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Wood fibre in pot plant culture; peat replacement up to 50% in volume?

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Abstract

Use of peat and coir in horticulture is under pressure because of the negative effects on the environment. Peat harvesting releases CO_2 into the atmosphere and changes the wetland ecosystem. Coir production can cause salt pollution in the country of origin as the product has a high salt level and is washed with fresh water before use as a substrate. HydraFiber, a specific wood fibre product was tested as substitute for (part of) peat and coir in professional potting soils.

Wood fibre was mixed in 3 volume percentage ratios (30, 40 and 50 %v/v) with peat or coir. Nutrient content and stability were used to calculate appropriate fertiliser levels for each mixture for growth of a Begonia crop in an ebb and flood system. Addition of up to 50% v/v wood fibre to peat or coir has no negative effect on the rate of development to flowering of a 10 week crop. The ratio of weight/length of the plants is similar for all treatments. Addition of 40% and 50% v/v wood fibre to peat reduces water content by 16% v/v and increases air content by the same amount in the substrate in the range of -6 to -100 cm pressure head. Addition of wood fibre to coir has a similar effect.

A lower average water content in substrate mixes of peat and wood fibre indicates it is more difficult to overirrigate but that it also requires a more precise monitoring of both, water content and nutrient status. It also requires a higher frequency of irrigation and more frequent adaptations of the nutrient level in the water supply. Using wood fibre in percentages from 30 to 50% v/v may also require an adaptation in the growing medium used for propagation plugs.

Keywords: peat reduction, N accumulation, irrigation, peat alternative, begonia.

INTRODUCTION

Peat is the most common rooting medium component in the glasshouse industry and has been used for many years for container plant production (Boldrin et al., 2010; Schmilewski, 2014). Peat is harvested from peat bogs, which in origin are areas with a unique biodiversity and the removal of peat releases CO_2 into the environment (Fraser et al., 2005). Alternatives for peat such as coir are available, but, there are issues on sustainability (Gruda, 2019) such as releasing salt into the environment in the country of origin when washing out the substrate. One potential substitute for peat with a lower environmental impact is wood fibre (Jackson et al., 2010; Jackson, 2021). Wood fibres have been used since the early 1980s and are still seen as a suitable alternative to perlite and more recently to replace part of the peat. Wood fibre is produced from pine trees as a byproduct of the timber processing industry and many commercially available wood fibres originate from FSC- or PEFC-certified forests in America and Europe. The term wood fibre describes material from a process that combines wood and/or bark and thermally processes them in a pressurized vessel to create singulated, small-diameter, long, thin strands with a large surface area. This process creates a fibre that is more stable than in a production process without heating and pressure (Barrett et al., 2016) and this wood fibre has good water uptake and retention properties and a high air volume content (Owen et al., 2014).

Previous research into the production process and chemical and hydrological properties of wood was carried out in 2014 by Owen et al. where wood chips were used as aggregates (20% volume) in greenhouse substrates giving positive results in pot plants. A low salt concentration, low bulk density, high air content and good water uptake characteristics must be present. Assessment of possible damage to the crop by wood chips or wood fibre such as the reduced N accumulation in plant tissue (Harris et. al, 2020) must be investigated by testing the biological stability of the material. Additionally, the wood fibre should not have an effect on EC and pH. As the wood fibre is mixed with other substrates, it is important to conduct an analysis to establish the required fertilization levels for the mixtures (Blok et al., 2019). Any wood fibre offered as an alternative substrate to peat and coir, must be thoroughly tested on chemical, physical and hydrological properties to give the growers, potting soil producers and suppliers insight into the properties of fine wood fibre. This research focusses on wood fibre that has been thermally processed (HydraFiber® from Profile Inc. USA) from byproducts of the timber industry. Furthermore the volume of wood fibre in potting soil mixes is usually 15-30% v/v because of the restrictions in the properties mentioned (Owen et al., 2014). It would however be convenient if wood fibre products would be further developed into products which would not be restricted by any property in the volume used in potting soils. This would bring wood fibre products on par with peat and coir products which both are used without restriction in the percentage of volume used in mixes. Admittedly, this may mean a wider range of wood fibre products is needed to create mixes with widely different properties, just as peat and coir are offered in a wide range of products for this very reason. This approach warrants a world wide standardisation on the measurement and interpretation of the methods for water retention, uptake and methods to compare physical, chemical and biological properties of the substrates involved (Barrett et al., 2016).

The objective of this present study was to first test thermally processed wood fibre in ready made mixes on the properties required to make it a suitable alternative to peat. A second objective was to find the highest possible volume fraction of wood fibre which could be used in a semi-commercial pot plant culture.

MATERIAL AND METHODS

To investigate the suitability of the wood fibre (HydraFiber® 160WB) for a plant trial when mixed with coir and peat, 8 mixtures were supplied by HydraFiber (Table 1). Two control treatments were included, either peat (100% v/v peat) or coir mix (70% v/v coir plus 30% v/v peat). Mixes of the peat control with 30, 40 or 50% v/v HydraFiber and of coir with 30, 40 or 50% HydraFiber were made in the US and transported to Bleiswijk for the tests and trial. Previous tests up to 40% v/v wood fibre have shown positive results (Harris et al., 2020) and therefore 40 and 50% v/v wood fibre were used.

Table 1. Description of the material in the treatments as used in this experiment in % volume (v/v).

description	peat control % v/v	peat +30% v/v HF	peat + 40% v/v HF	peat + 50% v/v HF	coir mix 30% v/v peat	coir + 30% v/v HF	coir + 40% v/v HF	coir + 50% v/v HF
fine peat	85	70	60	50	30			
peat >10mm	15							
coir < 5mm					70	70	60	50
HydraFiber 160WB		30	40	50		30	40	50

Laboratory tests

The available nutrients in the original mixtures (Table 1) were quantified using a ICP-MS (Groen Agro Control, Delfgauw, NL) in a 1:1,5 analysis which is used for organic products such as coir and peat (Sonneveld en van Elderen, 1994). The pH and EC were determined in the same sample (EN 13038, 1999 and EN 13037, 1999). The physical and hydrological properties of all the mixtures were tested. The dry bulk density, pore size and water characteristics were measured (EN 13041, 2011) at the Business unit Greenhouse horticulture in Bleiswijk. Organic and mineral percentages are determined using a muffle furnace at 550oC (EN 13039, 2011). The biological stability of the 100% wood fibre was analysed following the protocol using the OUR method (Veeken et al., 2003; CEN 16087, 2011).

Mixing model

Once the characteristics of the mixtures were established in the laboratory tests, the data were entered into a mixing model (Blok et al., 2009; Blok et al., 2019). This model is nowadays adjusted to calculate the amount of fertiliser that should based on a) crop demand; b) the amount of lime required to reach pH 5.3; c) the amount of extra nitrate to compensate for nitrogen mobilization by microbial degradation of the potting soil constituents used; d) the amount of extra iron to compensate for iron uptake by microbes active in the degradation of the potting soil constituents used. This was important to ensure that the different concentrations of wood fibre in the peat or coir could be compared and that the EC and pH of the treatments were similar. In the mixes before fertilizers and lime were added, the EC was reduced on addition of HydraFiber and the pH was dependant on the type of substrate. The coir mix had a lower EC because 30% v/v peat was included in this mix. The EC and pH before fertilizing and liming (raw), the fertiliser additions and EC and pH at the start of the greenhouse experiment are in Table 2.

Table 2. In the heading the description of the material in the treatments as used in this experiment in % volume (v/v). First two rows the raw EC and pH before addition of fertiliser (1:1,5 analysis). Then the amount of fertiliser added calcium carbonate (lime), calcium nitrate, NPK and Fe (chelate) before the experiment started and last two rows the EC and pH at start after addition (1:1,5 analysis).

property	unit	peat (control)	peat 30% HF	peat 40% HF	peat 50% HF	coir mix 30% peat	coir 30% HF	coir 40% HF	coir 50% HF
EC raw	(mS$^{\text{-cm}}$)	0.14	< 0.10	< 0.10	< 0.10	0.18	< 0.10	0.11	< 0.10
pH raw	(-log[H])	4.1	4.2	4.3	4.3	4.6	6.5	6.5	6.5
$CaCO_3$	(g$^{\text{-L}}$)	4.20	2.94	2.52	2.10	1.68	0.00	0.00	0.00
$Ca(NO_3)_2$	(g$^{\text{-L}}$)	0.29	0.31	0.34	0.34	0.29	0.34	0.34	0.34
NPK	(g$^{\text{-L}}$)	0.98	1.20	1.17	1.17	0.84	1.17	1.01	0.69
Fe	(g$^{\text{-L}}$)	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01
EC start	(mS$^{\text{-cm}}$)	0.71	0.60	0.79	0.72	0.62	0.68	0.68	0.60
pH start	(-log[H])	5.1	5.1	5.1	4.9	4.8	5.3	5.3	5.2

Greenhouse trial

In July 2019, sixty 13 cm (0.75 L) pots were filled with each of the 8 fertilized mixtures. One plot of 20 pots per treatment was placed on each of the 3 benches as shown in Figure 2. The rooted Begonia cuttings in a plug were placed into the pots. The pots were first placed adjacent to each other. The pots were spaced when the leaves touched the next pot and the final spacing was to approx. 20 plants/m^2.

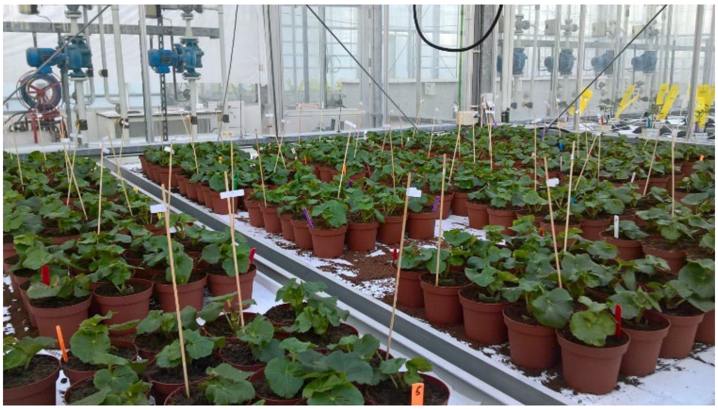

Figure 2. Three benches in the greenhouse, each with eight treatments. Each plot per bench has 20 pots and each treatment has 60 pots.

Plants were irrigated using ebb and flood irrigation. From the start of the experiment pots were weighed before and after ebb and flood irrigation to record the amount of water taken up by the plants in the greenhouse situation. The volume of the water in the pots was calculated by using the dry bulk density of the eight mixes and the pot volume (0.75L). The pots were weighed, and the weight of the pot, the weight of the plug and the weight of the dry bulk density were subtracted from the total weight. This value was the weight of the water in the pot. All calculations took the pot volume into account. After 10 weeks the flowering plants were measured. Each bench is regarded as a block for the ANOVA statistics.

RESULTS

Physical properties

The dry bulk density (DBD) of the mixes is shown in Table 3 and the differences between the controls and the mixes are visible in the laboratory results. The addition of HydraFiber to both the peat and coir/peat control reduces the DBD; in peat on average 20% and for the coir/peat control on average 51%. Easy available water (EAW) is a characteristic for peat based substrates and is the volume of water between a pressure head of -10 and – 50 cm. The easy available water in all the mixes without plants is shown in Table 3. In the coir mixtures the addition of HydraFiber seems to reduce EAW. In peat the addition of HydraFiber seems to slightly increase the EAW.

The total pore space (TPS) is increased by the addition of HydraFiber meaning that the volume occupied by solids decreases, the pore space increases slightly (1.5 – 3% v/v) with the three levels of HydraFiber in peat but remains fairly stable on the addition of HydraFiber in the coir mixtures.

Table 3. In the heading the description of the material in the treatments as used in this experiment in % volume (v/v). Dry bulk density (g/L), Easy available water (EAW in % v/v), Organic matter (OM in %), Total pore space (TPS in % v/v) and solids (% v/v).

property	unit	peat (control)	peat 30% HF	peat 40% HF	peat 50% HF	coir mix 30% peat	coir 30% HF	coir 40% HF	coir 50% HF
DBD	(g^{-L})	143	123	102	125[a]	125	70	72	65
EAW	(%v)	21.9	25.5	24.5	27.5	23.7	17.8	17.2	16.6
OM	(%w)	96.6	95.3	96.1	95.4	93.6	94.0	94.3	95.2
TPS	(%v)	90.9	92.2	92.9	96.6	92.2	95.6	95.5	95.9
solids	(%v)	9.1	7.8	7.1	6.4	7.8	4.4	4.5	4.1

[a] rather high value

To illustrate the effects of the most extreme wood fibre applications, Figure 2 shows that at a pressure head of -10cm (pF 1) the peat products in a laboratory test lose water less readily than the coir products because of the unique structure of peat compared to coir. The coir/peat mix control (70% v/v coir and 30% v/v white peat) has similar water characteristics as the 100% v/v peat. The coir with 50% v/v HydraFiber is the driest substrate but the rewettability is good as the final value of the graph is equal to the control. All the additions of HydraFiber lose water easier than the controls but rewet to within 10% v/v of the initial level.

Figure 3 shows the situation in the greenhouse for the most extreme wood fibre applications. The uptake per pot is very similar in the peat treatments, in the coir there is 13% more uptake in the drier mix (50% v/v woodfibre). Drying of the pots between the irrigation cycles (equivalent to the laboratory increase in pressure deficit) can also be seen, the peat control reaches minimal 37% v/v moisture while the 50% v/v wood fibre treatment reaches 29% v/v moisture. For the coir/peat mix control this value is 34 % v/v and the 50% v/v wood fibre treatment reaches 31% v/v moisture. Addition of wood fibre does reduce minimum water content but not water uptake.

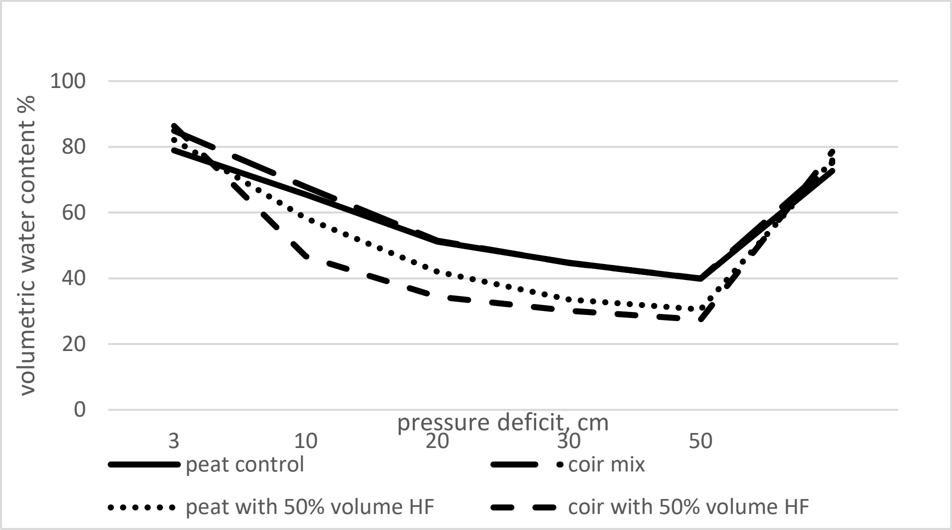

Figure 2. Water characteristics of the extreme mixes; peat control, 50% v/v HydraFiber in peat, coir mix and 50% v/v HydraFiber in coir measured in the laboratory.

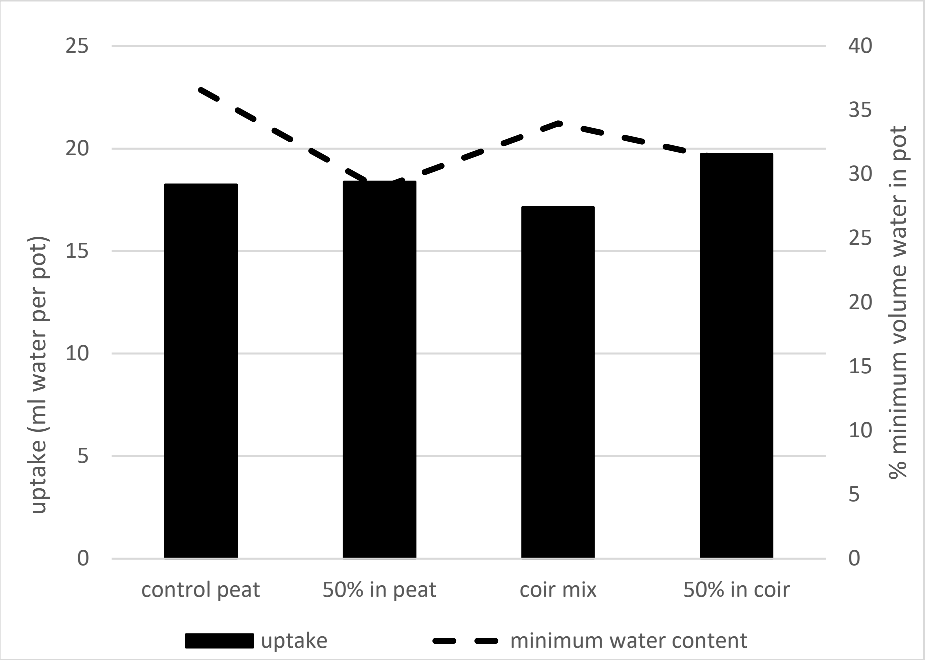

Figure 3. Water characteristics of the extreme mixes; peat control, 50% v/v HydraFiber in peat, coir mix and 50% v/v HydraFiber in coir measured in the greenhouse.

Plant growth in greenhouse experiment

Nine plants from each of the three plots per treatment were harvested at the end of September after 10 weeks in the greenhouse. The plants in a treatment with coir were in general slightly longer than the plants with peat with the longest plants in the coir with 40% and 50% v/v HydraFiber but the differences were small (Table 4). The plants in coir also had a higher fresh weight than the plants in peat but the length weight ratio was similar for all treatments (Table 4, bottom row). The final appearance of the plants is shown in Figure 4.

Table 4. In the heading the description of the material in the treatments as used in this experiment in % volume (v/v). Length, number of flowers, fresh weight, dry weight, dry mass and the length/weight ratio of the plants at the end of the experiment at final harvest (n=27). Different letters in subscript show significant differences (<0.05).

plant	unit	peat	peat 30% HF	peat 40% HF	peat 50% HF	coirmix 30% peat	coir 30% HF	coir 40% HF	coir 50% HF
length	(cm)	36.4^{ab}	35.6^{a}	35.9^{ab}	35.5^{a}	36.5^{ab}	36.1^{ab}	37.2^{bc}	38.2^{c}
flower	(#)	14.2^{a}	14.8^{a}	14.9^{a}	13.9^{a}	15.8^{a}	16.9^{a}	15.1^{a}	16.2^{a}
fresh wt.	(g)	247^{ab}	249^{ab}	259^{ab}	238^{a}	261^{ab}	258^{ab}	259^{ab}	275^{b}
dry wt.	(g)	19.5^{bc}	20.5^{bc}	20.5^{bc}	19.2^{b}	19.9^{bc}	17.5^{a}	19.8^{bc}	20.8^{c}
dry mass	(%)	4.12^{d}	4.02^{cd}	4.14^{d}	3.98^{bc}	4.00^{c}	3.82^{a}	3.88^{ab}	3.96^{bc}
leng/wt	ratio	0.15	0.14	0.14	0.15	0.14	0.14	0.14	0.14

The biological stability of the pure wood fibre was measured between 7-8 mmol O_2/kg dry matter/hour. All values below 12 are suitable for substrate use but some extra nitrate is required to safeguard against nitrogen immobilization. The nitrate levels in the substrate at the start of the experiment were rather lower than expected in the coir mixtures. The nitrate levels in the substrate at the end of the greenhouse experiment were lower except in the peat control, the coir mix treatment and in the peat 30% v/v wood fibre (Table 5). The largest decrease (up to 34%) was in the 50% v/v wood fibre treatments and in the coir treatments with wood fibre.

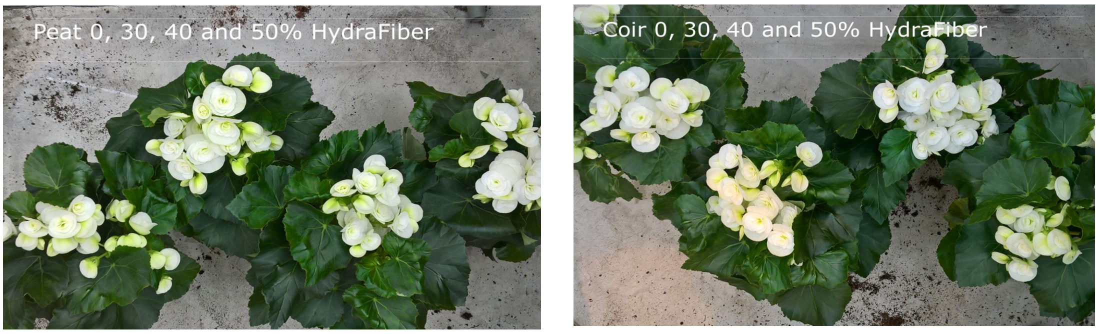

Figure 4. Illustration of the Begonia plants at the end of the experiment. Left photo from left to right peat, 30% Hydrafiber, 40% HydraFiber and 50% HydraFiber. Right photo from left to right coir, 30%, 40% and 50% HydraFiber.

Table 5**.** In the heading the description of the material in the treatments as used in this experiment in % volume (v/v). Total nitrogen (mmol/L) in potting substrate (1:1,5 soil analysis) at start and at end of the experiment.

property	unit	peat	peat 30% HF	peat 40% HF	peat 50% HF	coir mix 30% peat	coir 30% HF	coir 40% HF	coir 50% HF
Total N wk 31	(mmol^{-L})	5.0	4.2	5.4	5.0	4.0	4.5	4.4	3.8
Total N wk 39	(mmol^{-L})	5.0	5.0	4.6	4.2	4.3	3.5	3.2	2.5

DISCUSSION

The addition of up to 50% v/v HydraFiber to peat or coir had no negative effect on the development of the Begonia's grown in this experiment. The ratio of weight/length was similar for all the treatments. In coir addition of 50% v/v HydraFiber had a positive effect on the plant growth compared to the addition of 30 – 40% v/v HydraFiber (in coir). The plants in the 50% v/v mix of HydraFiber in coir had a significantly larger fresh weight.

Water retention is the suction force that keeps water in the substrate (expressed in cm water pressure deficit). The tension with which the water is retained in the growing media also represents the opposite force which the roots must use to absorb the water. Total pore space (TPS) is the total volume not occupied by solid materials. Total porosity (TP) is a combination of the aqueous and gaseous phases and is related to the shape, size and orientation of media particles. The total growing media filled volume minus the volume of the solid materials present in the substrate, constitute the TP. Part of the TP consists of pores that are able to retain water against the force of gravity (capillary force); another part of TP consists of pores filled with air. The air filled pores determine the availability of oxygen to the roots during cultivation. Substrate aeration is positively related to the air filled pores (AFP): an increase of AFP increases oxygen transportation and root expansion, but reduces the water content in the media. This means that substrates with high AFP have high drainage capacity and are suitable to reduce the risk of over irrigation, but at the same time need more frequent irrigation cycles.

Addition of HydraFiber to peat does not reduce the air content at container capacity (saturated) but the addition of 40% and 50% v/v HydraFiber to peat reduces water content by 16% v/v and increases air content by the same amount in the substrate in the range of -6 to -50 cm pressure head. Addition of HydraFiber to coir does not reduce the air content at container capacity (saturated) but the addition of 30%, 40% and 50% v/v HydraFiber to coir reduces water content and increases air content in the substrate in the range of -4 to -50 cm pressure head. This increase in air content is a desirable property as 20% v/v of air filled space in growing media is thought to be necessary for undisturbed air exchange at maximum plant growth rates (Verhagen, 2013). The amount of extra air is at the same time lower than expected based on a proportional share of the air content of the HydraFiber material itself. This indicates a fair amount of interstitial filling, which allows the peat and coir mixes to remain fairly wet. This is advantageous as potting soil mixes should be as wet as possible as long as the air content does not drop below 20% v/v to allow fast transport of water and nutrients to the roots (Blok et al., 2017).

HydraFiber did not increase the water uptake rate in the greenhouse situation. The water uptake rate was similar for all treatments on the ebb and flood system. In general the coir mixes with 40-50% v/v wood fibre and the peat mix with 50% v/v wood fibre were drier when the ebb/flood irrigation was started. These mixes should be irrigated more frequently to prevent a low water volume. Laboratory measurements mask this effect as they assume equilibrium between suction force applied and water content. In a greenhouse, changes in water content are much faster than the time required for equilibrium.

The pH values in the peat mixes at the start were acceptable, but slightly lower (5.0) than the target value (5.3). It seems the peat was slightly more acid or the pH increase estimated for the HydraFiber was almost absent. So a slightly higher addition of calcium carbonate for the mixtures containing peat was in order. The lime equivalent for HydraFiber is thus lower (almost absent) than for the wood fibre products currently in the market. The addition of fertilisers to HydraFiber mixes must be done with care and may never be forgotten as HydraFiber does not contribute to EC and nitrate levels. The HydraFiber showed no extra manganese release which can occur with wood fibre.

The HydraFiber used in this experiment did seem to cause slight nitrogen immobilization by micro-organisms which take up the nitrogen so that it becomes less available for the crop. This reduction in nitrogen in the pot seems to increase when a higher volume of wood fibre is used. Another possible explanation for a lower nitrate concentration in the pot may be the reduction in water content in the pot with the higher volume of woodfibre but this did not negatively affect the plant growth. The coir used in the coir mixes clearly also fixed some nitrate (due to the small fraction) and this should also be anticipated when preparing the substrates. We now added 50 mg/L calcium nitrate extra for 50% v/v HydraFiber in both peat and coir but a better dose could have been 100 mg/L for peat/HF 50%/50% v/v and 150 mg/L for coir/HF 50%/50% v/v. The treatments with HydraFiber lowered the dry bulk density and reduced the mass of the growing media used.

Using wood fibre in percentages from 30 to 50% v/v may also require an adaptation in the growing medium used for the propagation plugs because of the ability of the wood fibre to loose water more easily than for example peat. If a peat plug is placed into wood fibre the peat plug will remove water from the wood fibre and remain too wet.

CONCLUSION

The thermally processed wood fibre used in this research can substitute peat or coir for up to 50% in a greenhouse pot plant crop of at least 3 months. Careful fertilisation is important as the wood fibre has a very low EC. The nitrate fertilisation must be increased to compensate for slight nitrogen immobilzation.

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