Way ANOVA</th>
<th>Growth increment since the first salt application</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot length</td>
</tr>
<tr>
<td>D. pits vs. G. pods</td>
<td>0.829</td>
</tr>
<tr>
<td>Organic vs. Mineral</td>
<td>0.260</td>
</tr>
<tr>
<td>-NaCl vs. +NaCl</td>
<td>0.166</td>
</tr>
<tr>
<td>Interactions</td>
<td>-none-</td>
</tr>
</tbody>
</table>
3.4.2. Daily evapotranspiration from the planting pots

Curves showing the average daily evapotranspiration throughout the second part of the growth period did not reveal major differences between the treatments (Fig. 17).

![Graphs showing daily evapotranspiration for different treatments](image)

**Figure 17**: Average daily evapotranspiration from organically fertilized planting pots in ml per plant. Shown are the mean values.
Tendentially the planting pots containing soil amended with high amounts of organic material had a lower daily evapotranspiration than corresponding treatments of the medium or low fertilization level. In the +S treatments the daily evapotranspiration appeared to decrease compared with the corresponding –S treatments by the end of the growth period. Daily evapotranspiration did not seem to depend on the identity of the organic material.

The total evapotranspiration was larger for pots that contained soil amended with G.pods compared with D.pits, but there was no difference depending on the fertilization level (Fig. 18).

Figure 18: The total evapotranspiration during the second half of the growth period in ml per plant. Shown are the mean values with standard deviations for organically fertilized treatments (top), and treatments of the medium fertilization level (bottom).
Table 1: Results of the Three Way ANOVA performed on data for the total evapotranspiration in ml per pot obtained for organically fertilized treatments (top), and treatments of the medium fertilization level (bottom). Shown are the P-values for factor effects. Those indicating a significant (P < 0.05) effect, are printed in bold.

<table>
<thead>
<tr>
<th>Three Way ANOVA on data for organically fertilized treatments</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods (T)</td>
<td>0.022</td>
</tr>
<tr>
<td>Fertilization level (L)</td>
<td>0.190</td>
</tr>
<tr>
<td>Application of NaCl (S)</td>
<td>0.051</td>
</tr>
<tr>
<td>Interactions</td>
<td>-none-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Three Way ANOVA on data for treatments of the medium fertilization level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>0.198</td>
</tr>
<tr>
<td>Organic vs. Mineral</td>
<td>0.014</td>
</tr>
<tr>
<td>-NaCl vs. +NaCl</td>
<td>0.094</td>
</tr>
<tr>
<td>Interactions</td>
<td>-none-</td>
</tr>
</tbody>
</table>

When the plants of the medium fertilization level were compared, total evapotranspiration was higher for the mineraly fertilized treatments, compared with the organically fertilized controls (Fig. 18). Salt application or the identity of the organic amendment had no effect.

3.4.3 Water use efficiency and plant dry weight at the time of harvest

The water use efficiency (WUE) did not show a significant (P < 0.05, Three Way ANOVA) difference among the treatments (Data not shown).

Total plant dry weight, shoot dry weight, leaf dry weight and stem dry weight were not different depending on either of the three factors tested (P < 0.05, Three Way ANOVA). The plants had a dry weight of between one and two g, and tendentially the mineraly fertilized controls appeared larger compared with the organically fertilized treatment (Fig. 19 and 20).
The root dry weight was not different among the organically fertilized treatments (data not shown). However, when the treatments of the medium fertilization level were compared, minerally fertilized plants had a significantly ($P < 0.05$; Three Way ANOVA) higher dry weight compared with the organically fertilized treatments (Fig. 20). The application of NaCl appeared to increase the root dry weight slightly, but this effect was not significant ($P = 0.066$).
The shoot/root ratio was not affected by the type of organic material applied to the soil, or the level of the fertilizer application (Fig. 21, Tab. 12). Salinity, however, led to a decrease in the shoot/root ratio, irrespective of the type of fertilizer that was applied. This was mainly due to an increased root growth under salinity. Among the plants of the medium fertilization level, those that received mineral fertilizer had a lower shoot/root ratio compared with those that were organically fertilized. Salinity decreased the shoot/root ratio also in the minerally fertilized plants. Tendentially amendment with D. pits led to a higher shoot/root ratio. However, this effect was not significant.
Figure 21 The shoot/root ratio for the organically fertilized plants (top), and the treatments of the medium fertilization level. (Bottom) shown are the mean values with standard deviations.

Table 12: Results of the Three Way ANOVA performed on data for the shoot/root ratio obtained for organically fertilized treatments (top), and treatments of the medium fertilization level (bottom). Shown are the P-values for factor effects. Those indicating a significant ($P < 0.05$) effect, are printed in bold.

<table>
<thead>
<tr>
<th>Three Way ANOVA on data for organically fertilized treatments</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods (T)</td>
<td>0.268</td>
</tr>
<tr>
<td>Fertilization level (L)</td>
<td>0.117</td>
</tr>
<tr>
<td>Application of NaCl (S)</td>
<td><strong>0.004</strong></td>
</tr>
<tr>
<td>Interactions</td>
<td>-none-</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Three Way ANOVA on data for treatments of the medium fertilization level</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>D.pits vs. G.pods</td>
<td>0.494</td>
</tr>
<tr>
<td>Organic vs. Mineral</td>
<td><strong>0.004</strong></td>
</tr>
<tr>
<td>-NaCl vs. +NaCl</td>
<td><strong>0.016</strong></td>
</tr>
<tr>
<td>Interactions</td>
<td>-none-</td>
</tr>
</tbody>
</table>
Figure 22: The dry weight of the leaves that were lost over the growth period in g per plant. Shown are the mean values with standard deviations for treatments of the medium fertilization level (bottom).

3.5 Discussion and recommendation

This experiment aimed at testing the hypothesis that soil amendment with ground D. pits and P. pods would support plant growth as well as a mineral fertilization. Indeed there was no significant difference between mineral and organically fertilized treatments of the medium fertilization level in the total plant dry weight after harvest. The level of basic mineral fertilization supplied to soil that received organic amendments was very low, and it is unlikely that plants would have been able to grow up to 2 g of dry matter without mobilization of nutritional elements from the organic soil amendments. Our results thus suggest that ground D.pits and G.pods were able to supply plants with nutritional elements. On the other hand, plant growth remained largely unaffected by the fertilization level. Eventually plant growth was limited by a factor other than nutrient supply. Another explanation could be that microbial mobilization of nutritional elements from the organic material was not linearly correlated with the level of fertilization.

We hypothesized that G.pods would encourage plant development better than D.pits, due to its higher tissue concentration of nitrogen. However, no such difference was observed. On the contrary, plants fertilized with D.pits appeared to grow slightly
better compared with those amended with G.pods. It is possible that nitrogen was not a limiting factor for organically fertilized plants, or that D.pits delivered other beneficial effects in compensation.

When maize and barley plants were grown on D.pits of G.pods substrate, they were not well able to establish, most likely due to growth inhibitory compounds within the organic by-products (Chapter 2). Interestingly, none of the plants that received soil amendment by D.pits or G.pods appeared to be negatively affected in growth by harmful compounds in the soil. It is possible that soil bacteria quickly degraded harmful compounds within the D.pits and G.pods. Eventually dicotyledonous plants like S. trilobata are also less sensitive towards phenolic compounds in the soil. Future experiments need to test, how monocotyledonous plants like maize and barley would respond to soil fertilization with D.pits and G.pods.

At the time of harvest, organically fertilized plants that received D.pits had more leaves compared to treatments that received G. pods. The evapotranspiration showed obviously that the organic mater had a higher retention of the irrigated water comparing with the mineral treatments. In organically fertilized treatments the main results showed that the high level treatments had better (lowest) evapotranspiration and the saline treatments had a lower than the non-saline in all treatments and that may be due to the hydrophilic properties of NaCl. To which extent the organic mater enhanced the physical properties of the soil, such as aggregate stability and water holding capacity, needs to be investigated in future experiments. The water use efficiency (WUE) did not show differences among the treatments. Total plant dry weight, shoot dry weight, leaf dry weight and stem dry weight in all treatments had no significant differences, only root dry weight had a significant differences in two groups, mineral vs. organic treatments and medium organic treatment when D.pits vs. G.pods. Effects of organic matter in the soil on root growth are very variable, and depend on the type of organic soil amendment and plant involved. In our plants, root growth in relation with that of the shoot was decreased in response to organic fertilization. Whether growth inhibitory compounds, the level or nutrient availability, or mechanical factors were mainly responsible for this observation remains unknown. Salinity led to a decrease in the shoot/root ratio in this experiment. Such a response is relatively common in plants, as roots are often not as sensitive as shoots towards toxic effects of sodium and chloride. Other effects of salinity on plants were small, probably due to the relatively low salt application level.
When considering the dry weight as a fundamental indicator of the plant growth, it is suggested that the D.pits and G.pods could be a promising local organic fertilizer and it is recommended to apply them in a larger scale at a production plants. Further research could be conducted to examine the affect of the organic fertilizers in many approaches; such as applying it for longer periods, also it could be fermented (and compared to fresh organic fertilizers), also it could be examined on production of vegetables and forages. Further research could be conducted to examine the affect of a combination and overlapping of the two materials, especially in saline conditions. D.pits could be subjected to the two way fermentation (aerobic and anaerobic) as applied on the G.pods (first approach-third attempt). Two types of experiments could be conducted, the first is examining the productivity of the land beneath Ghaf trees under the condition of UAE, second is to sheet the soil beneath the Ghaf trees canopy with consideration of the depths, direction and plant specifications. Where the Ghaf trees is available in a large quantities in most regions in UAE in and its number is increasing; it is suggested that a national programme could be established to have a comprehensive projects consisting of three aspects, organising, research and extension, to have a clear view in investing in Ghaf trees. UAE has a widespread forest specialy in Abu Dhabi so it is a large opportunity to apply an organized agroforestry system, and it could have a significant proportion of the organic and healthy vegetables in the market, this idea is preferable to apply it under a well organized project by a governmental body with the respect of the environment aspect (with cosideration on to the conservation of the Ground water). Poschen (1986) mentioned that growing *Acacia albida* as a permanent tree crop, on farmlands with cereals, vegetables and coffee underneath or in between, is an indigenous agroforestry system in the Hararghe highlands of Eastern Ethiopia.
4. References


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First of all I would like to gratefully acknowledge the supervision of my advisor, Dr. Elke Neumann, who has been abundantly helpful and has assisted me in numerous ways. She was instrumental in me learning high standards of research ethics. I rarely felt that she is my advisor because of her humility; she was helping me for hours and even in the executive tasks. I especially thank her for her infinite patience. The discussions I had with her were invaluable. I would like to thank Dr. Safdar Muhammad the director of Master of Science in horticulture program for his support and cooperation. Special thanks to the external and internal reviewers Prof. Hameed J. Al Juburi, Dr. Moustafa A. Fadel and Dr. Mohamed Salman Al Hammadi for their important guidance and suggestions. I am also grateful to Mr. Saad K. Ismail, Mr. Rashid H. Abdul-Fattah, and Mr. Abou-Elmaged Elmatwally. I dedicate this thesis to my parents, wife and brothers for their encouragement. And very special thanks for Dr. Ghazi Alkaraki (Faculty of Agriculture, Jordan University of Science & Technology, Jordan) under whose guidance I chose this topic. My final words go to Dr. Mohamed Salman Al Hammadi for his encouragement to enroll in this master program, I would like to express my sincere gratitude to him.
برنامج ماجستير علوم البدان

إمكانية استخدام نوى نخيل التمر (Phoenix dactylifera pits) كوصفت زراعي، أو كمحسن لخصوبة التربة (Prosopis cineraria pods) الغاف.

سعيد خليفة الشعالي

باشر

د. إل. كاكا نيومن

إلى

جامعة الإمارات العربية المتحدة

كلية الأغذية والزراعة

استكمالاً لمتطلبات الحصول على درجة الماجستير في علوم البدان

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