COCONUT FIBRE AS AN ALTERNATIVE GROWTH COMPOUND FOR LIVING GREEN WALLS

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ABSTRACT

Living Green Wall (LGW) is also known as the Vertical Garden that in a way is a selection of plants, enclosed in a substance or a growing medium, distributed along the wall by the use of dedicated enclosure methods and irrigation systems. It is believed that the concept originates from the Hanging Gardens of Babylon, which has been both a remarkable masterpiece of Engineering and pride to the people of Babylon that dates back to 600 B.C., as described in historic writings. Our days the Living Green Wall is perceived as a nice-to-have luxurious feature that is generally attributed to commercial places and those with daily large numbers of passers-by. So far, there is a scattered knowledge of the benefits the Living Green Wall offers in terms of mitigating the air pollution and noise control as well as providing scope for bio-diversity and thermal insulation, etc. Equally, public sees the Living Green Walls as an aesthetic feature, however is overall demotivated by the installation and maintenance costs of such as it does not come cheap. The concept of LGW is quite a simple structure, however it can use a number of innovative ideas to address further the issues of sustainability and environment. This paper reports on the current use, benefits and costs that are associated with traditional soils and fertilizers used in LGW compared to that of coconut fiber and coir. In addition, this paper will lead the way into sustainable coconut by-product utilization and review of the Supply Chain Management LGW.

Keywords

Living Green Wall, Coconut Fiber and Coir, Vertical Garden, Soil & Fertilizers

1. INTRODUCTION

People first began to settle and farm the flat, swampy lands in southern Mesopotamia before 4500 B.C. Later on, every July, rains and melting snow from the mountains of east Africa caused the Nile River to rise and spill over its banks. When the river receded in October, it left behind a rich deposit of fertile black mud called silt. The peasants would develop a network of irrigation ditches to water their crops on rich silt or black soil (Beck, et al., 2009). Nowadays the soil is classified in many ways to represent its quality and chemical properties and also is referred to as compost and may be mixed with fertilisers to support and improve plant growth.

The concept of creating floral beds on the walls & roofs goes back to the hanging gardens of Babylon that is one of the Seven Wonders of the World dating back to 600 B.C. We observe the creeping plants, Hedera Helix, roses, and grapes on the walls of castles, manors, or picket fences being fashionable in 17th century. In 1988's, those plants were incited to grow further and higher on vertical surfaces by constructing systematic panels comprising wooden mesh or steel cables on which they were creeping. In 1990's, the world famous French botanist Patric Blanc created the Vertical Gardening System and for the first time in recorded history, the plants had been growing on the vertical surface of a hydroponic culture with an integrated irrigation and fertilizing system. Thereafter, the concept of vertical gardening has constituted both a starting point and a source of inspiration for innovative plant companies (Saklidir, 2015).

As any plant, the plants used on Living Green Walls require an accurate selection of soil/compost and fertilisers with adequate water supply to maintain healthy growth. In the majority of cases, such choice falls on the compost with man-made fertilisers, which was 'manufactured' for the purpose. These growth compounds are hazardous for the environment both during the production, use and by-product utilization.

The purpose of this study is to assess the feasibility of use of sustainable organic substrates as coconut fiber in LGW as full or partial substitution to soil and fertilisers that are currently utilized by the green wall and plant companies.

2. SOIL & FERTILISERS

All soils, natural or manufactured, require mineral components to provide structure and organic components to provide essential nutrients and water-holding capacity. Components of manufactured soils range widely. Typical components include: Compost, sub-soil, dredge, sand, shredded bark, and other organic materials (AFS, 2017).

The soil is classified into three main types: (A) deep, fertile soils, occupying 40% of global surface (B) vulnerable to soil erosion, occupying 34% of global surface (C) represents soils that do not fall into either class, either because that soil type has a marginal agricultural suitability or because it cannot easily be classified into A or B (Vanwghem, et al., 2017).

There are two main types of fertilisers: (1) organic that are derived from plant or animal and (2) inorganic, which are man-made. Organic fertilisers: These are derived from plant or animal sources and contain plant nutrients in organic form. Organic products tend to be slower acting, as large organic molecules have to be broken down by soil organisms before the nutrients within them are released for plant use. Examples of organic fertilisers include: seaweed, hoof & horn, dried blood, fish blood & bone, bone meal, poultry manure pellets and liquid comfrey or nettle feeds (RHS, 2017). Inorganic fertilisers: These are synthetic, artificial forms of plant nutrients or naturally occurring mined minerals. Inorganic fertilisers are usually more concentrated and faster acting than organic fertilisers. Examples of trade names for inorganic fertilisers include: Growmore, Miracle-Gro, Phostrogen, Sulphate of Ammonia, Sulphate of Potash, etc.

There are many ways to apply fertilisers, and the chosen method will greatly depend on the products used. Here are some of the most common methods of application along with typical examples, see Table 1.

Table. 1. Fertilizer application methods (RHS, 2017).

Application	Example
Top dressing	Quick-acting fertilisers applied to the soil surface around plants to stimulate growth. Can cause scorching if gets in contact with leafs or roots, also causes pollution of ground water.
Base dressing	Incorporation of fertilizer into the soil or potting compost before sowing or planting.
Watering on	Liquid fertilisers or soluble powders and granules diluted in watered and applied on plant roots. The nutrients in liquid fertilisers are instantly available. Contact with leaf can cause scorching.
Foliar feeding	This is the application of a dilute solution of fertilizer to the leaves of plants, useful as an emergency treatment for correcting nutrient deficiencies or for providing quick supplementary feeding. Should not be applied in bright sunlight because the foliage may be scorched.

The demand for manufactured soils, and thus for sand or sand-like materials, is huge. 'The U.S. Department of Agriculture estimates that more than 13.5 million tonnes of sand are used annually in the horticulture market, which consists of a combination of plants grown in nursery beds and plants grown directly in pots. Many nursery operators blend their own soils and customize them to meet the needs of the plants. Others purchase manufactured soils from commercial soil blenders. Manufactured soils are also widely sold through landscaping companies, nurseries and retail establishments. Landscape contractors account for a large percentage of soils sales volume, due to the demand for topsoil and landscaping soils on residential and commercial properties. All bagged topsoil's and gardening soils sold in commercial establishments are manufactured soils' (AFS, 2017).

When designing soil blends, soil scientists consider other characteristics such as bulk density, organic carbon, caption exchange capacity and available water. A typical good native soil will have a bulk density of 1.2 - 1.4 g/cm^3 (AFS, 2017).

The costs of organic compost and fertilisers bought from the manufacturer in Taiwan for example vary in range of £76-£240 per tonne. The production of such is ecumenically not profitable, as it ranges from £74 - £596 per tonne, and relies on government subsidies, however is believed to benefit the environment as it reduces the amount of organic waste that ends-up in landfills. (Yi-Tui Chen, 2016).

Of the shelve cost of compost available in the UK market for domestic consumer ranges between: £3.5 - £7 for 50L bag. The retail price ranges from £2 - £5. Where the producer/manufacturer will charge between 10 - 20% cheaper if bought directly.

The benefits of using soil/compost and fertilisers are well known, they support quick growth due to effectively balanced nutrition, are easy to obtain and apply, can be selected based on chemical composition, can be used to control moisture retention, UV penetration and pesticide. Chemical fertilizers are rich equally in three essential nutrients: phosphorous, nitrogen, potassium that are equally distributed and needed for crops and plants if situation when and as demanded. 'Addition of natural nutrients to soil, increases soil organic matter, improves soil structure and tilth, improves water holding capacity, reduces soil crusting problems, reduces erosion from wind and water, slowly and consistently releases nutrients' (Diffen, 2017).

There are a number of problems associated with the use of manufactured soils and fertilisers. Several chemical fertilisers have high acid content, they have the ability to burn the skin, plants and roots and can change soil fertility. Chemical, man-made ferlisers foster underground water contamination and promote significant reduction of beneficial microorganisms. Organic fertilisers have slow release capability and the distribution of nutrients is usually unequal (Diffen, 2017).

3. COCONUT & FIBRES

Coconuts are produced in 92 countries worldwide on more than 10 million hectares (Applewhite, 1994), however predominantly, coconut palm trees grow in Caribbean Islands, Philippines, Malaysia, Indonesia, south of India, Sri Lanka, Maldives and the Laccadives (Lutz, 2011). Indonesia is the world's largest coconut producer, followed by Philippines and India, all together they account for 75% of world coconut production (Zafar, 2015). The coconut palm, Cocos Nucifera, is the only type of palm tree that produces coconuts. Within this species, however, there are dozens of different varieties of coconuts, which are usually divided into two main types: tall and dwarf (Huang, et al., 2013).

The coconut palm starts fruiting 6 - 10 years after the seed germinates and reaches full production at 15 - 20 years of age. The tree continues to fruit until it is about 80 years old, with an annual production of 50 - 200 fruits per tree, depending on cultivar and climate. The fruits require about 12 months to develop and are generally harvested regularly throughout the year. The fruit should be harvested fully ripe for copra and dehydrated coconut. Drinking nuts should be picked earlier, at about seven months. The nuts may be harvested by skilled climbers or may be cut from the ground, using a knife attached to a long pole. Use of climbing spikes is not recommended since the wounds caused by the spikes are permanent and may provide entry sites for diseases, such as *Thielaviopsis* of trunk and root (Broschat & Crane, 2014).

Coconut fibre and coir are extracted from the inner husk of the coconuts (see Figure 1). Coconut natural fibre is thick, coarse and durable (Bakiya, et al., 2016). The coconut fruit yields 40% coconut husks containing 30% fiber, with coir making up the rest (Zafar, 2015), see Figure 2. Coir (also known as coir pith, coir meal, coir dust and coco peat) is a waste product of the coconut industry (Arenas et al., 2002), consisting of the dust and short fibres derived from the mesocarp or husk of the fruit. In most areas coir is a by-product of copra production, and the husks are left on the fields as a mulch or used as fertilizer because of high potash content. India and Sri Lanka are the main countries where coir is extracted by traditional methods for the commercial production of a variety of products. The outer husk that is removed before export is comprised of long, rough fibres held together by a dust like pith as seen in Figure 2. The average fibre yield is dependent on geographical area and the variety of the coconut tree. In the south of India and Sri Lanka, for example, where the best quality fibres are produced the average yield is 80-90g fibre per husk. Caribbean husks, by contrast, are relatively thick and may yield up to 150g of fibre.

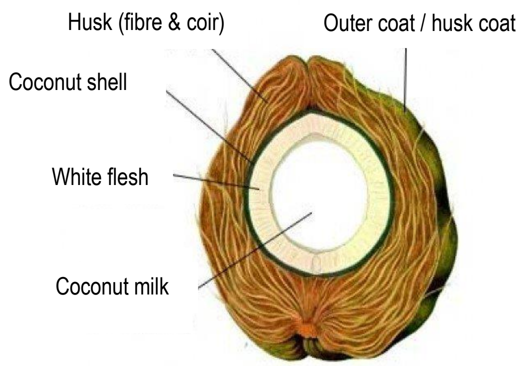

Figure 1. Coconut component schematics (Apse, 2017).

Figure 2. Coconut husk, fibre and coir (Greer, 2008).

General physical, chemical and biological properties of coir have been widely reviewed (Bragg, 1998, Prasad, 1997, Schmilewski, 2008a and Nichols, 2013) and, similar to peat, it provides a favorable balance of air and water to plant roots. In contrast to peat, which once dried out can be difficult to re-wet (Michel, 2010), coir has a high re-wetting capacity (Blok and Weaver, 2008). As such, it has been used as a peat replacement across many sectors of the horticultural industry, from soft fruit production to floriculture (Schmilewski, 2008a). As a waste product, not produced specifically for horticultural applications, it may not always be processed and handled in ways that makes it most suitable for use in growing media. As a result its physical, chemical and biological properties can vary widely (Smith, 1995, Evans and Stamps, 1996, Abad et al., 2005 and Nichols, 2013).

Husks are composed of 70% coir and 30% fibre on a dry weight basis. The ratio of yield of long, medium and short fibre, respectively, is on average 60:30:10. Based on these data and combined with the production data in Table 1, the maximum total world production of coir fibre, included short fibres, can be estimated to range between 5M - 6M tonnes per year. Only a small part, <10%, of this potential enters commercial trade. Continuous expanding production of brown fibre reached 216K tonnes, 70% in India and 27% in Sri Lanka, in 1996, while white fibre production, mainly in India, has remained stable at 125K tonnes (Dam, 2002). Table 2 demonstrates the current average values for coir availability.

Table 2. Raw coir material availability estimation (Dam, 2002).

Data is given in K tonnes	**Indonesia**	**Philippines**	**India**	**Sri Lanka**
Coconut Production	1000	700	600	260
Coconut fibre extraction	-	-	300	100
Domestic use *	100	70	60	26
Non-extraction	900	630	240	134
* Estimated 10 per cent of total production				
Estimated annual coconut production capacity × fibre yield (80-90 g/nut)				

According to prices quoted on the Alleppey market in India, coir husks costs on average £6 for 1000 husks which, after retting, may yield 90kg fibres at a price of £0.1 - £0.12/kg. Green decorticated fibre may cost up to £0.09/kg. There is little fibre wastage in spinning, so around 98kg of yarn is produced from 100kg of fibre. High quality Anjengo yarns may yield around £0.3/kg, while Vycome is quoted at £0.21/kg. Traditional hand spinning of fibre to yarn using a spinning wheel requires three people, who may produce 12 - 15kg of yarn per day. Export prices for finished coir products such as handloom mats and matting, rugs and carpets range between £ 0.85-0.97/kg (Dam, 2002).

Properties and benefits

The coconut shell has a density of about 1.2 g/cm^3 and is five times harder than the hardest hardwood, Hickory, mainly found in the North America. The extremely high density and hardness make coconut shell an excellent feed stock for charcoal and activated carbon filters. While the shell is widely used for these applications, the price of charcoal is low and demand for activated carbon filters utilize only a small fraction of the coconut shell that is available (Greer, 2008).

Coconut fibre has a density of 0.67 - 10.0 g/cm^3, which blends in well with excellent combination of tensile strength of 120 - 500Mpa, tensile strain of 20% and water absorption of 80 - 180% (Ali, 2011, Bujang, et al., 2007) that make it an excellent candidate to replace oil based synthetic fibers in polymeric composites. In addition, fibre has a tremendous property of good temperature management and hence exhibits good insulation properties.

The coir is extracted from the husk along with the fiber. It has two interesting properties that make it commercially attractive. Coir is both highly hydrophilic and chemically reactive. A micrograph of coconut coir internal structure can be seen in Figure 3. The coir structure comprises of thin hollow shells or tubes. These hollow tubes allow for the coir to absorb ten times its own weight in water and make it an excellent additive for gardening soil. There are some synthetic materials that can absorb more water, but they are expensive and are not bio-degradable (Greer, 2008).

A number of research works carried out on acoustical properties of porous materials have concluded that the coconut based soil can improve sound absorption by 20% if incorporated in a Living Green Wall (Berardi & Innace 2015, Romanova & Horoshenkov 2016). The best results were achieved where the coconut soil contained at least 50% of coconut fibre and coir mixture. For the sound absorbtion of the incident sound in the vicinity of the LGW to be more effective, the coconut soil moisture content is best to range between 5 - 10% (Romanova & Horoshenkov 2016).

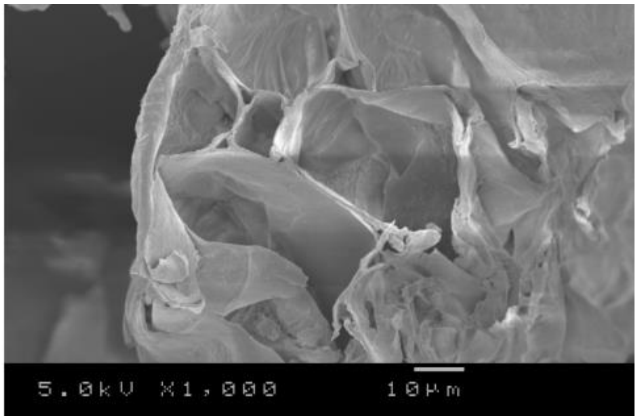

Figure 3. Micrograph of coconut coir structure (Greer, 2008).

Industrial products

Coconuts are the most widely grown nut in the world and contribute significantly to the economy of many tropical areas (Broschat & Crane, 2015). The short, tough fibers can be woven or pressed together for a number of uses and unlike man-made fibers, coconut is a renewable resource.

The coconut fibers are used for a number of applications: land and sea ropes, nets, matting, brushes and brooms, mattress stuffing, bags, garden beds, pressed pots and baskets, soil additive to retain water, peat for hydroponic gardening, roofing, concrete reinforcement (Myers, 2015, Ali et al., 2012), insulation in construction industry, geothechnical netting used for erosion prevention (Greer, 2008), safety netting (Wang & Chouw, 2017), upholsters padding for automobile sector, shock absorbent in transport industry, funrniture and furniture accessories.

Woven coconut leaves known locally as cadjan are used as thatch, while coconut timber is used widely as rafters and in the furniture industry. Coconut leaves and roots are used as fuel for the hearth. Mats and basketware are also woven from the treated leaves and their spiny ekels (mid-ribs). The residue after the oil extractions is a ready - made poonac or high protein & fat containing animal feed. There are also handicrafts made out of coconut shells and various other products (Nature's Bounty, 2013).

A coconut plantation is analogous to energy crop plantations, however coconut plantations are a source of wide variety of products, in addition to energy. The current world production of coconuts has the potential to produce electricity, heat, fiberboards, organic fertilizer, animal feeds, fuel additives for cleaner emissions, health drinks, etc. (Zafar, 2015).

Waste

Despite the benefits, remarkably, 80 - 90% of the coconut husks currently create pollution when they are treated as waste (Cimons, 2014). Coconut tree parts as empty fruit bunches, fibers, fronds, shells and trunks are discarded as waste and either burned in the open air or left to settle in waste ponds. This way the coconut processing industries contributed significantly to CO_2 and methane emissions (Datar & Shinde, 2015). Although, normally coconut fiber takes 20 years to decompose, without causing any harm for our environment, utilization of such products to good use should be encouraged for sustainable reasons (Uses of Coconut, 2017). Different avenues of coconut shell utilization are more or less known but none of them have so far proved to be economically viable or commercially feasible (Madakson, et al., 2012). Based on economic as well as environmental related issues, efforts should be directed worldwide towards coconut management issues i.e. of utilization, storage and disposal.

4. COCONUT SOIL BENEFITS

Also, coir that is derived from coconuts grown in coastal areas or washed in saline water (during primary processing) can release phytotoxic levels of sodium and potassium during use (Schmilewski, 2008a and Nichols, 2013). Consequently, in addition to a period of aging to stabilise the material (Carlile et al., 2015), coir requires several washings in fresh water and a ‘buffering’ treatment (in which calcium nitrate is added to the material to displace harmful concentrations of sodium and potassium) before it is suitable for use as a growing medium. (Nichols, 2013 and Poulter, 2014). This secondary processing adds significantly to the economic cost of coir (Schmilewski, 2008a and Poulter, 2014). Another relatively minor cost relates to transportation; commercial coconut production is geographically limited to tropical Africa, America and Asia. While dehydration and compression of the material can help to reduce long distance transport costs (Maher et al., 2008), these may still be of significance to the farthest markets in Europe (Schmilewski, 2008a). In its favor economically, coir is at present in plentiful supply for soilless growing media, where 50M tonnes of coconuts are produced annually in the world and 25% of production ends up as waste coir (Nichols, 2013). As environmental drivers have become increasingly important considerations within the horticultural industry, the relative expense of coir compared to peat are become less of a constraint and more of a common sense resource (Barrett, et al., 2016).

Generations of gardeners have recognized the benefits of adding peat moss to garden and potting soil. Although it has little nutrient value, it is a good soil amendment. It lightens the soil, allows air to enter, holds moisture without being soggy and generally improves soil structure. It seems that most gardeners don't realize that peat takes hundreds of years to form and hence is not considered as sustainable resource due to recovery time (McMahan, 2015). Hence, wetland ecologists say that peat is being harvested at non-sustainable rates. While the peat industry argues that peatlands can be managed at sustainable levels, it recognizes that alternatives to peat must be developed in order to meet environmental concerns of consumers and contend with increased regulation of peatland exploitation. As useful as peat is for horticulture, there are good alternatives, one substitute is coir, or coconut dust (McMahan, 2015).

In the past, this fine material was considered waste and left to accumulate in enormous piles. In Southeast Asian countries where coconuts are harvested commercially, some of these piles are thought to be as much as a century old. Not only is coir a renewable resource, its horticultural use helps solve a waste disposal problem in these parts of the world (McMahan, 2015).

Researchers at Auburn University and University of Arkansas compared peat and coir as soil amendments for horticulture. They found that coir performed on par with peat. Coir has proven to hold moisture well, wet more easily than peat, drain well, decompose more slowly and withstand compression better than peat. Plus coir dust does not have the small sticks and possible seeds that peat has.

Peat bogs are a special kind of wetland, many of which are thousands of years of accumulated plant material. They receive most of their water as rain or snowmelt rather than from runoff or streams. Peat mosses (*genus Sphagnum*) thrive, and acidify the soggy environment, making it difficult for many kinds of plants to grow. Only those that can cope under acid conditions survive. The acidity, low temperatures and lack of oxygen discourage bacterial decomposition, so over centuries and millennia, layers of peat moss and other bog plants become compressed, forming peat.

The wet, acidic and low-nutrient environment in peat bogs foster plant and animal communities highly adapted to these conditions, including insectivorous plants such as sundews, Venus fly-trap, pitcher plants and Oregon's cobra plants, also known as Darlingtonia. These fascinating plants trap insects, "digesting" them for nitrogen, which is a limiting factor for plants in their wet, acidic environment.

Built up layers of peat can preserve organic material that usually deteriorates quickly – wool, hair, skin, bone, wood, plant parts and pollen – providing an invaluable historic record. Peat bogs in Europe have turned up human artifacts as old as 12,000 years and preserved human remains from about 2,000 years ago.

Coir can be used as good and uncompromisingly effective alternative to peat which also has lower levels of acidity (McMahan, 2015). Available in bales at garden centers ready for use, coir, is also sold in compressed "bricks," that expand into several times their volume when moistened. The price of coir is usually comparable to peat (Richards, 2006). Coir is a material which is widely used to overcome the problem of erosion. When woven into geotextiles and placed on areas in need of erosion control it promotes new vegetation by absorbing water and preventing top soil from drying out. Coir geotextiles have a natural ability to retain moisture and protect from the suns radiation just like natural soil, and unlike geo-synthetic materials, it provides good soil support for up to three years, allowing natural vegetation to become established (Food and Agriculture Organization, 2017).

5. RESULTS

Based on the above review, the coconut fiber and coir based soil (A&B CFP) properties were compared to those of common black soil types A&B or also known as compost (A&B), soil A&B types mixed with organic fertilisers (A&B OF) and soil A&B types mixed with man-made or chemical fertilisers (A&B MF). Table 3 shows the variable-weight analysis for a number of parameters identified for all of the growth compound types that could be considered important for the application in a Living Green Wall. For each factor, the maximal value of 1 was assigned to the top value across all growth compounds, where the others are represented as relative fraction. In places where the factor can have a negative effect on the plant growth or the environment a minus sign is assigned. In the event of neutral effect a value of 0.5 is assigned. The factor analysis has been carried out considering a number of sources and averaged for obtained values, hence should be used as a reference comparison indication only.

Considering the factorial analysis in Table 3, a total score for the A&B of 7.2 is achieved, followed by 9.3, 7.5 and 11 for A&B OF, A&B MF and A&B CFP, respectively. This shows that in ideal scenario when each of the presented factors carried equal weight and perceived of the same importance, the most preferred growth compound (A&B MF) that is currently utilised by plant nurseries and landscaping companies has very low 'benefit' score. The man-made soil compost and fertilisers (A&B MF) have one major benefit, they can be manufactures to fulfill any plant requirements and can also stimulate quick and effective growth, which is very important for horticultural community. For A&B MF the factors as microorganism 'support' is low, ground water pollution is height, which yields negative value, and the general sustainability factor of manufacturing such compost blend is low in comparison to others. However, on the contrary the A&B CFP has performed well, gaining an overall score of 11. Mostly as the heat control, noise control, water retention, resistance to fungi and sustainability factors of such compost blends are high. The presence of other parameters are close to that of A&B OF, and although in this compound the plant grown rate will be slower, the minimal addition of the nutrients can help to stimulate and achieve the required growth rate.

Table 3. Soil, fertilisers and coconut fiber benefit comparison.

	Black Soil A&B type or compost	Soil A&B with organic fertilisers	Soil A&B with man-made fertilisers	Soil A&B with 50% coconut fibre & coir
Factors	**A&B**	**A&B OF**	**A&B MF**	**A&B CFP**
Acidity	0.5	0.5	-0.5	0.5
Weight	0.6	0.9	0.8	1
Fertility	0.5	0.8	1	0.7
Growth rate	0.5	0.6	1	0.7
Heat control	0.5	0.7	0.7	1
Microorganisms	0.5	1	0.4	0.8
Noise control	0.7	0.8	0.8	1
Nutrient value	0.5	0.8	1	0.8
Preparation	0.9	0.8	0.9	1
Water pollution	0.5	0.5	-0.5	0.5
Water retention	0.4	0.6	0.7	1
Resists fungi	0.5	0.5	1	1
Sustainable	0.6	0.8	0.2	1
Total	7.2	9.3	7.5	11

The cost analysis for 5 types of growth compounds have been performed and are presented in Figure 4. The production and retail cost averaged data was obtained from UK, EU, USA, India, Indonesia and Taiwan manufacturers.

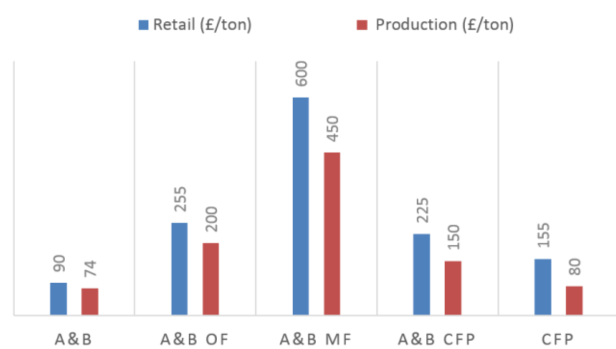

Figure 4. The average costs for different types of growth compounds (UK, EU, USA, India, Indonesia and Taiwan).

In countries as UK, EU and USA, the amount of private soil/compost companies dominate the market and they introduce a healthy margin on their products, especially on the 'chemically manufactured' compost, A&B MF. In countries as India, Indonesia and Taiwan, composts as A&B, A&B OF, A&B CFP dominate the market as they employ traditional methods, do not require sophisticated machinery and labs to produce and are promoted by the government due to their sustainability aspects. In the majority of cases the mentioned countries are unable to sponsor the manufacturing equipment and rely on cheap manual labor, which is available in excess. As the study shows, in the majority of cases the producers of A&B, A&B OF, A&B CFP are unable to make a profit and fully rely on government subsidies to survive (Yi-Tui Chen, 2016). On the contrary, a number of private manufacturers that have purchased dedicated machinery and have been able to secure contracts with horticultural companies outside their production country, have been able to make 30 - 70% profit per tonne of compost. However the general calculations show, that they will break even and pay off the expensive equipment, in 35 – 110 years, given current rates of production. The research also demonstrated that these manufacturers do not operate in full capacity, in come cases not even in half capacity rates, so there is a massive room for improvement (Yi-Tui Chen, 2016).

The cost of transportation is of great importance as well, not only as it adds to the final price of the product but also as it carries unsustainable factor of CO2 pollution directly associated with it. The majority of businesses in the UK tend to source from local companies as this is measured to be sustainable. Considering journey lengths this may seem so in short run, however may not necessarily be the case in the long run. For example, the comparison may be carried out between truck and ship cargo. Generally the cost of in-land transport is 10 - 60% higher than ship cargo, whereas in the ship cargo same or double the amount could be carried at once. The average cost for the in-land delivery in the UK, EU and USA, for 1km of fully loaded truck is £0.21 - £2.84. The average lorry or truck will produce 60 - 150g of CO2 emission per tonne per 1km of transportation. On the contrary, sea cargo will cost on average £0.006 - £0.12 per 1km, causing a CO2 emission level of 10 - 40g of per tonne per 1km of transportation.

In our case of composts, the A&B CFP or just CFP will be quite cheap to transport using sea cargo from the places of production to the UK, as they bulk weight is low. However, case-studies are required to fully prove the above statement.

6. CONCLUSIONS & RECOMMENDATIONS

Considering the above, the coconut fiber and coir based soil (A&B CFP) or fiber and coir based soil mixed with man-made fertilisers (A&B CFP + MF) can be effectively used to substitute the traditional black soil/compost and fertilisers in the Living Green Walls as growth medium.

First options will provide a healthy number of benefits both as a growth medium to the plants and to the environment in general, due to: sustainable extraction and resource utilization, insulation qualities, noise control, microorganism support, water retention, pesticide control and slight reduction transportation pollution due to lower bulk weight.

Second option can preserve the mentioned above benefits and the introduction of minimal number of man-made fertilisers can ensure the adequate amount of nutrients being delivered to the dedicated species of plants. This option should allow for an optimal compost blend to both satisfy the key requirement of the horticulturalists and provide a sustainable grown medium on a larger spectrum.

The above research is a starting point to conduct an in-depth comparison analysis of main soil/compost types based on their physical, chemical and environmental properties including full costs and transportation routes to end users. This will further be used in Supply Chain Management analysis of LGW companies in the UK to promote additional sustainable aspects in their daily business operations.

ACKNOWLEDGMENTS

The authors would like to thank HoD of the Applied Engineering and Management department Dr Alec D Coutroubis and the University of Greenwich VC Scholarship Grant under which the current work was commenced.

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