# SUMMARY MASTER THESIS

UGent Soil Physics Group

Thesis (in Dutch) by Lennert Nachtergaele
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Department of soil management

UNIVERSITEIT GENT

## "*Suitability of potential soil conditioners in the sports sector*"

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Clubs that exercises sport on natural turf surfaces desire a high-quality playing surface. The quality of the pitch depends on the way it is constructed and maintained which in its turn depends on the allocated budget. Soil conditioners are often added to the top layer to increase certain soil physical, biological and/or chemical characteristics.

The objective of this this master thesis by L. Nachtergaele was trifold:

1. To map a series of soil conditioners available on the market and to list their proclaimed benefits and respective cost prices.
2. To study the effect of these soil conditioners on grass growth under greenhouse conditions.
3. To link the observed benefits of the soil conditioners to their unit price, application rate and the total budget required during sports turf construction.

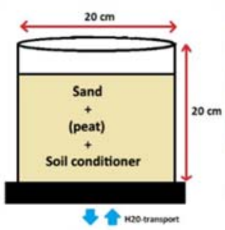
The TerraCottem® Turf soil conditioner was also included in the thesis research work and scored overall best. This document summarises the conclusions of that research work. Extra information is available as appendices or via info@terracottem.com.

## Trial work done at ILVO

**(Institute for Agricultural and Fisheries Research), Merelbeke, Belgium**

### 1. Trial set-up

- 33 treatments, with a total of 132 containers
- Each treatment = M32 - sand[1] + soil conditioner (+ peat[2])
- Control = M32 – sand + peat (90/10 – mix) + fertiliser[3].
- The soil conditioners can be classified as follows:
  - Organic soil conditioners: peat, GFT[4] – waste, coco fibre, dried sludge;
  - Inorganic soil conditioners: hydroabsorbant polymers, zeolite, lava, bentonite, diatomite;
  - Compound soil conditioners: **TerraCottem® Turf (TCT)**, biodress, cocodur;
- 8 parameters were analysed:
  - Grass growth (biomass production = grass clippings);
  - Root growth (biomass production);
  - Water Use Efficiency (biomass production in relation to water consumption);
  - Soil cover;
  - Microbiological activity;
  - Saturated hydraulic conductivity $K_s$;
  - Water retention capacity (WRC);
  - Bulk density;

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[1] Sand specially formulated for sports turf construction
[2] A mixture of 90/10 sand/peat, according to the Belgian Ganda criteria (see www.gandacriteria.be)
[3] A standard fertiliser with 20-3-5
[4] Biodegradable domestic waste from vegetables, fruits and gardens

## 2. Results

Below is the summary table presented by L. Nachtergaele at his master thesis dissertation. TerraCottem® Turf achieved a positive effect on 7 of the 8 parameters analysed and was overall best.

| Soil conditioner | Grass growth | Root Growth | WUE | Soil cover | Microbiology | Ks | WRC | Bulk density |
|---|---|---|---|---|---|---|---|---|
| Peat | neutral | neutral | neutral | neutral | neutral | positive | neutral | neutral |
| GFT - waste | positive | negative | positive | neutral | positive | positive | positive | positive |
| Coco fibre | neutral | neutral | neutral | neutral | neutral | neutral | neutral | neutral |
| Dried sludge | positive | negative | positive | neutral | neutral | neutral | neutral | positive |
| Polymers | positive | positive | positive | neutral | neutral | positive | positive | positive |
| Zeolite | positive | positive | positive | neutral | positive | positive | neutral | neutral |
| Lava | neutral | positive | neutral | neutral | neutral | positive | neutral | negative |
| Bentonite | neutral | neutral | neutral | neutral | neutral | neutral | neutral | neutral |
| Diatomite | neutral | positive | neutral | neutral | neutral | neutral | neutral | neutral |
| **TCT** | positive | positive | positive | neutral | positive | positive | positive | positive |
| Biodress | positive | positive | neutral | neutral | neutral | neutral | neutral | neutral |
| Cocodur | positive | neutral | positive | neutral | neutral | neutral | neutral | positive |

= positive effect    = neutral    = negative effect

### 2.1 Grass growth (biomass production = grass clippings)

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on biomass production:

- At 120g/m², more than double the amount of dry matter was observed as compared to the control substrate: **+205%**;
- At 240g/m²: **+241%**;

### 2.2 Root growth (biomass production)

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on root development: **+252%** as compared to the control in the 90/10 top layer;

### 2.3 Water Use Efficiency (biomass production in relation to water consumption)

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on water use efficiency:

- At 120g/m²: **+57%** as compared to the control in the 90/10 top layer;
- At 240g/m²: **+68%**;

### 2.4 Soil cover

When using the image analysing software, none of the soil conditioners showed a positive effect on soil covers although visual differences could clearly be observed. A possible explanation could be that the artificial lights in the greenhouse resulted in an overexposure of the images which "confused" the software.

### 2.5 Microbiological activity

The incorporation of TerraCottem® Turf **increased** the **soil biological activity**.

### 2.6 Saturated hydraulic conductivity Ks

Incorporating TerraCottem® Turf **increased** the **saturated hydraulic conductivity** of the top layer.

### 2.7 Water retention capacity (WRC)

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on the soil moisture characteristics:

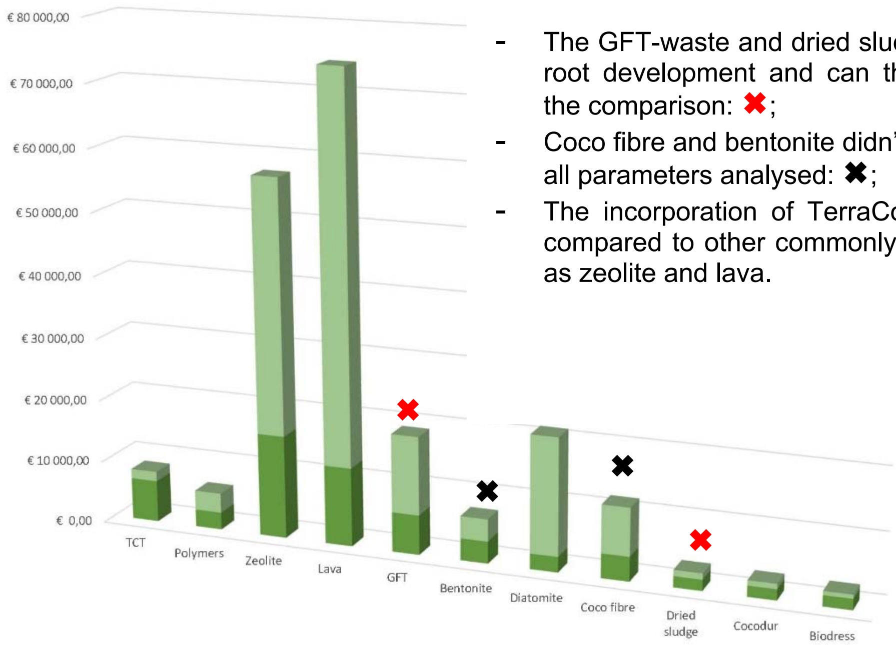
- At 120g/m²: an increase of **+84%** of the plant available water in the top layer;

### 2.8 Bulk density

The incorporation of TerraCottem® Turf **decreased** the **bulk density** of the top layer. This was true for most soil conditioners and may be due to the lack of play in the containers (which is present in field conditions).

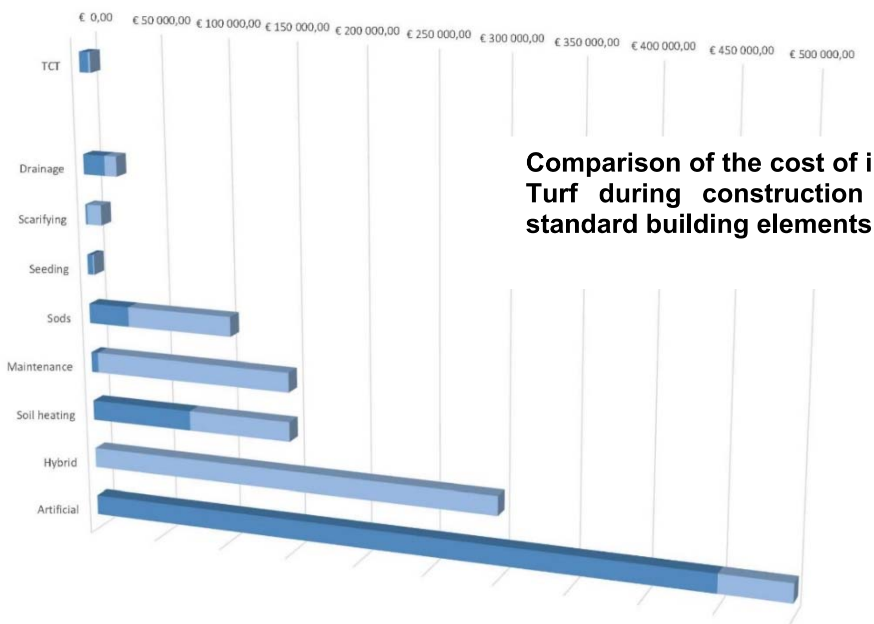
## 3. Cost / Benefit - Analysis

The prices used were those given by the manufacturers for each respective soil conditioner. Regardless of the examined parameters under "2. Results", L. Nachtergaele calculated the **application prices** taking into consideration the recommended minimum and maximum application rates:




- The GFT-waste and dried sludge had a negative effect on root development and can therefore be eliminated from the comparison: ✖;
- Coco fibre and bentonite didn't show any positive effect on all parameters analysed: ✖;
- The incorporation of TerraCottem® Turf is cost-effective compared to other commonly used soil conditioners such as zeolite and lava.

L. Nachtergaele interviewed a number of contractors in Belgium and asked them target prices for some common maintenance and construction criteria:




**Comparison of the cost of incorporating TerraCottem® Turf during construction of the pitch with other standard building elements and maintenance jobs.**

NATURE JUST GOT BETTER

## 4. Overall conclusion

**The research work done for this master thesis corroborates the cost-effectiveness of the soil conditioner TerraCottem® Turf in comparison to other commonly used soil conditioners.**

**APPENDICES**

"*Suitability of potential soil conditioners in the sports sector*"

## 1. Grass growth (biomass production = grass clippings)

### 1.1 Conclusion

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on biomass production:

- At 120g/m², more than double the amount of dry matter was observed as compared to the control substrate: **+205%**;
- At 240g/m²: **+241%**;

### 1.2 Method

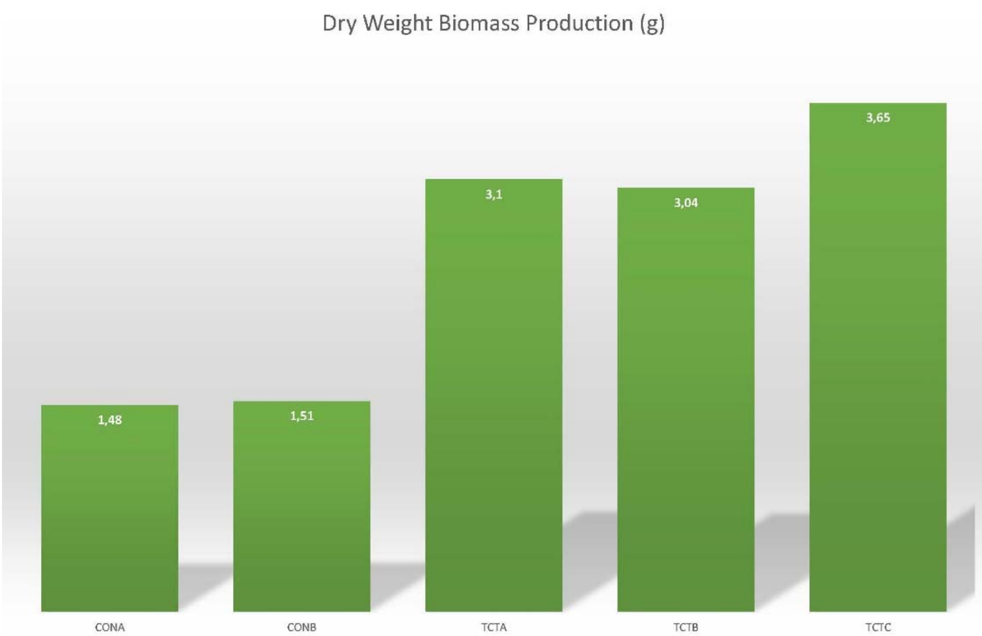
The grass was mowed on a weekly basis. The clippings were gather for each container and dried for 24h at 104°C. The cumulative dry weight biomass production per container was calculated at the end of the trial.

### 1.3 TerraCottem® treatments

| Treatments (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

### 1.4 Results




No significant effect ($P<0.05$) on dry weight biomass production was observed between the top layers with and without peat (CONB vs. CONA and TCTB vs. TCTA). The incorporation of TerraCottem® Turf significantly increased ($P<0.05$) dry weight biomass production (TCTA vs. CONA and TCTB vs. CONB). A double TerraCottem® Turf application rate further increased dry weight biomass production

2. Root growth (biomass production)

## 2.1 Conclusion

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on root development: **+252%** as compared to the control in the 90/10 top layer;

## 2.2 Method

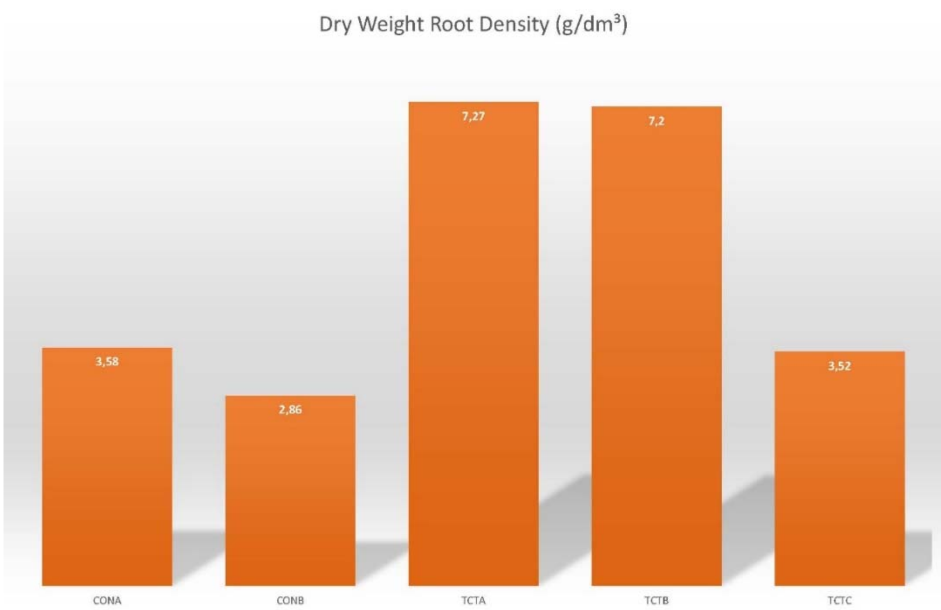
At the end of the trial, the containers were sampled with a hole cutter (Ø10cm = half the diameter of the containers). The root samples were washed over a 1.7mm sieve and dried for 24h at 104°C. The root density per container was calculated in g/dm³.

## 2.3 TerraCottem treatments

| Treatments (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

## 2.4 Results

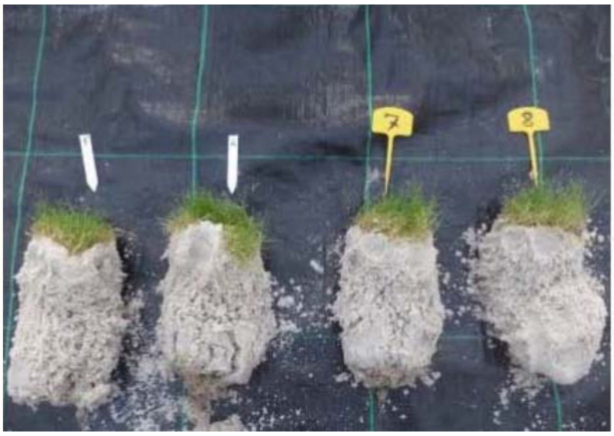



No significant effect ($P<0.05$) on dry weight root density was observed between the top layers with and without peat (CONB vs. CONA and TCTB vs. TCTA). The incorporation of TerraCottem® Turf significantly increased dry weight root density (TCTA vs. CONA and TCTB vs. CONB). A double TerraCottem® Turf application rate seemed to have no effect on dry weight root density.

The pictures below show the samples before washing. The CONA samples totally lacked structure: the loose sand fell from the root samples. Although the addition of peat seemed to have no effect on dry weight root density, the CONB samples seemed to keep their structural integrity better. This effect became even more apparent when TerraCottem® Turf was present in the top layer, both with peat (TCTB) and without peat (TCTA). The best structure was observed when a double application rate of TerraCottem® Turf was used (TCTC).


CONA


CONB




TCTA


TCTB


TCTC

## 3. Water Use Efficiency (biomass production in relation to water consumption)

### 3.1 Conclusion

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on water use efficiency:

- At 120g/m²: **+57%** as compared to the control in the 90/10 top layer;
- At 240g/m²: **+68%**;

### 3.2 Method

The Water Use Efficiency (WUE) is the ratio of the amount of dry weight biomass production in relation to the Water Use:

$$\frac{Dry\ Weight\ Biomass\ Production\ (g)}{Water\ Use\ (l)}$$

- **Dry Weight Biomass Production**
  The grass was mowed on a weekly basis. The clippings were gather for each container and dried for 24h at 104°C. The cumulative dry weight biomass production per container was calculated at the end of the trial.

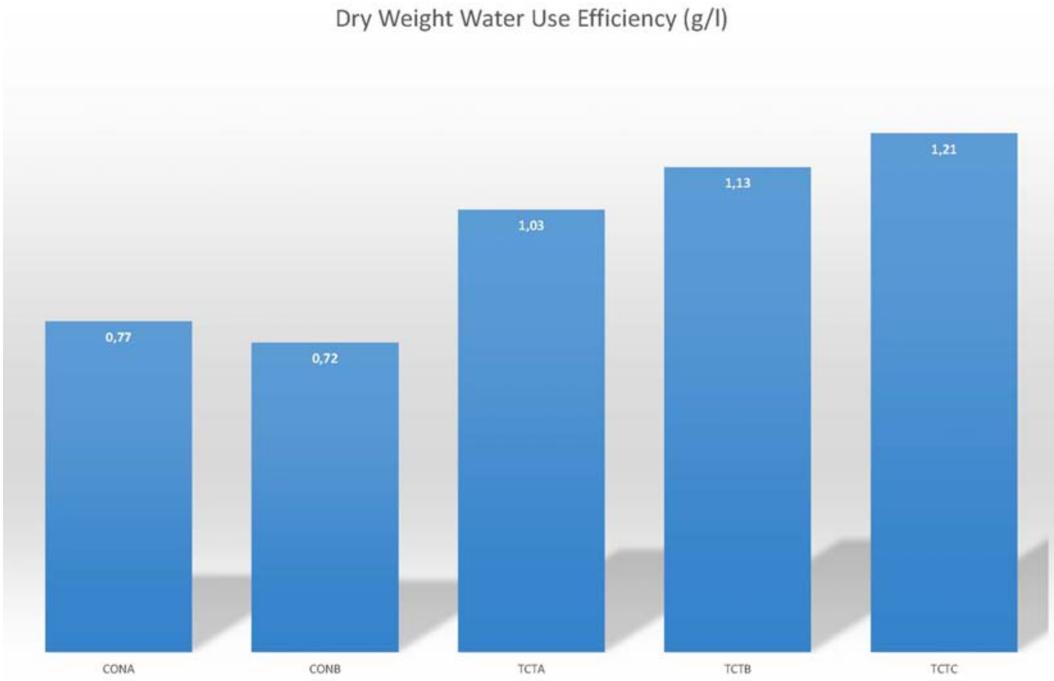
- **Water Use**
  At the start of the trial, all containers were saturated for 24h. Afterwards, 24h was waited (allowing free drainage of the excess water) and the containers were weighted. This weight = 100%. During the trial, the containers are weighted on a regular basis. As water is lost due to evapotranspiration, the weight of the containers gradually drops. When the weight drops under 70% of the starting weight, water is applied until the containers reach 90% of the initial weight. The cumulative amount of irrigation water is calculated as such.

### 3.3 TerraCottem treatments

| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

**3.4 Results**




No significant effect ($P<0.05$) on dry weight water use efficiency was observed between the top layers with and without peat (CONB vs. CONA and TCTB vs. TCTA). The incorporation of TerraCottem® Turf significantly increased the water use efficiency (TCTA vs. CONA and TCTB vs. CONB). Incorporating more TerraCottem® Turf further increased the dry weight water use efficiency (TCTC vs. TCTB).

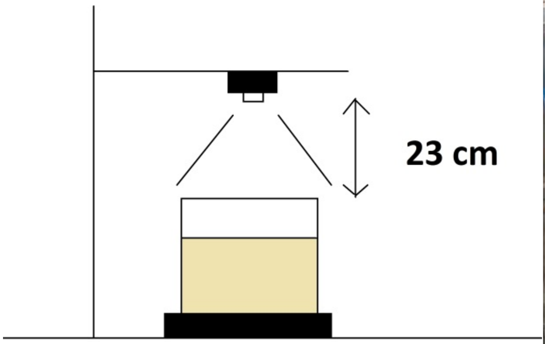
## 4. Soil cover

### 4.1 Conclusion

When using the image analysing software, none of the soil conditioners showed a positive effect on soil covers although visual differences could clearly be observed. A possible explanation could be that the artificial lights in the greenhouse resulted in an overexposure of the images which “confused” the software.

### 4.2 Method

During the trial, the grass was cut at regular intervals. After cutting, a digital picture was taken at a fixed height of 23cm.



The photos were analysed using the “GreenCropTracker” software. This software calculates the “green cover fraction” (or “vegetation fraction VF”). This is the rate of cover in each container based upon a histogram – based threshold value. The parameters were calculated:

- $VF^{3}$ (%): the cover, 3 weeks after seeding;
- $VF^{10}$ (%): the cover, 10 weeks after seeding;
- $VF^{50\%}$: the number of weeks until the cover in the container reaches 50%;

### 4.3 TerraCottem treatments

| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

### 4.4 Results

In most cases, no significant differences were observed ($P<0.05$) on $VF^{3}$, $VF^{10}$ nor $VF^{50\%}$. As mentioned above, a possible explanation could be that the artificial lights in the greenhouse resulted in an overexposure of the images which “confused” the software.

## 5. Microbiological activity

### 5.1 Conclusion

The incorporation of TerraCottem® Turf **increased** the **soil biological activity**.

### 5.2 Method

There is a direct relationship between the microbiological biomass and the microbiological activity in the soil. The latter affects the nutrient release in the soil and thus grass growth.

The method used in this trial is “fumigation”. Simply put, during this treatment organic carbon is released which is coming from the cells of the microorganisms, using the formula below:

$$C_{microbial}\left(\frac{mg}{kg\ dry\ soil}\right) = \frac{C_{microbial}\left(\frac{\mu g}{L}\right)\times(V_{extract}(L) + V_{in\ soil}(L))}{DS(g)}\times K_c\times 1000 \quad [8]$$

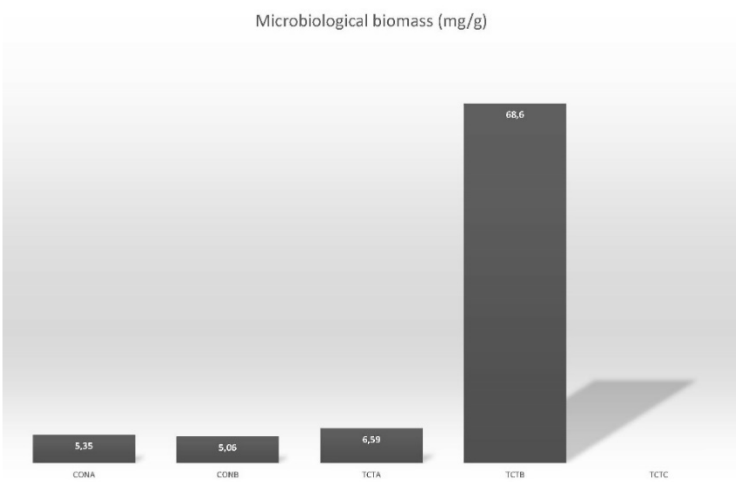
### 5.3 TerraCottem treatments

| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

### 5.4 Results

Not all results could be used in the data analysis due to errors or “impossible” outcomes[5] (for example, the results of TCTC). Furthermore, high standard deviations were observed between the different treatment.




No significant differences (P<0.05) were observed between the microbiological activity in the top layers with and without peat (CONB vs. CONA), which is “strange” because one would expect that the addition of organic material (peat) would increase the microbiological development.

Incorporating TerraCottem® Turf significantly increased (P<0.05) the microbiological biomass production (TCTA vs. TCTB). Especially in the top layer with peat, the increase is spectacular (TCTB vs. CONB).

[5] This can be due to incomplete fumigation or the presence of roots that needed to be removed in advance.

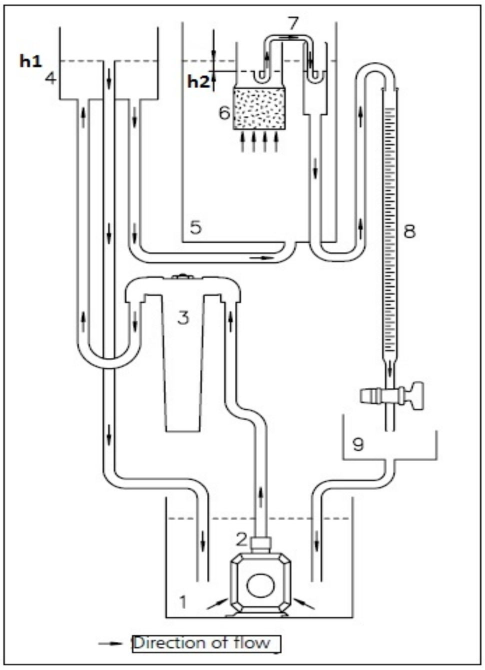
## 6. Saturated hydraulic conductivity $K_s$

### 6.1 Conclusion

Incorporating TerraCottem® Turf **increased** the **saturated hydraulic conductivity** of the top layer.

### 6.2 Method

The capacity of a soil to let water pass through is called the permeability. This is measured by placing soil samples (in Kopecky rings) in a laboratory permeameter:




This device is specifically designed to measure the saturated hydraulic conductivity $K_s$. The saturated samples (1) are placed under the influence of a constant water head (2). An upward water flow (3) is forced through the samples based upon the law of communicating vessels. The $K_s$ (m/s) can be calculated using the formula:

$$K_s = Q \frac{L}{\Delta h \, A} \quad [4]$$

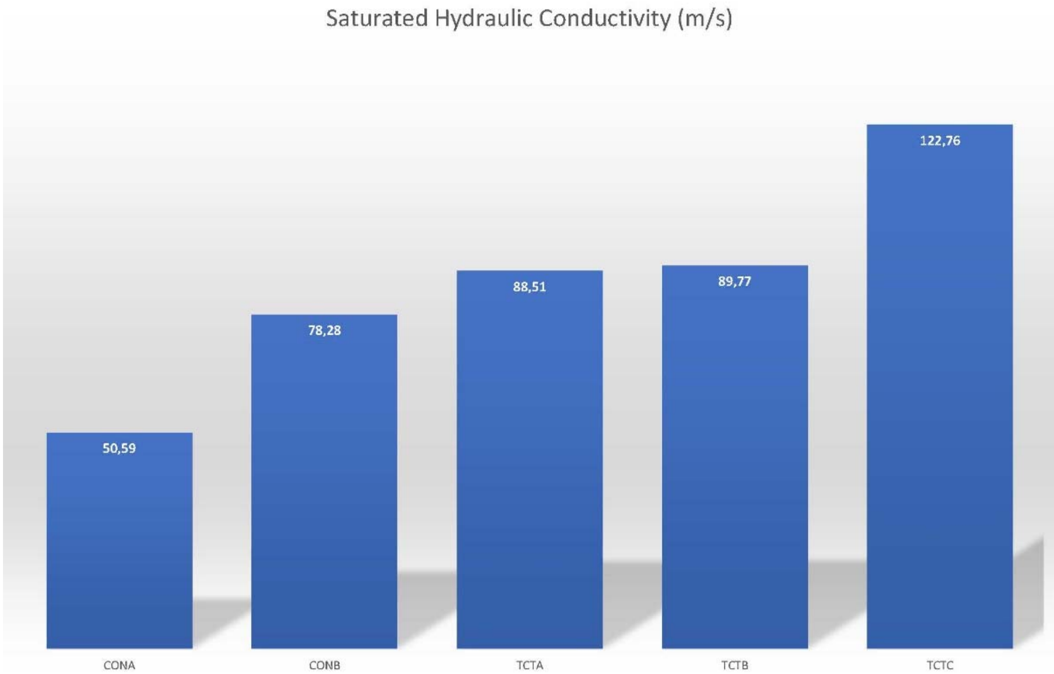
in which, Q is the flow rate (m³/s), ∆h the height difference (m), L the length of the soil sample and A its surface area (m²). A correction needs to be made for the water temperature.

### 6.3 TerraCottem treatments

| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

**6.4 Results**




The addition of peat significantly increased ($P<0.05$) the saturated hydraulic conductivity of the control top layer (CONB vs. CONA). The same is true for the incorporation of TerraCottem® Turf, both in the top layer with (TCTB vs. CONB) and without (TCTA vs. CONA) peat. When a double application rate of TerraCottem® Turf was used, the saturated hydraulic conductivity increased even further (TCTC vs. TCTB).

## 7. Water retention capacity (WRC)

### 7.1 Conclusion

TerraCottem® Turf showed a significant ($P<0.05$) positive effect on the soil moisture characteristics:

- At 120g/m²: an increase of **+84%** of the plant available water in the top layer;

### 7.2 Method

Water in the soil in subjected to different forces: capillarity, gravitation, adhesion, cohesion and osmosis. These determine the water availability for the plants and are expressed in the “matrixpotential”. The relation between the matrix potential (or pressure height h) and the volumetric soil water content $\theta_v$ is called the moisture retention curve or “pF – curve).

The containers were sampled and these samples were placed on a sand bed to which different pressures were applied: -10, -30, -50, -70 and -100 cm. After equilibrium and at each pressure, the volumetric moisture content was measured by weighing the samples. The same was done at bigger pressure, but now the samples were placed in between pressure plates. The mathematical model of van Genuchten was used to fit the datasets and plot the pF – curves, using the MATLAB software.

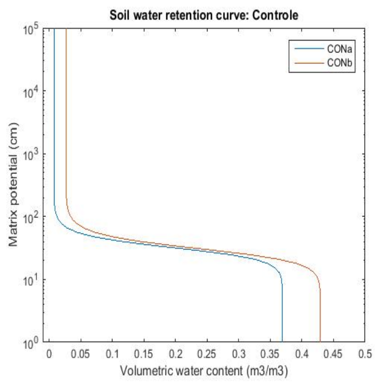
The moisture content at “field capacity FC” (pF = 2) and “wilting point PWP” (pF = 4.2) can be determined from these graphs. Furthermore, the “plant available water PAWC” is calculated as the difference in moisture content between FC and PWP: all moisture below FC (free drainage) and above PWP (bounded to strongly in the soil) is not accessible for the grass roots.

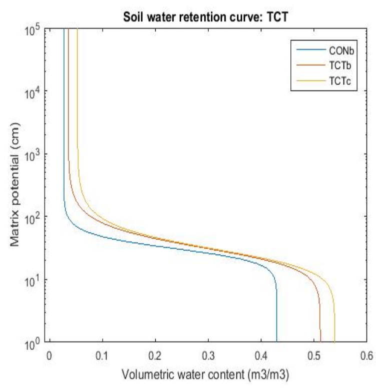
### 7.3 TerraCottem treatments

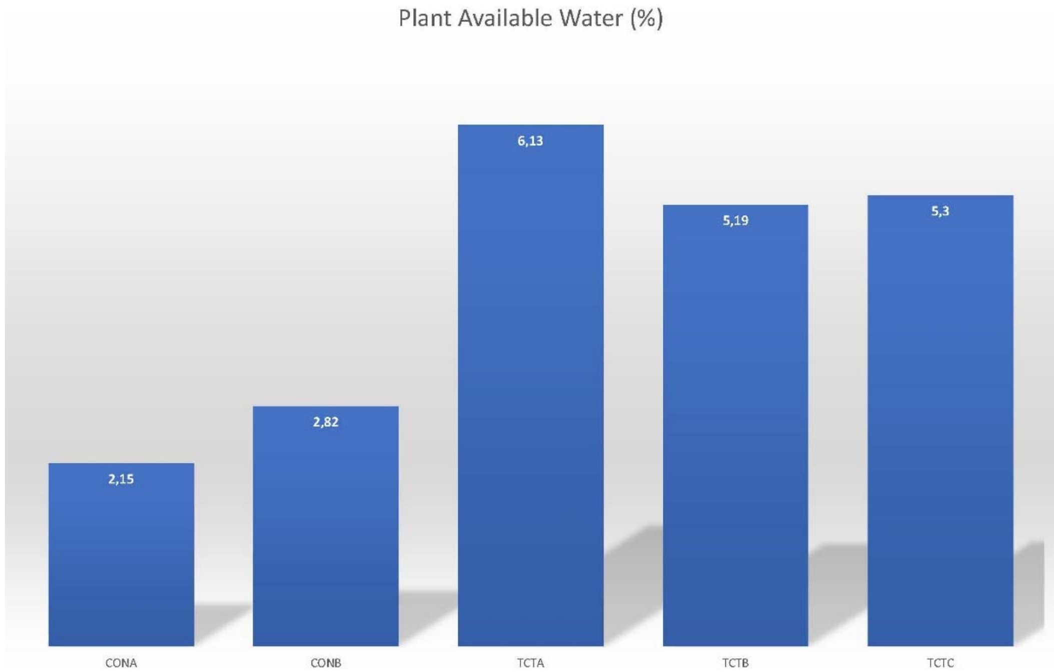
| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

### 7.4 Results






The addition of peat increased the plant available water (CONB vs. CONA), however non-significantly ($P<0.05$). On the other hand, incorporating TerraCottem® Turf almost tripled the PAW in the sandy top layer (TCTA vs. CONA) and almost doubled the PAW in the 90/10 top layer (TCTB vs. CONB). A double application rate seemed to have no extra effect on PAW.

# 8. Bulk density

## 8.1 Conclusion

The incorporation of TerraCottem® Turf **decreased** the **bulk density** of the top layer. This was true for most soil conditioners and may be due to the lack of play in the containers (which is present in field conditions).

## 8.2 Method

The bulk density (in g/cm³) can be calculated as the dry mass of the soil (in g, soil samples dried at 105°C for 24h) per volume (in cm³):

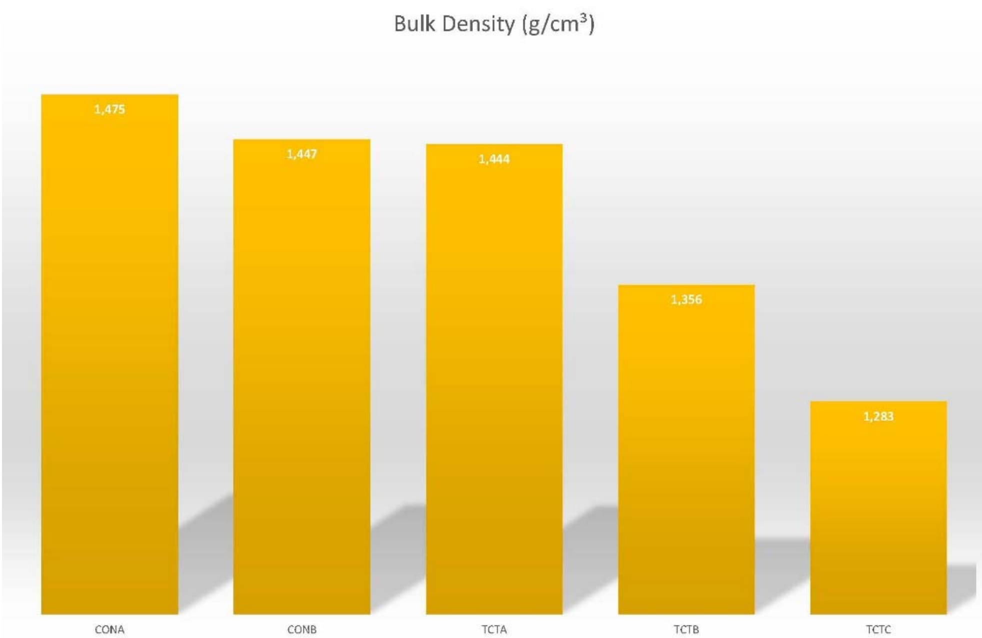
$$\rho = \frac{m_s}{V} \quad [1]$$

## 8.3 TerraCottem treatments

| **Treatments** (*) | M32 sand | Peat | TerraCottem Turf |
|---|---|---|---|
| **CONA** | 100% | - | - |
| **CONB** | 90% | 10% | - |
| **TCTA** | 100% | - | 120g/m² |
| **TCTB** | 90% | 10% | 120g/m² |
| **TCTC** | 90% | 10% | 240g/m² |

(*) All treatments followed a standard fertilisation regime with a liquid 20-3-5 fertiliser.

## 8.4 Results




The addition of peat significantly decreased (P<0.05) the bulk density of the top layer (CONB vs. CONA). The same is true for the incorporating of TerraCottem® Turf (TCTA vs. CONA and TCTB vs. CONB). Finally, a double TerraCottem® Turf application rate further significantly decreased (P<0.05). the bulk density (TCTC vs. TCTB).