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The suitability evaluation of lignocellulosic substrate as growing media substitute

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The use of peat moss (PM) as a growing media is decreasing due to high costs and environmental considerations. Therefore, diverse waste products are being used as organic amendments in certain soils before afforestation. The main objective of this work was to identify and evaluate possible substrate alternatives or amendments to peat moss. This study involves the physical and chemical characterization and growth test of lignocellulosic substrate (waste paper (WP), oakwood sawdust, hinoki wood sawdust and rice hull) in order to evaluate their use as components of growing media. Lignocellulosic substrates showed adequate physical and chemical properties compared to peat moss for their use as growing media. The mixtures growing media were prepared using different proportions as substrate to grow Chinese cabbage (Brassica rapa var. glabra) in a greenhouse. Different lignocellulosic substrates were compared with a commercially available substrate. The highest values for seed germination were obtained for 30% peat moss + 10% perlite + 60% waste paper substrate. The stem height and leaf area of the WP (containing 30% peat moss, 10% perlite and 60% waste paper) was higher than that of PM. Utilization of waste paper can be considered as an alternative media component to substitute the widely using expensive peat moss.

Key words: Growing media, waste paper, waste sawdust, rice hull, lignocellulosic substrate.

INTRODUCTION

Today, various organic substrate and inorganic substrate are used as growth media. Organic materials such as peat moss or pine bark and inorganic materials such as sand, calcined clay, perlite and vermiculite are used to formulate growth media to produce woody landscape plants in containers. Most of them are combined with various materials, such as a mixture of peat moss and pine bark, or a mixture of peat moss and pine bark with mineral materials like perlite or vermiculite. All over the world, stone wool and other materials like perlite, pumice, polyortanphome, zeolite, coco peat and sawdust are used as growth media in soilless culture (Ghehsarehet al., 2011, Tehranifaret al., 2012). The selection of media components in which grown plants can be successfully grown is usually based on freedom from soil pests and harmful chemicals, cost, shipping weight and local availability.

Peat moss is the most commonly used growing media. However, peatmoss is obtained from wetlands, which are being rapidly depleted, causing environmental concerns

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that have led to many individual countries to limit the extent of peat moss mining, and prices are increasing as a result. Research on peat moss alternatives is of great interest in the future. In this context, different authors have suggested that some organic materials such as well-composted municipal solid waste and biosolid composts could be feasible materials for a partial peat moss substitution. Also, alternative growing media are being sought in order to improve cost and sustainability (Hernandez et al., 2005). Alternative growing media were generally residual materials such as wood waste, coconut coir, rice hull (Bugbee, 2002; Wrigth et al., 2006; Salifu et al., 2006). Partially, composted pine bark is one of the most widely used substitutes for peatmoss and has been used for decades as a growing media. Currently, the use of other crop residues and by-product were increased.

A number of studies have shown that organic residues such as urban solid wastes, sewage sludge, paper waste, pruning waste, spent mushroom and even green wastes, after proper composting, can be used with very good results as growth media instead of peat moss (Ostos et al., 2008; Bustamante et al., 2008). The increasing interest in waste recycling is another cause to advocate the recycling and use of organic wastes and composts as soil or potting amendments; it could be one of the most attractive methods of solving the problem of waste disposal.

Waste paper, waste wood, agriculture residue may have potential as an organic component of artificial growth media. Bellamy et al. (1995) demonstrated the short-term benefits of amending agricultural soils with waste paper; however, they recognized a need to study the effects of repeated annual additions of waste paper on soil properties. Wood wastes, such as sawdust, are often composted with manure or supplemented with fertilizer to supply the needed nitrogen. Because of the inherent differences in chemical properties between different woods, however, the suitability of sawdust as an organic growing media component is extremely variable.

Rice hull is a product of rice milling process. It is mainly used in Korea generally as a mulching material (Roh and Pyon, 2004) and for water absorption (Kim et al., 2004). In a forest nursery in Greece (Tsakaldimi, 2006), rice hulls in a 1:3 mixture with peat moss were an effective substitute for growing *Pinus halepensis* seedlings. The properties of different material used as growing media exhibit direct and indirect effects on plant growth and production. The selection of a particular material depends on its availability, cost and local experience of its use (Klute, 1986). Physical and chemical features of alternative growing media such as degree of dispersion, pH, porosity, water holding capacity, must be considered for choosing the materials (Ezure and Wilson, 1983). To provide optimal characteristics, substrates are generally composed of a mixture of different materials in varying proportions. Based on the fact that it is not possible to predict with precision the performance of a mixture is based on its components, crop response to various mixtures must be tested and classified. Thus in evaluating the aptitude of a material for use as a new substrate for the cultivation of a variety of species, its physical, chemical and biological characteristics must be determined as well as its fertilization and water needs. Growth performance must also be evaluated to determine the quality of a substrate.

The objective of this study was to determine the physical and chemical characteristics of the various lignocellulosic substances and evaluate their potential for use as substrate components. This study was performed under greenhouse conditions, with peat moss, perlite and lignocellulosic substrate (waste paper, oak wood sawdust, hinoki wood sawdust and rice hull) as the main components of the growing media. The performance of the mixtures growing media was evaluated through the germination behavior of the Chinese cabbage (*Brassica rapa* var. *glabra*).

MATERIALS and METHODS

Growing media preparation

The commercial growing media used routinely at nursery was used as control (peat moss). The lignocellulosic substrate included wastepaper, oakwood sawdust, hinoki wood sawdust, rice hull. The lignocellulosic substrate was air-dried and hammer-milled to a particle size of -20 mesh/+80 mesh, and then stored in sealed plastic bags at 4°C until used. The mixtures growing media were prepared by mixing 30% of peat moss, 10% of perlite and 60% of waste paper, oakwood sawdust, hinoki wood sawdust and rice hull. Ratios of each component in each substrate are shown in Table 1.

Physical and chemical properties of growing media

The carbohydrate content of lignocellulosic substrate and mixture growing media were analyzed by gas chromatography (YL-6100, Young Lin Ins. Co., Ltd. Korea) with a DB-225 capillary column (15 m, 0.25 mm ID, 0.25 mm film thickness) (J&W Scientific, Folsom, CA). Injection samples were prepared according to ASTM 1821 - 96. This method describes a procedure for derivatizing monomers to their respective alditol acetates and tests for the sugars arabinose, xylose, mannose, galactose and glucose. Alditol acetates were identified by their retention time in comparison to a mixture of authentic monosaccharides. Monosaccharides were quantified on the basis of the peak area of the internal standard (*myo*-inositol added in known concentration) and normalized to the sugar content of the samples. Total carbohydrate content was calculated as the sum of the individual sugar. The pH was measured in water extracts of all lignocellulosic substrate (sample : distilled water ratio of 1:5) using an Orion (Cambridge, Mass.) pH meter. The ash content of lignocellulosic substrate was determined by a muffle furnace at 550°C according to ISO 1171-1981. Carbon (C) and nitrogen (N) content in lignocellulosic substrate were determined by using CN analyzer (Micro coder JM 10; G-Science Laboratory, Tokyo, Japan). The Mineral elements (K, Ca, Mg, Na, Zn, Fe, Mn and P) of lignocellulosic substrate were measured using inductively coupled plasma atomic emission spectrometry (ICP-AES, OPTIMA 3300 DV) to quantify aqueous constituents following microwave digestion with HNO_3- H_2SO_4-$HClO_4$ solution.

Table 1. Substrate mixtures used in the study.

Treatment	Formulation	Designation
1	100 % Peatmoss (commercial substrate)	PM
2	30 % Peatmoss + 10 % perlite + 60 % waste paper	WP
3	30 % Peatmoss + 10 % perlite + 60 % oakwood sawdust	OS
4	30 % Peatmoss + 10 % perlite + 60 % hinoki wood sawdust	HS
5	30 % Peatmoss + 10 % perlite + 60 % rice hull	RH

Table 2. Carbohydrate content of lignocellulosic substrate.

Growing media component	Dry weight (g / 100 gdry mass)						
	Arabinose	Xylose	Mannose	Galactose	Glucose	Total carbohydrate	Optimal range
Peatmoss	0.8	1.6	2.2	2.9	16.4	23.9[e]	
Wastepaper	1.7	5.0	3.1	0.0	57.1	66.9[a]	
Oakwood sawdust	0.9	10.5	3.2	1.8	42.5	58.9[b]	> 80
Hinoki wood sawdust	0.6	7.1	0.8	0.8	36.6	45.9[d]	
Rice hull	3.2	8.9	0.0	1.3	37.1	50.5[c]	

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test. Optimal range in growing media according to Abad et al. (2001).

The porosity and water holding capacity of lignocellulosic substrates were measured by Verdonck and Gabriels (Verdonck and Gabriels, 1992) methods. The measurements were carried out for three replicates, and values are an average of three replicates. The results are expressed as mean values ± standard deviation (SD).

Growth test

The plant species used to evaluate the suitability of the growing media was Chinese cabbage (*Brassica rapa* var. *glabra*). Twenty seeds of Chinese cabbage were placed in Petri dishes (three dishes per substrate) containing 10 g of each mixture substrate. The seed was cultivated in the greenhouse at 25°C for 5 days duration in light/ 8 h dark and 70% relative air humidity. Seed germination was recorded every day. The percentage of seed germination was calculated as follows:

$$\text{Seed germination (\%)} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds in all replicates}} \times 100$$

Statistical analysis

Obtained data were subjected to analysis of variance to determine the growing media effects. Statistical analysis had been carried out with SAS statistical software and according to analyzing from ANOVA test and comparing data mean to Duncan test. Duncan's multiple comparison range test was used to determine significant differences between the means.

RESULTS AND DISCUSSION

Chemical and physical properties of growing media components

The physico-chemical characteristics of substrates were shown in Tables 2 to 5. The four lignocellulosic substrates used as growing media were tested (Peat moss was a commercial growing media used as the control). The carbohydrate of lignocellulosic substrate was indices for the organic material. The carbohydrate content of lingo-cellulosic substrates was presented in Table 2. The total carbohydrate content differed significantly among sub-strates, with total carbohydrate ranging from 23.9 to 66.9 g / 100 g. The highest carbohydrate content was observed in waste paper. Glucose, together with xylose, represented a significant part of the total carbohydrate. Glucose modulates many vital processes in photosyn-thetic plants.

Organic material is one of the most important constituents of soils due to its capacity in affecting plant growth indirectly and directly. Indirectly, organic material improves the physical conditions of soils by enhancing aggregation, aeration and water retention, thereby creat-ing a suitable environment for root growth (Senesi and Loffredo, 1999). Recently, various organic material such as mulch, manure and compost, have been investigated for their effectiveness in soil remediation. It has been demonstrated that the application of organic material to

Table 3. Ashand C/N ratio of lignocellulosic substrate.

Growing media component	Ash (g / 100 g)	C (%)	N (%)	C/N ratio
Peat moss	6.1 ± 0.4[c]	45.0[b]	0.8[a]	56.3[e]
Wastepaper	15.6 ± 0.1[a]	42.3[d]	0.2[c]	211.5[c]
Oakwood sawdust	0.7 ± 0.0[d]	48.0[a]	0.2[c]	240.0[b]
Hinoki wood sawdust	7.8 ± 0.0[b]	43.4[c]	0.1[c]	434.0[a]
Rice hull	15.6 ± 0.1[a]	39.4[e]	0.5[b]	78.8[d]
Optimal range				20 - 40

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test. Optimal range in growing media according to Abad et al. (2001).

Table 4. Mineral elements of lignocellulosic substrate.

Growing media component	Dry weight (g / 100 gdry mass)							
	K	Ca	Mg	Na	Zn	Fe	Mn	P
Peatmoss	0.02 ± 0.0[e]	0.57 ± 0.1[b]	0.13 ± 0.0[b]	0.00 ± 0.0[c]	0.0 ± 0.0[a]	0.02 ± 0.0[b]	0.00 ± 0.0[a]	0.00± 0.0[a]
Waste paper	0.12 ± 0.2[c]	2.55 ± 0.7[a]	0.12 ± 0.0[b]	0.08 ± 0.1[b]	0.0 ± 0.0[a]	0.06 ± 0.0[a]	0.00 ± 0.0[a]	0.01± 0.0[a]
Oakwood sawdust	0.04 ± 0.0[d]	0.07 ± 0.0[c]	0.00 ± 0.0[c]	0.00 ± 0.0[c]	0.00 ± 0.0[a]	0.00 ± 0.0[c]	0.00 ± 0.0[a]	0.00± 0.0[a]
Hinoki wood sawdust	0.15 ± 0.0[b]	0.00 ± 0.0[d]	0.24 ± 0.0[a]	0.81 ± 0.0[a]	0.00 ± 0.0[a]	0.01 ± 0.0[bc]	0.00 ± 0.0[a]	0.00 ± 0.0[a]
Rice hull	0.24 ± 0.0[a]	0.00 ± 0.0[d]	0.00 ± 0.0[c]	0.00 ± 0.0[c]	0.00 ± 0.0[a]	0.00 ± 0.0[c]	0.00 ± 0.0[a]	0.01± 0.0[a]

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test.

Table 5. Comparison of physical properties of lignocellulosic substrate.

Growing media component	pH	Total porosity (%)	Water holding capacity (%)
Peatmoss	5.1 ± 0.0d	89.9a	47.0a
Waste paper	7.5 ± 0.2a	86.2b	30.8d
Oakwood sawdust	4.5 ± 0.0e	65.3d	35.3c
Hinoki wood sawdust	5.3 ± 0.0c	82.2c	42.9b
Rice hull	7.0 ± 0.1b	82.3c	18.9e
Optimal range	5.2 - 6.5	>85	20-30

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test. Optimal range in growing media according to Abad et al. (2001).

saline soils can accelerate Na leaching, decrease the exchangeable sodium percentage and electrical conductivity and increase water infiltration, water holding capacity and aggregate stability (El-Shakweer et al., 1998).

The ash, C, N and C/N ratio of substrate were presented in Table 3. The highest ash content (15.6 g / 100 g) was obtained from waste paper and rice hull, while the lowest ash content was obtained from oak wood sawdust (0.7 g / 100 g). Ash of lignocellulosic substrate was essentially a direct source of other major elements, notably P, Ca, Mg and especially K in soils. Since ash of lignocellulosic substrate generally contains very little carbon and nitrogen, its application to the soil may reduce the total contents in C and N, by increasing the solubility of organic carbon (Kahl et al., 1996) and the nitrification rate (Meiwes, 1995). The ratio of carbon to nitrogen is that the parameter most often considered in the growing media. Various lignocellulosic substrate showed differences in the C/N ratio. The trend in C/N ratio was hinoki wood sawdust (434.0) >oakwood sawdust (240.0) > waste paper (211.5) > rice hull (78.8). The C/N ratio was very high in waste paper, oakwood sawdust and especially in hinoki wood sawdust, which causes immobilization of N. The C/N ratio is important after composting because it determines the value of the mature compost as a soil amender material for plants. Some authors suggest that the C/N ratio is an extremely important property in the decomposition of organic matter by microorganisms (Marin, 2004), and for this reason, the organic matter added to saline soils plays an important role in the positive effect observed in microbial activity and enzymatic activities such as urease, alkaline phosphatase and dehydrogenase (Bellamy et al., 1995). Tejada and Gonzalez (2005) demonstrated that an increase in the organic matter content of saline soils increases soil structural stability, soil bulk density and, therefore, soil microbial biomass.

The results of comparison means for the concentration of mineral element in the lignocellulosic substrates are shown in Table 4. The levels of P, Mn, Zn and Fe were 0.00 to 0.06 g / 100 g, respectively, and were similar for all substrates. K, Ca, Mg and Na (g / 100 g) differed significantly among sources, ranging from 0.02 to 0.24, 0.00 to 2.55, 0.00 to 0.24 and 0.00 to 0.81, respectively. Generally, peat moss was poor in nutrients (K, Ca, Mg). It would require frequent or regular use of fertilizer if used as substrate. However, waste paper provides and contains a good reserve of nutrients: it is high in K, Ca and Mg. All physical properties tested differed significantly among substrates. Peat moss, waste paper, oakwood sawdust, hinoki wood sawdust and rice hull substrates, used in a growing media, can differ in their physical properties. Physical properties affect the air content and retain the volume of available water. It also adsorbs the rate of nutrients in substrate. Some physical properties of substrates are presented in Table 5. Depending on lignocellulosic substrate pH ranged from 4.5 to 7.5. In general, all the substrates, including peat moss, showed pH values within the established optimal range (5.2 to 6.5) suggested by different authors (Sanchez-Monederoet al., 2004; Herrera et al., 2008; Noguera et al., 2003). The pH of the waste paper, hinoki wood sawdust and rice hull should not interfere with nutrient assimilation, oakwood sawdust pH was highly acidic, which would negatively influence nutrient availability. Lignocellulosic substrates also maintain a more constant media pH, and in some cases contribute to acidification of the soil (Karp et al., 2006). One of the most influential factors determining the growth and composition of soil bacterial communities was pH. However, pH was often correlated with many other factors, including nutrient availability and plant community, and causality among factors is not easily determined. The pH was often correlated with important environmental factors influencing the microbial community, including nutrient availability, heavy metal availability and toxicity (Degryse et al., 2009; Fernandez et al., 2009) and plant community structure.

The total porosity space was expressed as a percentage, and can be divided into large pores (“macropores”) that provide for gaseous exchange and root growth, and small pores (“micropores”) that control the water holding capacity. Total porosity percentage that is, an index for root media aeration was high for waste paper (86.2%) and it was low for oakwood sawdust (65.3%). When root media aeration is sufficient, supply of water and nutrient elements for plants is easy. The total porosity of the media was important, probably more crucial than the portion of water holding capacity. On average, 10 to 30% of the media volume should be composed of air space, while 45 to 65% should be composed of water (Altland, 2006). The amount of water holding capacity was between 18.9 and 42.9% of the volume for the lignocellulosic substrates. These results showed that the particle size of perlite was greater than that of the coco peat, because by decreasing the particle size, the water holding capacity will increase. The same trend was reported by other researchers (Wada, 2005). Hence, the percentages of organic matter and fine granules in the substrate were increased, which increases the maximum water holding capacity and therefore potentially increases saturated weight and reduces air content at the maximum water capacity.

Physical and chemical properties of the mixtures growing media

Mixtures of varying proportions can be designed to take advantage of the positive characteristics of each substance and their interactions, in order to create optimal characteristics for plant growth (best water retention, pH levels, non-limiting salts, etc.). The mixtures substrate assayed were: peat moss (100%), peat moss (30%) + perlite (10%) + waste paper (60%), peat moss (30%) + perlite (10%) + oakwood sawdust (60%), peat moss (30%) + perlite (10%) + hinoki wood sawdust (60%), peat moss (30%) + perlite (10%) +rice hull (60%). Table 6 and 7 describe some of the characteristics of the various mixtures, along with the commercial substrate used as control (peat moss). Most of the mixtures growing media present pH levels close to optimal range. The pH of WP was slightly alkaline and was, therefore, not considered a limiting factor (Miller, 2004). The main physical characteristics of mixture growing media included increase of porosity and water holding capacity.

Substrates containing only organic components often lose macroporosity over time. Decomposition of organics creates an over abundance of small particles that hold excessive water and reduce air porosity. A mixture of organic and inorganic components, such as perlite, can help maintain the percentage of large pores later in the growing season (Warren and Bilderback, 2005). The mineral elements of mixtures substrate were presented in Table 7. The K, Ca, Mg and Na contents were high in mixture substrates. The WP was especially rich in Ca when compared to the other test mixtures growing media. Calcium is well known to have regulatory roles in metabolism, and sodium ions may compete with calcium ions for membrane-binding sites. Therefore, it has been hypothesized that high calcium levels can protect the cell membrane from the adverse effects of salinity (Cramer et al., 1986).

Table 6. Comparison of physical properties of mixtures substrate.

Mixtures substrate	pH	Total porosity (%)	Water holding capacity (%)
Peatmoss	5.1^{c}	89.9^{a}	47.0^{b}
Waste paper	7.9^{a}	88.1^{b}	50.5^{a}
Oakwood sawdust	5.0^{cd}	72.6^{e}	46.2^{c}
Hinoki wood sawdust	4.9^{d}	82.9^{d}	44.6^{d}
Rice hull	6.1^{b}	84.9^{c}	19.8^{e}

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test.

Table 7. Mineral elements of mixtures substrate.

Mixtures substrate	Dry weight (g / 100 g)							
	K	Ca	Mg	Na	Zn	Fe	Mn	P
Peatmoss	0.02 ± 0.0^{d}	0.57 ± 0.0^{c}	0.01 ± 0.0^{d}	0.00 ± 0.0^{d}	0.00 ± 0.0^{a}	0.00 ± 0.0^{c}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Waste paper	0.12 ± 0.0^{c}	3.39 ± 0.0^{a}	0.14 ± 0.0^{b}	0.20 ± 0.0^{b}	0.01 ± 0.0^{a}	0.07 ± 0.0^{a}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Oakwood sawdust	0.17 ± 0.0^{b}	0.20 ± 0.0^{d}	0.05 ± 0.0^{c}	0.09 ± 0.0^{c}	0.00 ± 0.0^{a}	0.02 ± 0.0^{b}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Hinoki wood sawdust	0.32 ± 0.0^{a}	0.14 ± 0.0^{e}	0.24 ± 0.0^{a}	0.72 ± 0.0^{a}	0.00 ± 0.0^{a}	0.02 ± 0.0^{b}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Rice hull	0.12 ± 0.0^{c}	1.40 ± 0.0^{b}	0.14 ± 0.0^{b}	0.20 ± 0.0^{b}	0.01 ± 0.0^{a}	0.07 ± 0.0^{a}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}

Mixtures substrate	Dry weight (g / 100 g)							
	K	Ca	Mg	Na	Zn	Fe	Mn	P
Peatmoss	0.02 ± 0.0^{d}	0.57 ± 0.0^{c}	0.01 ± 0.0^{d}	0.00 ± 0.0^{d}	0.00 ± 0.0^{a}	0.00 ± 0.0^{c}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Waste paper	0.12 ± 0.0^{c}	3.39 ± 0.0^{a}	0.14 ± 0.0^{b}	0.20 ± 0.0^{b}	0.01 ± 0.0^{a}	0.07 ± 0.0^{a}	0.00 ± 0.0^{a}	0.00 ± 0.0a
Oakwood sawdust	0.17 ± 0.0^{b}	0.20 ± 0.0^{d}	0.05 ± 0.0^{c}	0.09 ± 0.0^{c}	0.00 ± 0.0^{a}	0.02 ± 0.0^{b}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Hinoki wood sawdust	0.32 ± 0.0^{a}	0.14 ± 0.0^{e}	0.24 ± 0.0^{a}	0.72 ± 0.0^{a}	0.00 ± 0.0^{a}	0.02 ± 0.0^{b}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}
Rice hull	0.12 ± 0.0^{c}	1.40 ± 0.0^{b}	0.14 ± 0.0^{b}	0.20 ± 0.0^{b}	0.01 ± 0.0^{a}	0.07 ± 0.0^{a}	0.00 ± 0.0^{a}	0.00 ± 0.0^{a}

In each column, values with different letters indicate statistically significant differences ($p < 0.05$) by Duncan's test

Growth test

The objective was to test different ternary mixtures of the residual components as a substrate for growing Chinese cabbage (*Brassica rapa* var. *glabra*). Figure 1 shows that WP (containing 30% peat moss, 10% perlite and 60% waste paper), performed best, while those that performed most poorly contained 60% hinoki wood sawdust mixed with 10% perlite (HS) or 60% oakwood sawdust with 10% perlite (OS). The growth of the Chinese cabbage cultivated in the wood waste mixtures (oakwood sawdust, hinoki wood sawdust) was clearly lower than that of Chinese cabbage cultivated with the commercial substrate (100% peat moss). In growing media consisting of a mixture of rice hull with perite, the seed germination was similar to that observed in the PM (control). The inherent differences in chemical properties between different wood species, however, the suitability of sawdust as an organic growing media component was extremely variable. Mastalerz (1977) stated that sawdust from incense-cedar (*Libocedrus decurrens*), walnuts (*Juglans* spp.), or redwood (*Sequoia sempervirens*) is known to have direct phytotoxic effects, and sawdust from western red cedar (*Thuja plicata*) is toxic to many horticultural plants (Schaefer, 2009). The plant height and leaf area of Chinese cabbage grown in PM (control) and WP (containing 30% peat moss, 10% perlite and 60% waste paper) was presented in Figure 2. After 7 day, stem height and leaf area of the WP (containing 30% peat moss, 10% perlite and 60% waste paper) was much higher than that of the PM (control) (Figure 3). Results of this study confirm that waste paper can be used effectively in growing media.

Conclusion

Waste materials are not always adequately used in current commercial, agricultural practices, such as nurseries, despite the possible immediate benefits from using them, especially if they are readily available and less expensive than traditional substrates like peat moss. This work shows that the utilization of lignocellulosic sub-strate (waste paper, waste wood and agriculture residue)

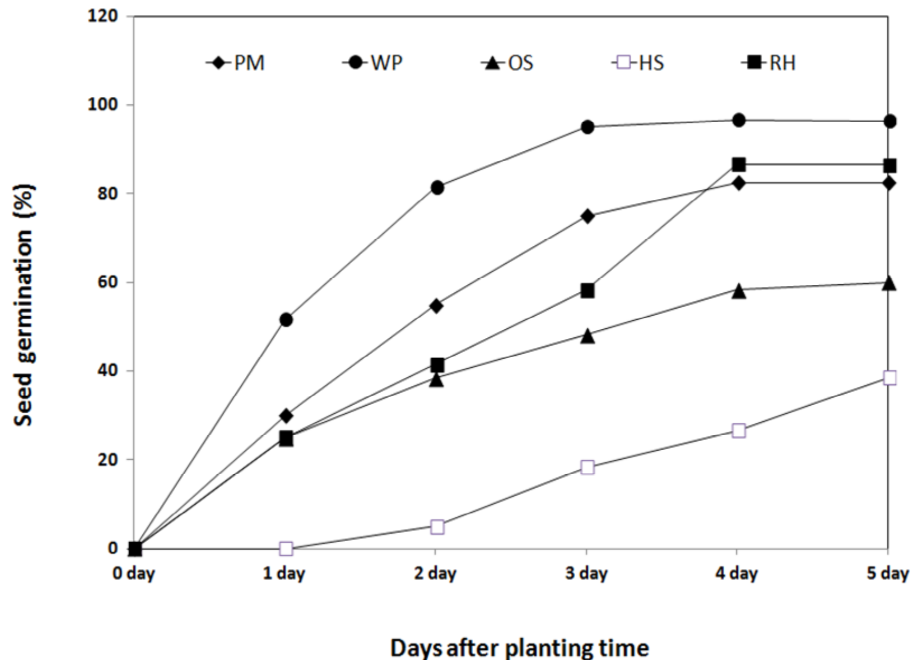

Figure 1. Seed germination (%) of Chinese cabbage grown in different mixtures.

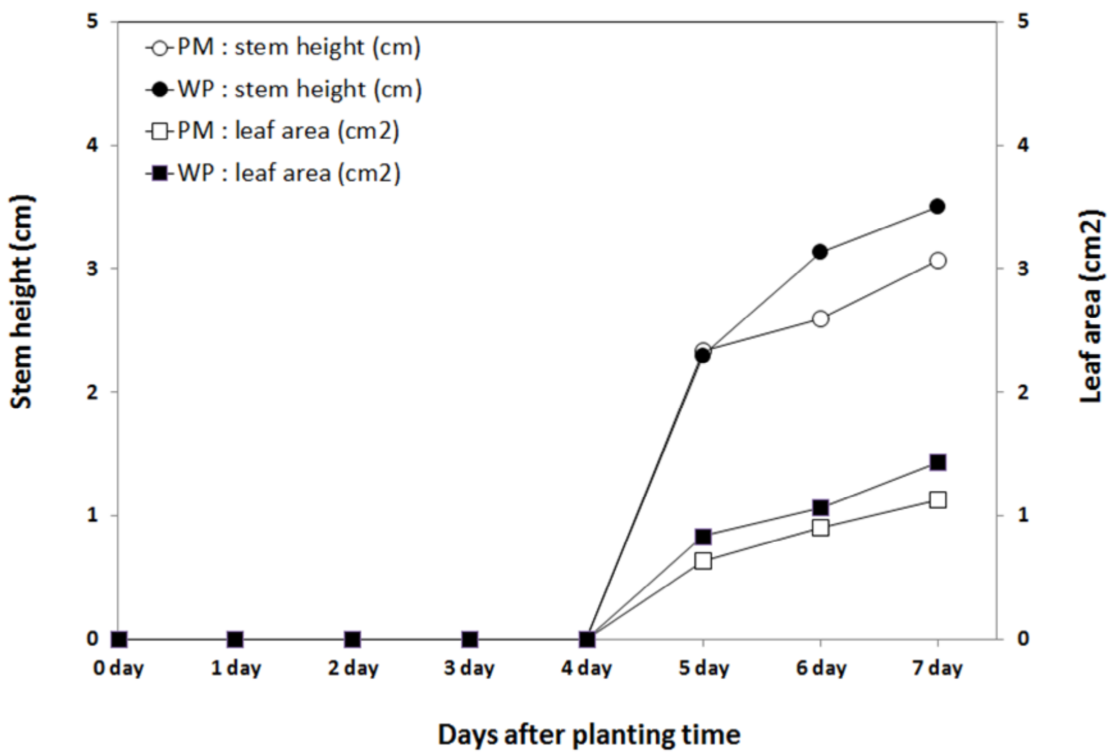

Figure 2. Plant height and leaf area of Chinese cabbage grown in PM (control) and WP (containing 30% peat moss, 10% perlite and 60% waste paper).

for peat moss substitution has proven to be a useful procedure to obtain suitable growing media. Moreover, due to physical and chemical characteristics of the media developed by mixtures growing media can be considered

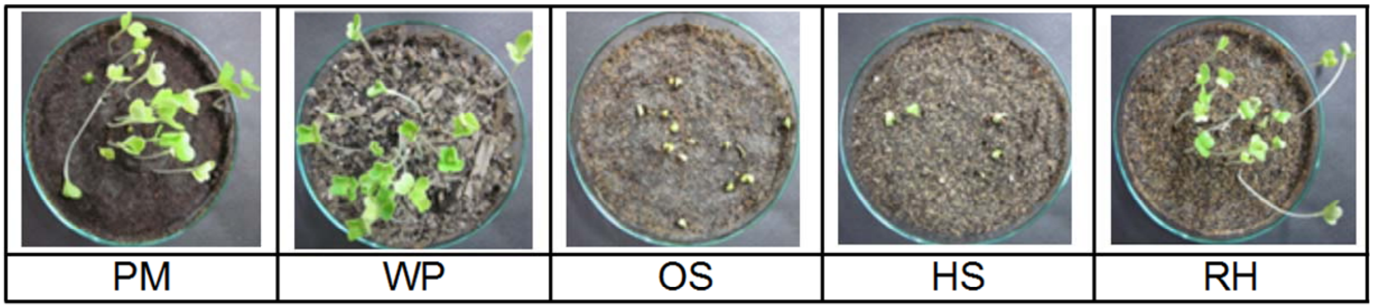

Figure 3. Chinese cabbage growth in different mixtures.

as valuable partial peat moss substitutes for Chinese cabbage, especially at the rates of 30% peat moss + 10% perlite + 60% waste paper substrate, which gave the maximum seed germination when compared to peat moss. In general, chemical properties and seed germination were enhanced by using the lignocellulosic substrate: the waste paper seemed to be more effective than the waste wood and agriculture residue for this purpose. The use of this kind of domestic refuse could contribute to solve two important problems: waste disposal and limit peat moss extraction. Also, this research indicates that waste paper may be utilized as a suitable replacement for peat moss in restoration of damaged land.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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