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Effects of Soil Type on the Growth of *Polytrichum Commune*

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Abstract

Mosses, classified as bryophytes, are of economic importance in the horticulture industry where they are used for decoration and gifts. *Polytrichum commune* (common haircap moss) is a popular moss species used in *TerraLiving*'s terrariums. However, moss growth is slow, taking up to 12 months for complete growth which limits its economic value. Moss is conventionally grown on peat soil but its prolonged use under the slow moss growth is uneconomical. Therefore, synthetic soil has been proposed as an alternative growth media. Hence, the aims of this study are to investigate the physicochemical characteristics of both peat and synthetic soils which affect the growth of common haircap moss (in terms of increase in horizontal length and number of shoots). Soil pH and cation exchange capacity (CEC) to study the rationale behind. *Polytrichum commune* was grown in both peat and synthetic soils over a course of 6 weeks (after an acclimatization period of 2 weeks) to determine their rate of growth in different soil types, measured in terms of horizontal length increment (in mm) and number of new shoots. It was observed that the moss grown in peat soil exhibited greater horizontal growth (9.280 ± 2.756 mm) than synthetic soil. This is heavily linked to the significantly lower pH and higher CEC of peat soil. The number of shoots formed was similar in both peat and synthetic soil (8.267 ± 1.535 and 7.8 ± 0.803 respectively), possibly due to similar levels of phytohormone production. In conclusion, peat soil is a better media for the growth and cultivation of *P. commune*.

Keywords

Polytrichum commune, haircap moss, growth, synthetic soil, peat soil

Introduction

Mosses are bryophytes, the most diverse group of land plants second only to flowering plants (Goffinet & Shaw, 2009). Moss has recently proven to be commercially important with the growing interest in its use within the horticulture industry, linked to Japanese zen gardens where moss symbolises age and calmness (Van Toner et al., 2002). The popularity of moss has been experiencing a steady increase worldwide, including Malaysia. The problem going forward is that moss growth is relatively slow and thus, this limits the commercial potential of moss as supply is always insufficient. The moss *Polytrichum commune* grows at an annual rate of approximately 30

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mm per year (Ermolaeva et al., 2013). Complete growth thus can take up to 12 months (Lim, 2019). If the rate of growth can be improved upon, the demands of moss can be satisfied.

Conventionally, peat soil consisting of partially decayed organic material is used as a growth media for most mosses (Rahgozar & Saberian, 2015). However, from an economic standpoint, continued and prolonged use of peat is not ideal. This has led to the development of synthetic soil. Synthetic soil presents several immediate advantages over peat soil. Chemically synthesized soil presents the opportunity to know and control exactly the constituents within the soil (as opposed to the organic material within peat soil). This allows one to specially design and formulate the components of the growth media, closely tailored to enhance moss growth. Hence, the uncertainties of each batch of peat soil are avoided and it also removes any reliance on the supplier of peat and potential to reduce the costs of entirely depending on peat.

In the case of the synthetic soil procured by TerraLiving, it has not been characterized in studies before. Hence, its performance as a growth media remains largely unknown. Furthermore, synthetic soils have not been studied widely, thus information on this topic is difficult to obtain. Hence, this study and the resulting data obtained is economically important as it provides an insight into the performance of synthetic soil as a peat soil alternative. Furthermore, it will act as the basis for future studies into the optimization of soil parameters to increase the yield of moss.

P. commune was used in this experiment as it represents one of the more popular species of moss on *TerraLiving*'s catalogue. Thus, it makes commercial sense as to increase the supply, and at the same time reduce the costs of growing and producing the best-selling product. The aims of this project are: 1. To characterize the physicochemical parameters of both peat soil and synthetic soil in terms of their pH and cation exchange capacity (CEC) and 2. To compare the growth (in terms of increase in horizontal length and number of shoots) of the moss *Polytrichum commune* in peat soil and synthetic soil.

Methodology

Soil analysis

pH of the soil and cation exchange capacity (CEC) were conducted for soil analysis. Both pH and CEC were measured at week 0. The pH of soil was measured using the method detailed by Southorn (1977). CEC is defined as the quantity of negatively charged sites able to retain cations by electrostatic forces on soil surfaces (Jaremko & Kalembasa, 2014). The CEC of the soil was estimated by means of the methylene blue method (Reckitt Benckiser Group, 2017). A standard graph was first plotted by measuring the A_{668} of different concentration of methylene blue.

From the concentration of methylene blue (mol/L), the number of moles of methylene blue remaining in the extract (at original concentration) was calculated as:

$$MB_{at\ original\ concentration} = \left[\frac{[MB_{assay}] \times V_1}{V_2}\right] \times V_3$$

where $[MB_{assay}]$ is the concentration of methylene blue (mol/L) interpolated from the standard curve using the A668 value of the sample, V_1: volume in L of the volumetric flask (0.1L); V_2: volume in L of methylene blue solution aliquoted for dilution in volumetric flask (0.005L); V_3: volume in L of methylene blue solution after dilution with 15mL of deionized water (0.025L).

The CEC_{A668} of the soil (mmol/100g) can be calculated as:

$$CEC_{A668} = [MB_{stock} - MB_{at\ original\ concentration}] \times 1000 \times \frac{100}{m}$$

where CEC_{A668} is the cation exchange capacity estimation based on spectrophotometric measurements of A_{668} (mmol/100g), MB_{stock} is the initial number of moles of methylene blue in extraction solution (at original concentration) and $MB_{at\ original\ concentration}$ is the number of moles of methylene blue remaining in the extract (at original concentration); *m*: dry mass of soil sample (1g).

Growth of moss sample

The moss sample, *P. commune*, were obtained from a mother culture grown and maintained in the moss culture room (originally provided by TerraLiving). Peat soil (Black Gold brand) containing harvested Canadian sphagnum peat (Black Gold, 2016) and synthetic soil samples were obtained from TerraLiving as well. In this study, the moss *P. commune* was grown in two different types of soils namely peat soil and synthetic soil.

The haircap moss was allowed to acclimatize to the new growth environment (increased light intensity and humidity) for the first two weeks after the initial planting (U.S.EPA, 1996). The growth conditions were a light source of two 24-watt white light (total of 48 watts), controlled temperature of 20°C and a maintained relative moisture (Ganeswaran, 2019). The growth was measured in terms of the increase in horizontal length of the primary shoot as well as the number of new shoots. The horizontal length was measured using a piece of thread to estimate its length, and the estimation is measured with a digital vernier calliper in millimetres (mm). The measurements of the moss were taken to serve as baseline and subsequently measurements of growth were recorded twice per week, over the course of 6 weeks.

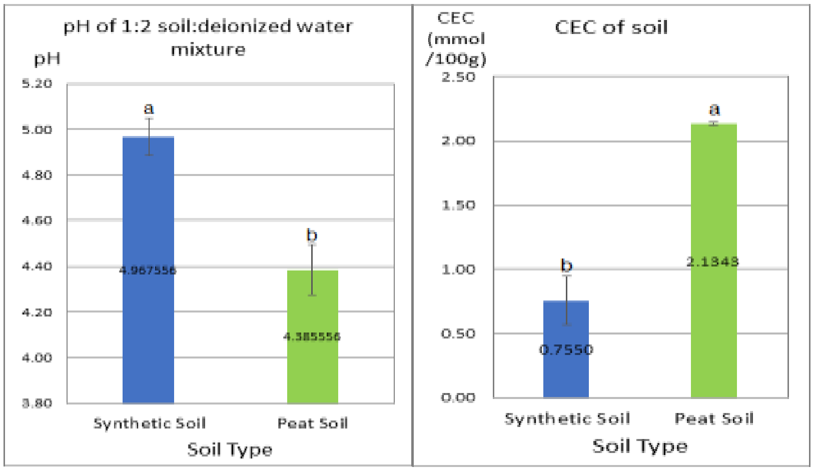
Statistical analysis

Data obtained from both peat and synthetic soil samples regarding the increase in horizontal shoot length (mm) and number of shoots of *P. commune*, pH and CEC (mmol/100g) was statistically analysed using IBM SPSS Statistics 23. One-way analysis of variance (ANOVA) was conducted at a confidence level of 95% to detect significant differences between the pH, CEC and performance of peat and synthetic soil as the growth media.

Results and Discussion

Soil analysis

In Figure 1 (a), it was found that the pH of peat soil (pH=4.39) was significantly ($P<0.05$) lower than that of synthetic soil (pH=4.97). The recorded pH of peat soil falls within its typical pH range, of 3.5 to 6.0 (Delicato, 1996). Though in certain literatures the optimum pH for *P. commune* may be slightly different where Sarafis (1971) stated 3.0 to 6.5 whereas Ganeswaran (2019) stated 4.5 to 6.5, it is possible that the lower pH has contributed to the increased horizontal growth rate. Soil pH is directly related to the availability and uptake of nutrients by plants from the soil (Miller, 2016; Gentili et al., 2018). At an acidic pH, NH_4^+ concentration is maintained and NO_3^- uptake is optimal (Jensen, 2010; Miller, 2016). A range of other micronutrients (e.g. Bo, Zn, Mn, Cu, etc) tend to be more available at lower pHs as well.



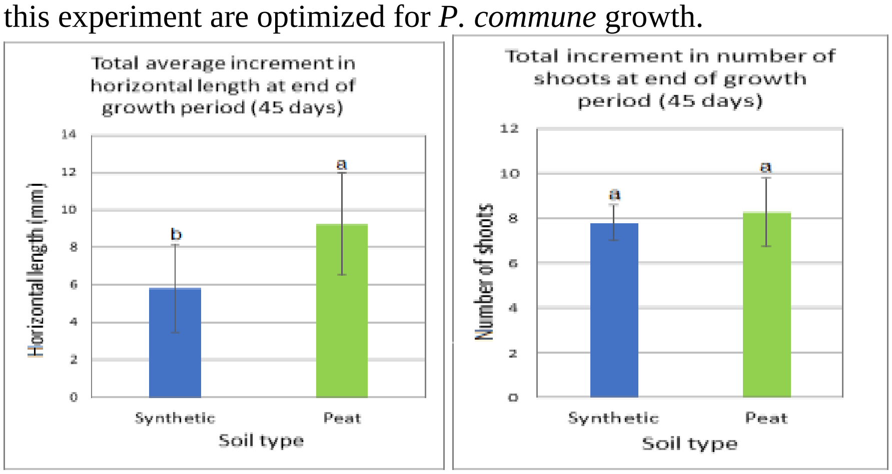
(a) (b)

Figure 1 Soil analysis for (a) pH of peat and synthetic soil (b) cation exchange capacity of peat and synthetic soil in mmol per 100 of soil. Error bars are based on standard deviation (n = 9), [a, b:] different alphabets in each column show the different significant means (ANOVA, P<0.05).

Figure 1 (b) shows the average cation exchange capacity (mmol/100g) of peat and synthetic soil, the CEC of peat soil (2.134 ± 0.015) was significantly higher (P<0.05) than that of synthetic soil (0.755 ± 0.186). In its natural state, CEC of peat ranges from 50 meq/100g to 100 meq/100g (Delicato, 1996). The lower experimental values for the CEC of peat can be attributed to the different types of peat, the age of the peat and the different methodologies used in the measurement of CEC. As for synthetic soil, the very low CEC value recorded suggests that the soil does not have the capacity to hold nutrients in their ionic form and by itself, does not have a high content of nutrients.

Growth *P. commue* in peat and synthetic soil

The total increment in horizontal length in both peat and synthetic soil is shown in Figure 2 (a). Over a course of 45 days, moss grown in peat soil achieved an average growth of 9.28 ± 2.756 mm, significantly higher (P<0.05) than moss in synthetic soil which exhibited an average growth of 5.847 ± 2.354 mm. The results showed that the growth rates of mosses within both soils exceed that of *P. commune* in nature, (Ermolaeva et al., 2013). This confirms that the various controlled conditions (i.e. constant supply of 48-watt white light, 20°C growth temperature, etc) used within this experiment are optimized for *P. commune* growth.



(a) (b)

Figure 2 The total average increment in (a) horizontal length of *P. commune* (mm) and (b) number of shoots grown in peat and synthetic soil, over a growth period of 45 days. Error bars are based on standard deviation (n = 15), [a, b:] different alphabets in each column show the different significant means (ANOVA, $P<0.05$).

Figure 2(b) shows the average number of new shoots formed by the common haircap moss in peat and synthetics soil over the course of the growth period. It was found that common haircap moss in peat soil exhibited an average of 8.267 ± 1.535 new shoots, while moss in synthetic soil showed an average of 7.8 ± 0.803 new shoots. Similarly, the number of new shoots formed in peat soil is not significantly higher ($P>0.05$) than that of synthetic soil. This suggests that compounds that contribute to the formation of new shoots in *P. commune* are present in similar amounts, in both peat and synthetic soil. However, it is unclear if number of shoots formed is considered higher or lower than wild *P. commune* in nature, due to the lack of specific documentation on shoot formation.

Correlation between growth and soil analysis

Despite the significantly lower pH of peat soil compared to synthetic soil (Figure 1 (a)), there was no significant difference in the number of new shoots formed between the two soil types (Figure 2 (b)). This suggests that the pH of soil has little to no effect on shoot or bud formation in *P. commune*. The obtained results are in agreement with the findings of Rahbar & Chopra (1982) that pH, temperature and light intensity (among other factors) do not directly induce bud formation.

From the experimental results alone (Figure 1 (b)), there is a strong correlation between the CEC value of a given soil and the horizontal growth of the moss (Figure 2 (a)). In general, a soil with a higher CEC value is better considering that exchangeable cations serve as an immediately available nutrient source for plants (Mukhopadhyay et al., 2019). Thus, CEC is vital maintaining sufficient amounts of these ions to be supplied to the plants (Jaremko & Kalembasa, 2014). The synthetic soil was subsequently identified as 'Pafcal', a soil-free growth media to substitute soil (Midorie, 2016). On the Pafcal website, there was no mention of the material's nutritional value, only that is "clean" and "soilless". Thus, this would suggest that nutrients within the soil will aid in the horizontal growth of *P. commune*.

Conclusion

In this study, *Polytrichum commune* was found to have greater growth horizontal growth (9.28 ± 2.756 mm) in peat soil compared to synthetic soil, over the growth period of 45 days. The improved horizontal growth is heavily linked to the lower pH (4.386 ± 0.111) and higher cation exchange capacity (2.134 ± 0.015 mmol/100g) of peat soil. Based on the results, peat soil is better than synthetic soil in the growth and cultivation of *P. commune*.

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