Development of ornamental seedlings and cuttings for hydroponics using different substrates

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Abstract: This research paper focuses on investigating the effect of using various substrate materials on the development of seedlings for ornamental plants. Bermuda grass (*Cynodon dactylon*), *Petunia* (Compacta Enana Rosa) and *Epipremnum aureum*, Bermuda; *Petunia* and *Epipremnum aureum* were cultivated in different substrates. Synthetic sponge (Polyurethane sponge), Rockwool and sterilized cotton were used as the substrate materials in each case where an experimental water-circulating apparatus was designed and installed to execute the test. Results showed that after 15 days, Bermuda grass in Rockwool reached a germination rate of 70% while it did not exceed 50% in sponge or in medically treated cotton. The highest germination rate after 20 days for *Petunia* was observed to be 30% when treated cotton was used, while it was 22% and 7% when Rockwool and sponge were utilized, respectively. Statistical analysis showed that germination of *Petunia* in the three substrates was significantly different. Propagation of the cuttings of *Epipremnum aureum* developed the highest number of shoots when treated cotton was used where it gave 10 shoots after 10 days while it just gave seven shoots when Rockwool and sponge were used as the propagation substrate.

Keywords: hydroponics, germination, seedlings, cuttings

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1 Introduction

Hydroponic systems are used widely because of its high efficiency of water utilization compared to typical soil-based farming systems (Jensen and Malter, 1995). Although various studies on hydroponic systems were published, only a small number of research articles focused on the preparation of seedlings to be used in hydroponic systems, such as the study of substrates characteristics (Treder et al., 2006). To use any seedling in hydroponics, it should comply with the main concept of physical and biological cleanliness for the hydroponic system later as well as with environmental sustainability concerns.

Torellas et al. (2012) stated that, a detailed environmental analysis showed that the manufacture of Rockwool and plastic elements is the main ecological loads of greenhouse production systems. Also, Pluimers et al. (2000) concluded that the production of Rockwool and electricity contributes to one-fifth of the total emission of acidifying compounds, a contribution that cannot be ignored. Furthermore, Kleiber et al. (2012) emphasized that a serious drawback of the use of Rockwool is also connected with problems with its management after the completion of the culture cycle, due to the fact that it is non-biodegradable. Furthermore, Allaire et al. (2005) reported that the greenhouse industry needs renewable, cheap and available substitutes for Rockwool, a major component of the ecological footprint of hydroponic production systems.

For lettuce germination stage, which lasts for 11 days, Rockwool should be moistened with nutrient solution with the pH value 4.5-5.0 to ensure that pockets of high pH contaminants can be removed (Brechner and Both, 2015). They recommended that trays on an Ebb and

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Flood bench are sub-irrigated by water for ¼ hour every 12 hours. For the initial 24 hours, lighting is maintained at 50 μmol m^{-2} s^{-1} with a photoperiod (day length) of 24 hours to ensure good germination if a germination room is used. They added that fertilizer solution is applied top-irrigation or sub-irrigation water 24 hours after sowing. The EC of the water is maintained at 1200 μS cm^{-1} above the EC of source water. The pH of the solution is adjusted to 5.8 with possible addition of a base, potassium hydroxide (KOH) and nitric acid, when it is too high. The temperature is raised to 25 ℃ and the lights are increased to 250 μmol m^{-2} s^{-1}. These environmental factors are maintained for the remainder of the time of the crops in the germination area. Sub-irrigation continues for 1/4 hour every 12 hours until Day Six, and the photoperiod remains 24 hours.

Researchers used various substrates to grow different plants. For example, Tocquin et al. (2003) investigated a setup which was designed, which was tested by a hydroponic system for Arabidopsis and which is based on two units, a seed holder and a 1-L tank with its cover. The original agar-containing seed-holder allows the plants to grow from sowing to seed set, without the transplanting step, with minimal waste. On the other hand, Rolot and Seutin (1999) studied the production of potatoes in mini tubers in a soilless setup using clay balls as the substrate to maximize the productivity of mini tubers per unit area, where they could exceed the traditional methods of production by 400%-800%.

While most of the available literature focused on either production of different plants in hydroponic systems or assessing the effect of water salinity levels on germination rates, Zhang et al. (2011) compared germination rate of 12 turf grasses in three different germination media according to its performance under various salinity levels. They concluded that germination method was a detrimental factor affecting the evaluation result and it should be considered in a seed germination test of turf grass for salinity tolerance. Also, various germination media have been used to evaluate relative salinity tolerance in turfgrasses during seed germination. McCarty and Dudeck (1993), Wang and Zhang (2010) germinated bentgrass (*Agrostis spp.*) seeds on agar medium on different salinity levels, while Dai et al. (2009) also compared salinity tolerance of green-type *Poa annua* L. annual seeds on agar medium. Germination rate and seedling growth (blade length and tissue weight) of perennial ryegrass, Kentucky bluegrass and tall fescue cultivars in saline conditions were evaluated in hydroponic systems by Horst and Beadle (1984), Horst and Dunning (1989), Horst and Taylor (1983). On the other hand, Chen et al. (2006) introduced the methods of cutting seedling of eucalyptus and the basic conditions of cutting nursery of eucalyptus, and discussed the advantages and disadvantages of cutting nursery of field in hydroponic systems.

The major objective of this study is to evaluate potential substitutes for Rockwool as germination/ breeding substrates to produce seedlings of different ornamental plants. Furthermore, compatibility of substrates with different targeted plants will be investigated as well.

2 Materials and methods

An experimental hydroponic setup was developed in order to examine the feasibility of hydroponic seedling production in different substrates. The examined substrates were synthetic sponge (Polyurethane sponge), Rockwool and sterilized cotton. The plants under investigation were Bermuda grass, *Petunia* (Compacta Enana Rosa) and *Epipremnum aureum*, where Bermuda was used as a turf grass, *Petunia* was used as a flowering plant and *Epipremnum aureum* was used as an indoor ornamental plant.

Dimensions of the investigated slabs were limited by market availability and were as follows:

-Sponge: length 24 cm, width 15 cm, height 3 cm

-Rockwool: length 24 cm, width 15 cm, height 4 cm

-Cotton: length 24 cm, width 15 cm, height 5 cm

Substrates physical properties:

Bulk density and Easily Available Water (EAW) were determined for each media as described by Allaire et al. (2005) who quoted the research of Milks et al. (1989)

In the first two weeks, continuous water with the flow rate of 580 L h^{-1} was applied while in the third week, flood/drainage protocol was applied as listed in Table 1.

Table 1 Watering protocol

Substrate	Watering intervals	Number of daily water cycles	Total amount of pumped water per day (Liter)
Sponge	15 Min. ON –1 Hr. OFF	19	2,755
Rockwool	15 Min. ON –8 Hr. OFF	2.9	420
Cotton	15 Min. ON –9 Hr. OFF	2.6	377

The hydroponic setup shown in Figure 1, is a small-scale aquatic-based germination apparatus which circulates water in an interval of preset time. It has nine containers; each container accommodates three substrates of equal size. Three setups were installed in three replicates in order to run separate experiments for the three types of seedlings. Each setup contained a reservoir of 60 L and three growth containers of 32 L, where each container was watered using a water pump of 12 W, equipped with a filter. Additionally, air pumps of 10 W were used to pump air into water reservoirs. The three growing media (Rockwool, sterilized cotton and sponge) were laid in each container. Flood/drainage protocol and continuous water flow which was enriched in aeration in the water reservoir were adopted. Both Rockwool and sponge slabs were holed to accommodate *Petunia* seeds and the cuttings of *Epipremnum aureum* while it was furrowed in perpendicular lines to hold Permuda grass seeds. Since applying the same watering schedule to the three substrates would create considerable irregular moisturizing pattern, a specific schedule was applied to each substrate as stated in Table 1 to guarantee the similar wetting conditions of all the substrates.

Figure 1 Developed germination/propagation aquatic unit

Seeds of both *Petunia* and Bermuda grass was sown directly on the top of the investigated substrate while cuttings were submerged in growth hormone (Gabrellic Acid 10 mg L^{-1}) for 5 minutes before each of them was wrapped in sterilized cotton sheet or held in sponge or Rockwool slabs.

To determine statistical significant differences among the examined treatments, single factor ANOVA (Analysis of variance) was run using Excel®.

3 Results and discussion

Bulk density of Rockwool, cotton and sponge was 0.06, 0.00072 and 0.126 g cm^{-3} respectively, while Easily Available Water values were 11.85, 13.673 and 7.26 g of water per gram of media mass.

Since the used fluid was just pure water without nutritional elements, no visually observable marks of micro-organisms growth was detected in any part of the system nor stage of the experiment.

As shown in Figure 2, germination of Bermuda turf grass started after the third day, after sowing, in all substrates while germination in all substrates was considerable and showed the same trend and values. In Day 15, germination in Rockwool continued the same trend while germination percentage of the other two substrates remained almost at 50%.

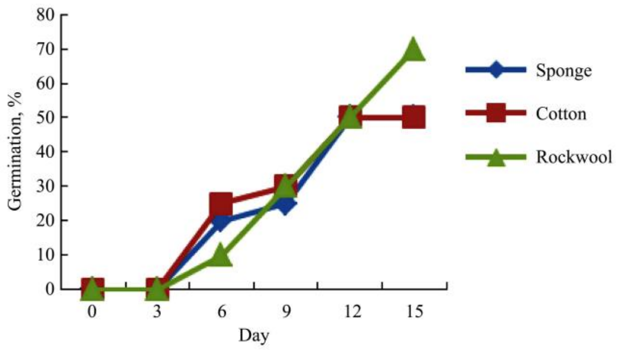

Figure 2 Turfgrass germination percentage in different substrates

Statistical analysis showed that, on the 95% level, there was a significant difference between Rockwool and cotton or sponge, but there was no significant difference of turfgrass germination between cotton and sponge.

Evaluation of cutting propagation focused on qualitative and quantitative parameters. Figure 3 displays average number of shoots which developed in each plant. Cuttings, especially those grown in cotton where the number of developed shoots exceeded the number of shoots developed in both Rockwool and sponge, in all investigated substrates performed well. It seems that wrapping around the plant with the cotton increased the contact area of plant surface and provided more moisturized media while inserting cuttings in Rockwool or sponge did not supply the plant with the optimum moisture although watering protocol for cotton had the lengthiest time (nine hours) compared to both Rockwool and sponge of eight hours and one-hour dry time respectively.

Results of the statistical analysis showed that there was no significant difference between Rockwool and sponge while the difference was significant among cotton and sponge as well as between cotton and Rockwool.

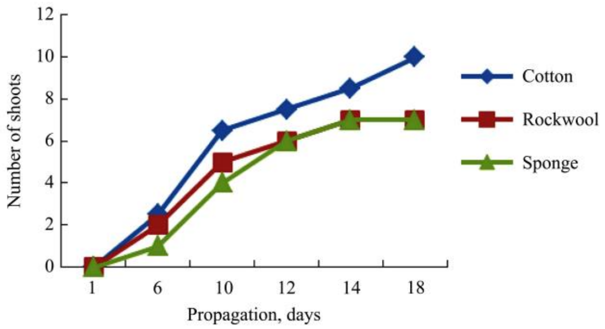

Figure 3 Propagation of cuttings in different substrates

Germination rates of *Petunia* seeds shown in Figure 4 demonstrate the performance of seed germination in the three substrates. It is clear that sponge was not suitable to be a substrate since germination rates are considerably lower than those of seeds sown in cotton and Rockwool. On the other hand, cotton provided the best substrates to germinate *Petunia* seeds where it reached 30% at day 20. Poor germination rates in sponge may be due to its low water holding capacity, in addition to susceptibility to heat and high ratio of air to water. The statistical analysis showed that, on the level of 95%, differences among the levels of germination of *Petunia* in the three substrates were significant.

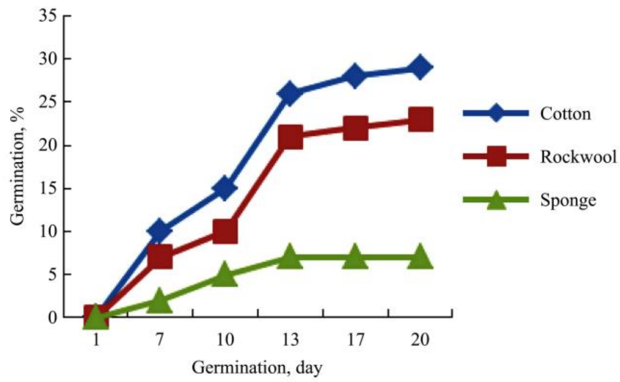

Figure 4 Petunia germination rates in different substrates

4 Conclusions

Germination of Bermuda grass in Rockwool was significantly better than it in cotton and sponge where the rate of it reached 70% after 15 days. Cuttings propagation was significantly better in cotton than in the other two substrates, which may be due to the ability of cotton to wrap around the cuttings and to keep the cut wet for longer time. Cotton also performed better in *Petunia* germination compared to the Rockwool and the sponge which was the least efficient germination media for *Petunia*.

It may be concluded that sterilized cotton should be investigated to be utilized in such application since it is degradable and eco-friendly substrate. Pure water used in this stage was combined with disinfected substrates and void potential biological growth of seeds was due to the absence of nutrients.

Having a specific system for germinating or propagating plants before transferring them into the permanent hydroponic system may be a good management strategy to save time, energy and the costs of keeping the hydroponic system working for longer time since three weeks of plant life will be spent in the germination system while the previous crop is still in the hydroponic stage. Furthermore, having germination/ propagation systems requires much less space and investment and can be a separate production project.

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References

Allaire, S. E., J. Caron, C. Ménard, and M. Dorais. 2005. Potential replacements for Rockwool as growing substrate for greenhouse tomato. *Canadian Journal of Soil Science,* 85(1): 67–74.

Brechner, Melissa, A. J. Both, and C. E. A. 2015. Staff "Hydroponic Lettuce Handbook" Cornell Controlled

Environment Agriculture. Available at: http://www. cornellcea.com/attachments/Cornell%20CEA%20 Lettuce%20 Handbook%20.pdf. Accessed 28 March 2015.

Chen, S. F, Y. J. Xie, and Y. Peng. 2006. Study on Hydroponic Technology of Eucalyptus Cutting Nursery. *Eucalypt Science and Technology,* 23(1): 40–44.

Dai, J., D. R. Huff, and M. J. Schlossberg. 2009. Salinity effects on seed germination and vegetative growth of green-type Poa annua relative to other cool-season turfgrass species. *Crop Science,* 49(2): 696–703.

Horst, G. L., and R. M. Taylor. 1983. Germination and initial growth of Kentucky bluegrass in soluble salts. *Agronomy Journal,* 75(4): 679–681.

Horst, G. L., and N. B. Beadle. 1984. Salinity affects germination and growth of tall fescue cultivars. *Journal American Society for Horticultural Science,* 109: 419–422.

Horst, G. L., and N. B. Dunning. 1989. Germination and seedling growth of perennial ryegrass in soluble salts. *Journal American Society for Horticultural Science,* 114(2): 338–342.

Jensen, M. H., and A. J. Malter. 1995. Protected agriculture, a global review. *World Bank Technical Paper,* 253: 156.

Kleiber, T., B. Markiewicz, and A. Niewiadomska. 2012. Organic substrates for intensive horticultural cultures: yield and nutrient status of plants, microbiological parameters of substrates. *Polish Journal of Environmental Studies,* 21(5): 1261–1271.

McCarty, L. B., and A. E. Dudeck. 1993. Salinity effects on bentgrass germination. *Hortscience A Publication of the American Society for Horticultural Science,* 28(1): 15–17.

Milks, R. R., W. C. Fonteno, and R. A. Larson. 1989. Hydrology of horticulture substrates: I. Mathematical models for moisture characteristics of hortictural container media. *Journal of the American Society for Horticultural Science,* 114: 48–52.

Pluimers, J. C., C. Kroeze, E. J. Bakker, H. Challa, and L. Hordijk. 2000. Quantifying the environmental impact of production in agriculture and horticulture in The Netherlands: which emissions do we need to consider. *Agricultural Systems,* 66(3): 167–189.

Rolot, J. L., and H. Seutin. 1999. Soilless production of potato minitubers using a hydroponic technique. *Potato Research,* 42(3): 457–469.

Tocquin, P., L. Corbesier, A. Havelange, A. Pieltain, E. Kurtem, G. Bernier, and C. Périlleux. 2003. A novel high efficiency, low maintenance, hydroponic system for synchronous growth and flowering of Arabidopsis thaliana. *BMC Plant Biology,* 3(1): 1–10.

Torrellas, M., A. Antón, M. Ruijs, N. G. Victoria, C. Stanghellini, and J. I. Montero. 2012. Environmental and economic assessment of protected crops in four European scenarios. *Journal of Cleaner Production,* 28(6): 45–55.

Treder, W., K. Klamkowski, and A. Tryngiel-Gac. 2006. Investigations on greenhouse hydroponic system for production of strawberry potted plantlets. *In XXVII International Horticultural Congress-IHC 2006: International Symposium on Advances in Environmental Control, Automation,* 761.

Wang, S., and Q. Zhang. 2010. Responses of creeping bentgrass to salt stress during in vitro germination. *Hortscience A Publication of the American Society for Horticultural Science,* 45(11): 1747–1750.

Zhang, Q., S. Wang, and K. Rue. 2011 Salinity Tolerance of 12 Turfgrasses in Three Germination Media. *Hortscience A Publication of the American Society for Horticultural Science,* 46(4): 651–654.