# Functionality, Appearance and Water Purification Rates of Perfused Vegetation Mats for Water Treatment at Private Swimming Ponds

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## Introduction, problem statement and objective

Swimming ponds are advancing in Austria and Germany as an ecological and economical alternative to swimming pools treated with chemicals (GRAFINGER 2004). To get clear water, nutrient content is minimised by artificial circulation through natural filtration systems (FLL 2004 & 2006). The successful water purification is guaranteed more by substrates than by plants. In current swimming ponds mainly helophytes from eutrophic sites are used, showing nutrient-deficiency-symptoms as a result of high purification rate due to strong filtration (KIRCHER 2007).

The aim of this investigation was to evaluate an experimental set-up testing different oligo- and mesotrophic planting variants. There are relatively few helophytes from oligotrophic natural sites growing submerse or in shallow water, and these species mainly are difficult to cultivate (KIRCHER 2005). Pilot projects proved that oligotrophic and mesotrophic marginal vegetation with emerged plants from acid bogs, transition bogs and lime-fens are suitable as emerse marginal planting zones on top of submersed gravel filters (KIRCHER 2007).

Planning and construction of swimming ponds in private gardens is difficult because of limited space. Most potential owners of private swimming ponds enjoy the framework of plants around the bathing area. A new trend seems to establish swimming ponds, optical similar to pools, with clear structure but purified in a biological way without vegetation (WEIXLER 2004).

A three year lasting trial was established to prove that plant mixtures with low demands on nutrients are suitable for private swimming ponds. These plant mixtures are tested as perfused shallow vegetation mats as a roof garden for water purification. The research is funded by the Federal Ministry of Education and Research (BMBF), two industrial partners (Petrowsky wetland-plant nursery and HELD Teichsysteme) and is situated on the campus of Anhalt University of Applied Sciences (**Figure 1**: roof garden as external filter zone for private swimming ponds).

## Methods of the Research

Plant mixtures from mesotrophic and oligotrophic natural sites were designed. These plant mixtures are established as thin layered vegetation mats on shallow boxes combined with a water reservoir (**Figure 2**: section of the perfused roof garden trial). The water reservoir resembles the swimming pond. Water from the miniature swimming pond is pumped into the flat boxes and water perfuses the plant mixture and the water purification rate is tested during a three year trial. (**Figure 3**: trial perfused vegetation mats) Following plant variants are tested:

- lime fen on coconut fibre
- lime fen on wood fibre
- eutrophic meadow

These variants were compared with two conventional variants of roof garden systems and an unplanted perfused variant.

- coconut mat (perfused)
- gravel roof (not perfused)
- sedum roof (not perfused)

The gravel roof and the sedum roof are not perfused by water. These variants being a common way for roof gardening are used for comparing the results of the visual rating. The coconut mat is perfused as a wet variant without plants to have a comparison about the water purification rates.

Methodology of trials concerning functionality and Aesthetical value

| Degree of coverage of the plot | Vitality of the plot | Aesthetical value rated according to MESSER (2008) | Secchi depth |
|---|---|---|---|
| The coverage of every variant was rated. The results were investigated by descriptive statistic. | The statistical operations were the same like | 20 probands graded the variants in ten calendar weeks in 2008. Based on the calculated Median the average value of each vegetation type | The Secchi depth was measured by filling a 300 cm transparent tube until the secci disc on the bottom of the tube was invisible. Tests proved |

| | | | |
|---|---|---|---|
| Contingency tables were created. | "Coverage of the plot". | was calculated. The annual aspects and the monthly values are presented. | that the tolerance to the measurement by secci disc is below 3 %. |

Methodology of trials concerning water quality

| pH-Value, conductivity, water hardness | Acid capacity | Phosphorus, nitrate and ammonium concentrations |
|---|---|---|
| pH-Value, conductivity and Hardness were measured ten times during 2008. | Carbonat hardness was measured ten times in 2008. Acid capacity is calculated by the carbonat hardness. | All dissolved anions and captions were examined four times in 2008 by a Ion Chromatograph (concentration of more than 1 mg/l are detectible) |

Due to the low amount of recurrences only descriptive statistical operations were used. All statistical tests were performed by using SPSS 16 (BACKHAUS et al. 2006).

## Results

Functional aspects

Degree of vegetation coverage

The degree of the vegetation coverage of the vegetation in the plots was rated in %. The values are shown in figure 4.

The coverage of the all four plots increased during the first and second evaluation period. The lime fen on wood fibre continued to increase the coverage during the second and the third evaluation. In this time period the degree of the vegetation coverage of all other variants stagnated or declined but clearly not lower or close to the origin.

Vitality of the plots

The results of the vitality rating were divided into the following categories: Undersupply with nutrients, optimal and excessive growth (figure 5). Considering the sedum variants, the rate of excessive growth was 100%. 38% of the lime fen vegetation on coconut fibre variants was evaluated within category of undersupply with nutrients. 72% of the evaluated rates allocated the lime fen on coconut fibre variants an optimal supply of nutrients. 61 % of the lime fen on wood fibre variants had deficient nutrition distribution, and 39% had an optimal supply with nutrients. The variants of the eutrophic fen were evaluated with 55 % undersupply with nutrients; the rest was assessed receiving the optimal amount of nutrients.

## Results of aesthetical investigations

The ratings on aesthetical appearance ranged from 1 to 9. This scale was divided into intervals. The grades from 1 to 3 represent a negative subjective aesthetical impression. Grades from 4 to 6 indicate an acceptable perception, and grades from 7 to 9 reflect a positive aesthetical appearance. The assessment was done by non professionals according to MESSER (2008).

### Monthly Aesthetical impression

The Median for each plant variant for every month was calculated, the lowest and highest rate are mentioned in brackets.

The variants of perfused coconut mat were rated 1 [1;4]. The appearance of the gravel roof was expressed by a median ranging from 2 to 3 [1;7]. The monthly rating of the appearance of the plots with the sedum roof varied between 4 and 7 [2;9]. The plots of the lime fen on coconut fibre variants were rated between 3 and 5 [2;9]. The grades of the plots for the lime fen and wood fibre variants varied between 3 and 6 [1;9]. The eutrophic fen received medians between 2 and 5 [1;9] (figure 6).

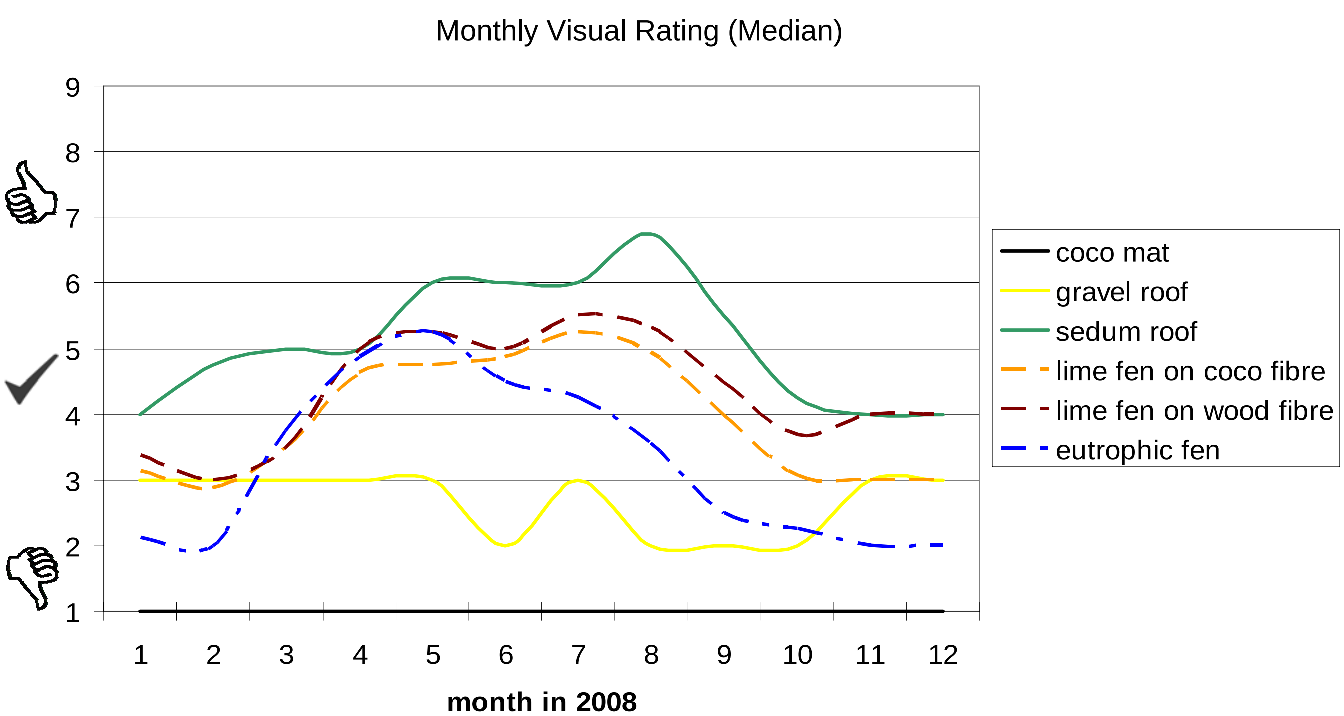


**Figure 6: monthly non professional rating**

## Results of water quality measurements

### Secci Depth

The results of the Secci Depth measurement is shown in table 1. The Coconut variant had the lowest and the variants of the eutrophic fen had the highest Secci Depth.

**table 1: Percentage of hits in four Secci Depth categories**

| | Secci Depth | | | | |
|---|---|---|---|---|---|
| Plant mixture | ≤ 99 cm | 100 – 199 cm | 200 – 299 cm | ≥ 300 cm | Total |
| Coconut mat | 75 % | 25 % | 0 % | 0 % | 100 % |
| Lime fen on coconut fibre | 19 % | 31 % | 42 % | 8 % | 100 % |
| Lime fen on wood fibre | 13 % | 22 % | 33 % | 32 % | 100 % |
| Eutrophic fen | 0 % | 31 % | 31 % | 38 % | 100 % |

### pH value

According to the FLL (2006) the critical pH value is 6-9. Only 5 % of the coconut mat variants had a pH value of more than 9. The other variants were in the critical value of the FLL guidelines. The values varied between 7.41 and 10.51 pH.

### Acid capacity

The FLL (2006) recommends an acid capacity higher than 2 mmol/l. All the variants had a lower acid capacity. The results varied between 0.064 and 0.51 mmol/l.

### Phosphorus

The critical value of the concentration of total phosphorus is < 0,01mg (FLL 2006). Dissolved Phosphorus was not traceable in the water of any variant.

### Conductivity

FLL (2006) states a critical value of conductivity less than 1000 µS. All the tested variants had lower results varying between 162 and 363 µS.

### Nitrate

The FLL (2006) determine a critical concentration of nitrate less than 50 mg/l. All measurements showed lower values. The results varied between 0.01 and 0.2 mg/l.

Ammonium

FLL (2006) determines a concentration below 50 mg/l Ammonium as the limit for refill. All measurements showed lower values ranging between 0.06 and 0.17 mg/l

Water hardness

FLL (2006) suggests values of water hardness higher than 1mmol/l for public and private swimming ponds. 65% of the measurements of the coconut mat variant showed values lower than 1 mmol/l. For the lime fen variants on coconut fibre the percentage was 45%, for the lime fen on wood fibre 50%, and for the eutrophic variants 30% of the measurements were below 1 mmol/l (Figure 7).

## Discussion

The results of the trial show that installing perfused shallow mats as regeneration zones for private swimming ponds is practicable. We could prove that even with these filter systems it is possible to produce oligotrophic water, shown by low nitrate and ammonium concentrations like in conventional swimming ponds. All variants adapted well to the oligotrophic situations but especially the last measurements on degree of coverage and vitality indicate that the plots of the eutrophic fen variants begin to show symptoms of nutrient deficiency. The lime fen variants showed the best values of coverage, they adapted well to the oligotrophic situation and had high expansion rate. The eutrophic vegetation did not show the deficiency symptoms, immediately. This was because the plants seemed to be able to extract nutrients from flushing water much better than from standing water (SCHWOERBEL 1987; KIRCHER 2008). Appearance of the eutrophic fens was similar to the lime fen variants in the beginning of the year. In autumn the eutrophic fen is less attractive due to the flowering season of Allium *cernuum* and Allium *suaveolens*. It seems that the eutrophic variants were more invasive and therefore they lost the attraction. The weaker plants of the lime fens seemed to keep a better structure with clear visible relief in the late summer.

Comparing the perfused mats, the lime fen plots were supplied with nutrients best and showed the best results for the annual aesthetical appearance as well. The variant ‘lime fen on wood fibre’ seemed to develop better than the variant on coconut fibre. The investigations on the Secchi depth showed better results for the lime fen variant on wood fibre, compared to the variant on coconut fibre. The Secchi depth was always higher in planted variants giving evidence of the importance of the chosen vegetation on shallow purification filters.

The critical values determined by the FLL (2003) are considered for public facilities. These facilities make great demands on the natural purification as needed for private swimming ponds. Even the variants not meeting these thresholds, were not at risk of loosing their functionality concerning limpidity as being expressed by the measurements on Secchi depth, provable phosphate concentration, and low concentrations of nitrate and ammonium. The lime fen variants lead to a very recommendable design concept for private swimming ponds with oligotrophic water.

## Conclusion / Forecast

Planting combination with species of lime fen communities seemed to be suitable for shallow substrate wet roof garden vegetation with the function of a swimming pond filter. The lime fen variant needs to be tested in a higher amount of repetitions. Pilot facilities should be installed to investigate the optimal benefit, precisely compared with cooling roofs (POSSMANN 1993). During the trials the cooling effect of perfused roof garden vegetation was pretested and first results were encouraging. Accurate measurements and statistical analyses should help in estimating the practical use of swimming pond filters for roof insulation. The roof planting should also help in cooling the buildings in summer. Considering climate change, the installation of water bodies in urban landscape might contribute to improve life quality as well (ABROMAS, GRECEVICIUS, MARCIUS 2007; KUCINSKIENE, MALAKAUSKIENE 2007).


## Summary

During a three year trial six perfused vegetation variants showed encouraging results for an application of biological filters for private swimming ponds. Functionality, aesthetical appearance and purification rates compared to German guidelines were investigated. Plant mixtures derived from lime fen vegetation lead to a very recommendable design concept for private swimming ponds with oligotrophic water (table 2).


## Literature


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## Figures:

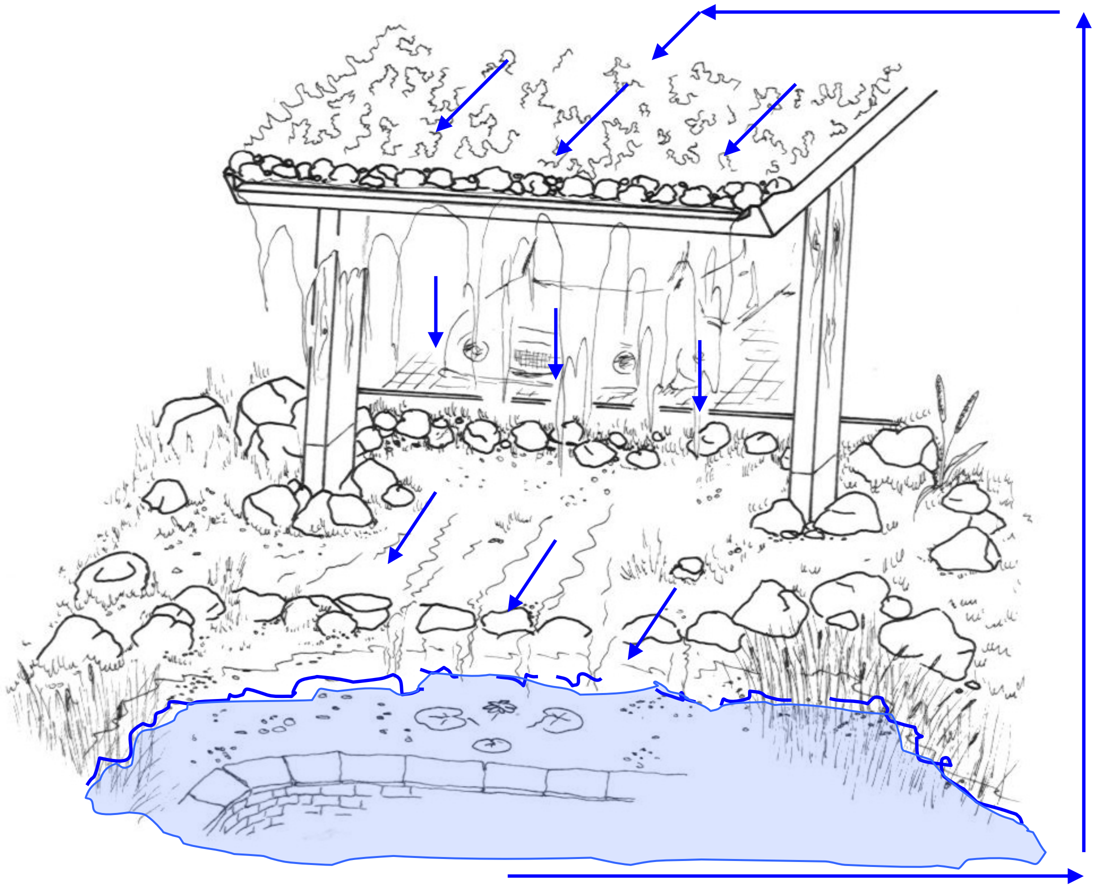

**Figure 1: roof garden as external filter zone for private swimming ponds (WEINREICH, 2005)**

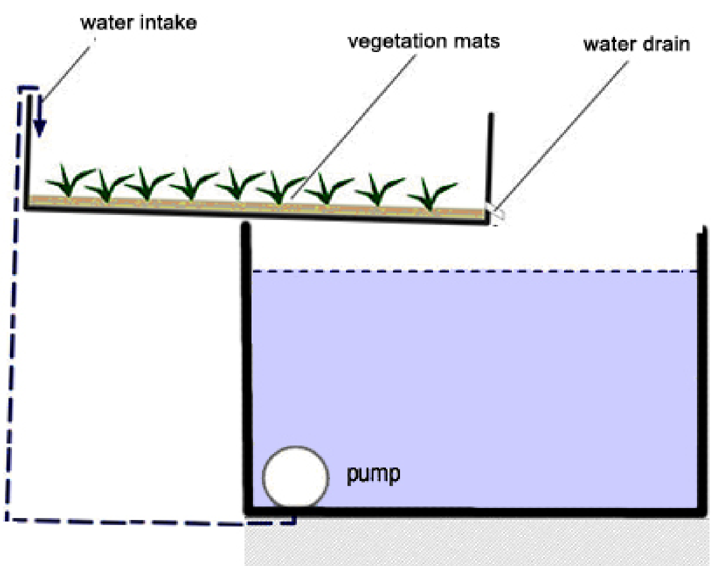


**Figure 2: section of the perfused roof garden trial**

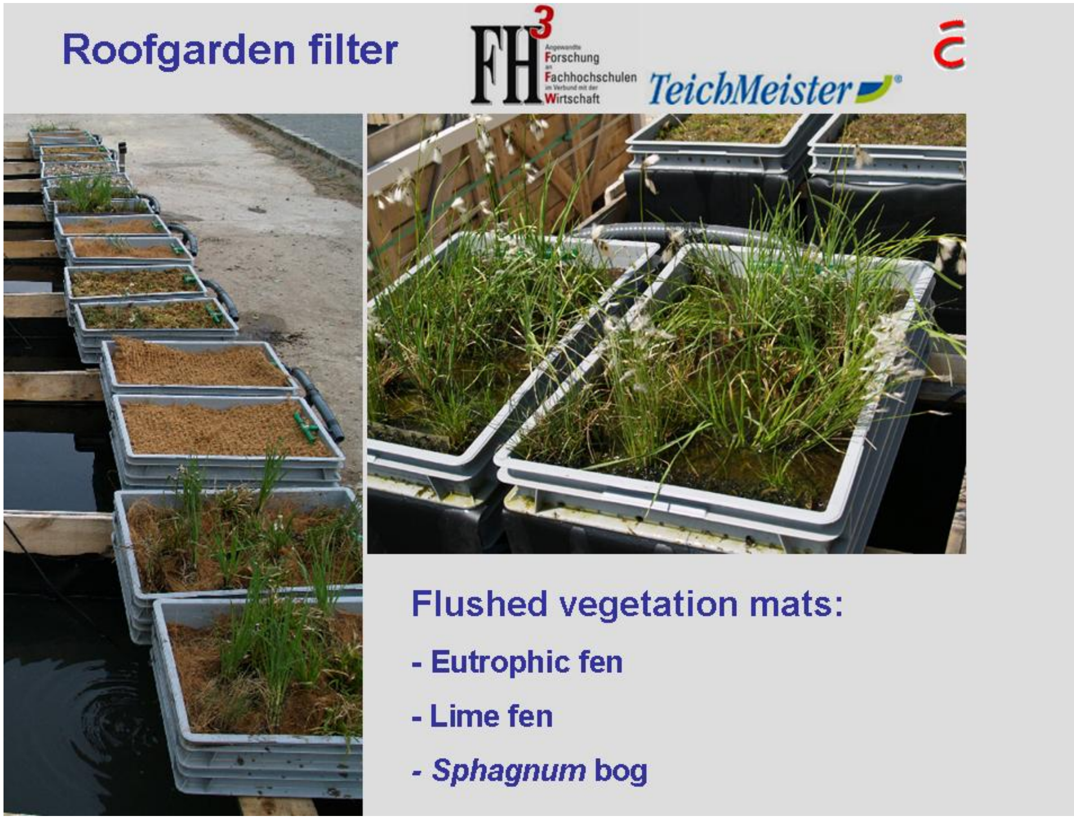


**Figure 3: trial perfused vegetation mats**

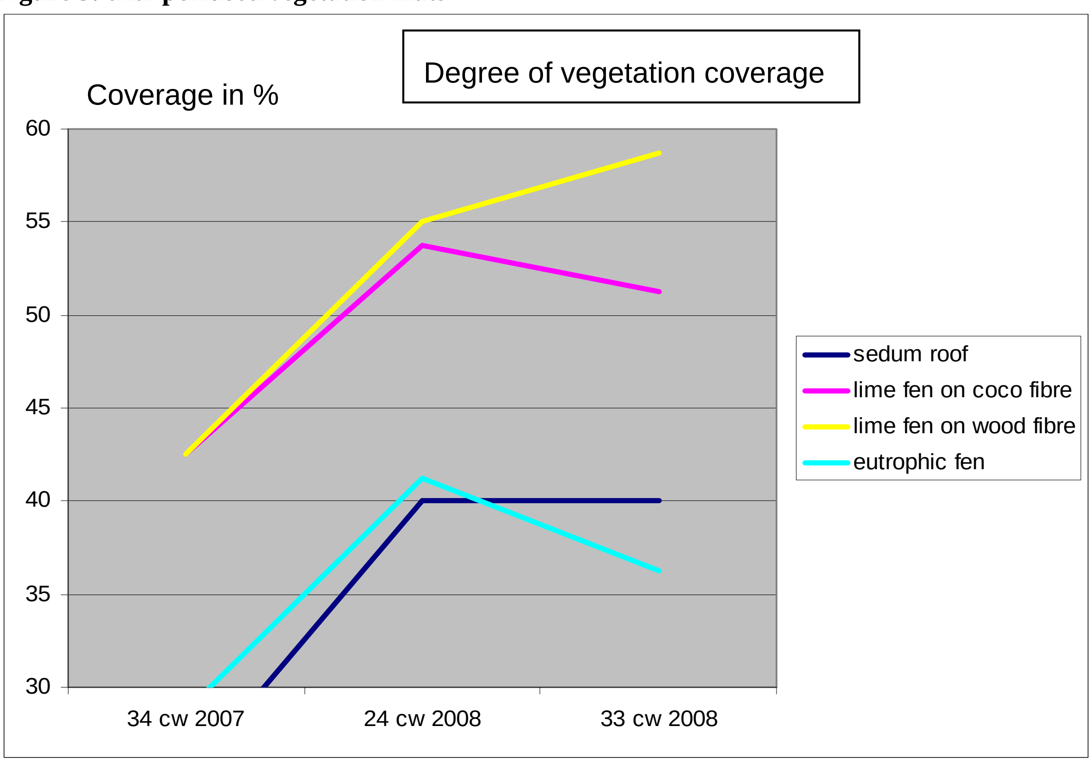


**Figure 4: coverage of the plots in calendar weeks (cw)**

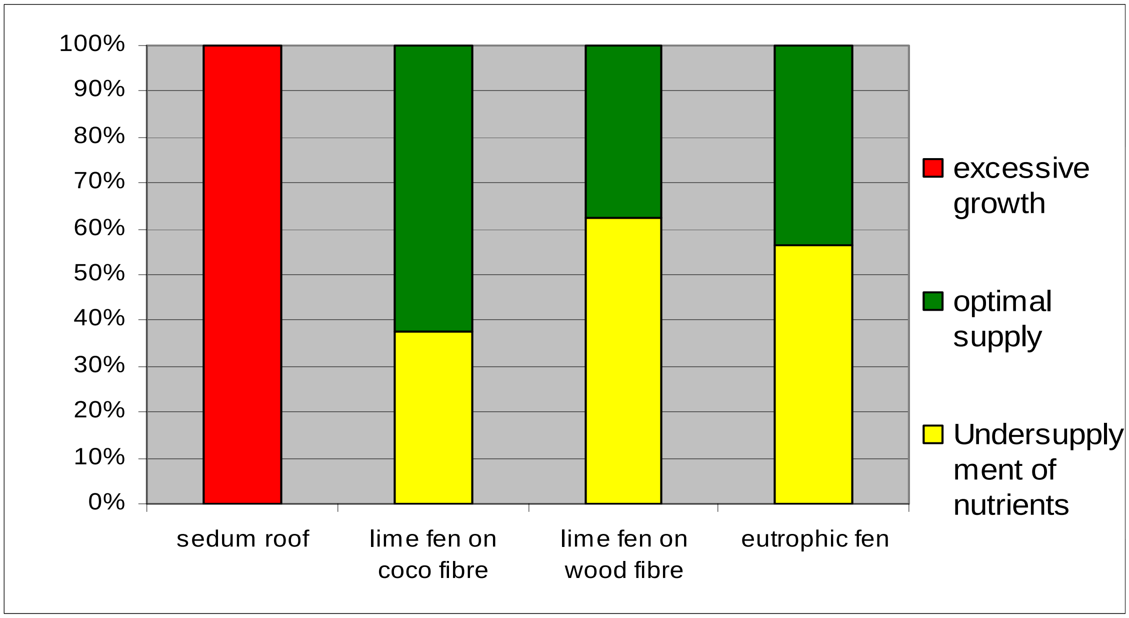


**Figure 5: Vitality of the plots**

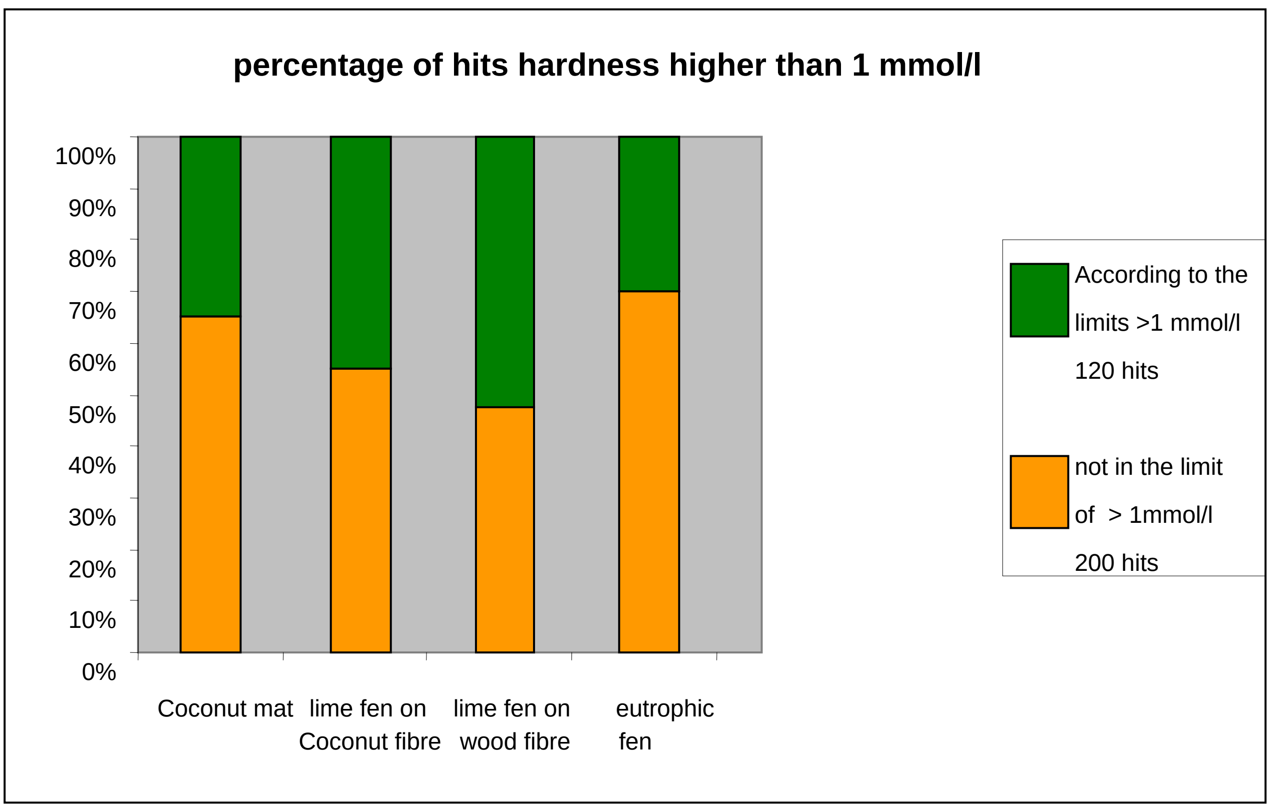


**Figure 7: water hardness**

**Table 2: Plant mixtures**

| **Plant mixture for lime fen variant** | **Plant mixture for eutrophic fen** |
|---|---|
| Allium *angulosum* | Thelypteris *palustris* |
| Allium *cernuum* | Lysimachia *nummularia* |
| Carex *davalliana* | Caltha *palustris* |
| Carex *viridula* | Lythrum *salicaria* |
| Eriophorum *latifolium* | Carex *diandra* |
| Allium *suaveolens* | Typha *minima* |
| Blysmus *compressus* | |
| Trichophorum *alpinum* | |
| Carex *maritima* | |