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Use of Coconut and Sugarcane Residues as Rooting Substrate for Pulpwood Clonal Plants Production

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Abstract

Success of the containerized clonal plants production relies largely on the rooting substrates. The partially decomposed coconut residue (coir pith) is being used for the production of seedlings/ clones for horticulture and plantation development. A study was conducted to find out the possibility of including sugarcane residue—sugarcane bagassse pith (SBP) as a substrate or partial substitution to coconut coir pith (CCP) for pulpwood clonal plants production. These two residues were mixed in different proportions (100, 75, 50 and 25 %), co-composted using fungal-bacterial consortia and analyzed the substrates for various physicochemical and chemical properties. The results showed that composted substrates met the standards of rooting media. The pH, EC, exchangeable cations and available nutrients were increased. The bulk density and organic carbon content of the substrates were found reduced and. The C/N ratio was reduced from >100 to the range of 20 to 30, which is ideal for rooting substrates. The survival of *Casuarina* and *Eucalyptus* hybrid clonal plants showed that 50 % of the CCP can be effectively substituted with SBP. The growth parameters (root volume, shoot length, root/ shoot ratio and number of new leaves) of these two pulpwood clonal plants were improved using the co-composted/ mixed substrates. Therefore, this study concluded that 50 % or 25 % of coir pith can be substituted with bagasse pith for co-composting and utilization in the pulpwood clonal plants production.

Keywords

Rooting substrate, sugarcane bagasse pith, coconut coir pith, pulpwood clonal plants production, casuarina, eucalyptus

1. Introduction

In India, about 700 pulp and paper industries exist and 28 industries are using pulpwood as raw materials. Paper industries remain under pressure to cater the raw material due to limited land resource availability and therefore, these industries promote pulpwood plantations (farm forestry) with an annual target of 75000 hectares per annum [1]. To meet out the planting target, containerized transplant clonal plants production has became more popular in the last two decades owing to its advantages of healthy and homogenous population, effective pest/ disease control and effective management of land, energy and time [2].

The success of clonal plants production mainly relies on the substrates used for transplanting the cuttings. Peat soil, vermiculite, quartz sand, perlite, Zeolite, pumice were some of the common physical growth substrates used earlier for seedlings/ clonal plants production and scientific studies [3]. Due to increased demand, escalated cost, decreased availability and adverse impact on environment limits the use of these substrates. Therefore, the cost-effective and locally and easily available rooting substrates made up of agricultural residues gained importance in large scale production of clonal plants from mother propagules.

The quality of rooting substrate is to satisfy the need of good clonal plants growth within the limited volume of the container and to prepare a successful transplanting in the field. The physical, chemical and biological properties of the rooting substrate determine the development of healthy, fibrous root system and successful growth of clonal plants. The physical properties of the rooting substrate should be within the appropriate range as a small quantity of this substrate aids the growth of clonal plants. A good rooting substrate should be light in weight, having desirable bulk density, well drained but better water holding capacity and constant volume when wet or dry [4]. The pH, EC and organic carbon content of the rooting substrate are extremely important as they are directly linked with the substrate microbial consortium and plant nutrient availability [5]. The substrate should be with minimum of ash content, sand and silt particles and easy to handle and blend with other substrates i.e. consistency of the physical and chemical properties should not alter during long time storage [6]. On biological point of view, the rooting substrate should be free of weed seeds, spores of disease causing pathogens, nematodes and eggs of insect pests [7].

In India, about 81 thousand hectares of land is cultivated with coconut [8] and the area expansion under coconut is increasing gradually in southern India because of improved management of coconut cultivation, increased use of coconut products and increased market price for coconut products [9]. The agro waste produced during the extraction of coir fibre, known as coir pith, which is about 50-60 % of the coconut husk is used for various purposes in agriculture. Coir pith, due to its high water retention capacity (500-600 %), high cation exchange capacity, lower bio-degradability (high lignin content) and environmentally amenable nature, is preferred as rooting substrate for containerized nursery plants production and considered as better alternate for soil and other inorganic rooting substrates [4]. At present, in India, decomposed coir pith is being used as rooting substrate at most of the pulp and paper industries for producing pulpwood clonal plants.

With a favorable geographic and climatic potential, India is the second highest sugarcane producing country in the world, next to Brazil with annual production of 352.14 million MT of sugarcane [10] and 60- 100 million MT of bagasse [11]. The bagasse is being utilized in India for various agriculture related activities (for e.g. soil amendment, soilless growth media and as organic fertilizer). The use of sugarcane bagasse or sugarcane compost as rooting substrate was earlier reported by [12-15]. Other than agricultural use and power generation, sugarcane bagasse poses a big environmental threat for disposing such large quantity generated every year. Therefore, an attempt was made to study the sugarcane bagasse pith (SBP) as rooting substrate for pulpwood clonal plants production, either solely or in combination with coconut coir pith (CCP).

2. Materials and Methods

The rooting substrate treatments in this study consisted the following combinations (v/v): Treatment 1- 100% coconut coir pith (CCP); Treatment 2- 75 % CCP + 25 % sugarcane bagasse pith (SBP); Treatment 3- 50 % CCP + 50 % SBP; Treatment 4- 75 % CP + 25 % SBP; Treatment 5- 100 % SBP. To process the substrates for using as rooting media in the mist chambers, separate windrows were formed as shown in fig.1 for each substrate combinations and subjected to quick decomposition for 35 days (5 weeks) using the fungal strain *Pleurotus sajor caju* and microbial consortium (*Trichoderma viridae* + *Bacillus velezensis* + *Psedomonos flurosence*). The substrates were analyzed for their physicochemical and chemical properties during before and after the decomposition process. After decomposing, the substrates were dried at 60°C in hot air oven, powdered and analyzed for various physicochemical and chemical properties. The pH and electrical conductivity of the substrates were determined in the aqueous extract of 1:2.5 (w/v) solid water ratios [16].

The dry bulk density of the substrates was determined with the procedure advocated by Gohardoust *et al*. [17]. In this, the air dried mass of the substrates occupying a specific volume was measured in 1 L measuring cylinder and oven dried mass per volume (bulk density) was calculated with the formula:

Bulk density (BD; g cm^{-3}) = M_{OD}/ V_C

Where, M_{OD}- oven dried mass of substrate (g) and V_C- volume of the oven dried substrate in the cylinder (cc). For the mixed substrates of coir pith and bagasse pith, BD was calculated with the modified formula of

Bulk density (BD; g cm^{-3}) = $M_{OD1} + M_{OD2} / V_C$.

Where, M_{OD1} and M_{OD2} denote the oven dried masses of substrate 1 and substrate 2 respectively.

The water holding capacity of the substrates was determined as per the procedure prescribed by Gabriel *et al*. [18]. One liter container was filled with dry substrate and saturation volume of irrigation water was estimated. The total pore volume (TPA) was recorded as the volume of water required to saturate the substrate. After saturation, the volume of the drained water is taken as aeration pore volume (APV). The percentage of total porosity, aeration porosity and water holding capacity were calculated as per the formulae:

Total porosity (TP; %) = TPV × 100/ CV

Aeration porosity (AP; %) = APV × 100/ CV
Water holding capacity (WHC; %) = TP- AP.

Where, CV- container volume, TP= total porosity, AP- aeration porosity, TPV- total pore volume, APV- aeration pore volume and WHC- water holding capacity.

Figure 1. Composting of substrates using fungal- bacterial consortia in windrows method.

The estimation of exchangeable cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) in the substrates were carried out after extraction by shaking 2 hours with 1 M ammonium acetate by shaking 2 hours [19, 20]. The exchangeable calcium and magnesium was determined by titrimetric method while exchangeable potassium and sodium was determined by the flame photometric method [16]. Organic carbon content of the substrates was determined by wet acid chromic digestion method [21]. The total N in the substrates was estimated by Kjeldahl digestion and steam distillation method [22]. Determination of other nutrients (P, K, Ca, Mg, Na) were carried out using the wet digestion method based on 25- 5- 5 ml of HNO_3- H_2SO_4- $HClO_4$ acids [23]. Phosphorus was estimated by using colorimeter with red filter at 600 nm [24]. Ca, Mg, Na and K were determined as mentioned earlier.

The pulpwood species used in this study are *Casuarina* hybrid (clone number CH-5) and *Eucalyptus* hybrid (clone number TNPL- 193). For evaluating the suitability of various rooting substrates for pulpwood clonal plants production, substrates were filled in the 40 cell root trainer containers of 93 cc capacity / cell, placed inside the mist chamber arranged randomly with three replications. Uniformed size of 10 cm cuttings of casuarina and eucalyptus were planted in the root trainer containers as per the treatments and allowed developing as clonal plants. After 30 days in mist chamber, the fully grown clonal plants were taken out for hardening for 10 days and thereafter biometric observations were taken.

To evaluate the substrates performance on pulpwood clonal production, survival (%) and some growth parameters including root volume (Volume displacement gravimetric method; g cm^{-3}), shoot length (cm), root shoot ratio (using oven dried root & shoots) and number of new leaves per plant were measured after hardening stage of casuarina and eucalyptus clonal plants.

All the data represents mean of three replications. Standard deviation (±) were estimated for the data consisting survival and growth parameters of the pulpwood clonal plants, examined by one - way analysis of variance (ANOVA) and subjected to Least Significance Test (LSD) at $P < 0.05$. To determine significance difference between means, Duncan's tests were performed at a significance level of $P \leq 0.05$.

3. Results and discussion

The results in Table 1 show the physicochemical and chemical properties of substrates used in this study. Before composting, the CCP and SBP were acidic in pH (< 7.0) and EC was found lower in SBP (0.18 dS m^{-1}) than in CCP (0.89 dS m^{-1}). The bulk density and water holding capacity of SBP were about 31 % and 9 % higher than CCP. The total exchangeable cations were found higher with CCP. While the CCP recorded 9.56 C mol (p^{+})/ kg of Ca and 8.79 C mol (p^{+})/ kg of K, SBP recorded 8.78 and 4.94 C mol (p^{+})/ kg respectively. The exchangeable Na was found 11 fold higher with CCP as compared with SBP. The exchangeable Mg was recorded higher in SBP (2.96 C mol (p^+)/ kg), comparing to CCP (0.14 C mol (p^+)/ kg). The organic carbon (OC) content of substrates revealed that CCP had slightly higher OC (28.56 mg kg^{-1}) than SBP (23.26 mg kg^{-1}). Likewise, the chemical constituents *viz*. N, P, K, Ca and Na were found higher with CCP. However, the content of Mg was twofold higher in SBP (0.72 mg kg^{-1}) than in CCP (0.36 mg kg^{-1}). The C/N ratio of both the substrates was more than 100 (105.78 in CCP and 110.96 in SBP).

Marked differences in physico-chemical and chemical properties of the substrates were observed after decomposing with fungal strain and microbial consortia. The pH and EC were increased after 35 days of decomposing. The increased pH implies the highly effective aerobic metabolism of carbohydrate present in the substrates with no organic acid production by the fungi- bacterial consortium [25]. After decomposing, the bulk density of both the substrates was reduced. The water holding capacity was also decreased as water holding capacity is directly proportional to bulk density [15]. The increased EC and cations indicate the release of nutrient ions in to the substrates during decomposition. Reduction in Na was due to leaching of excess sodium ions present in the substrates during composting. Decrease in organic carbon content and C/N ratio was recorded due to exhaust of carbon as a source for the energy to the microbes [26]. In the nutritional point of view, the studied elements viz. N, P, K, Ca, Mg and Na were increased in CCP and SBP, while Na was found decreased in CCP.

The co- composting of CCP and SBP substrates brought the desirable range of bulk density (0.22 to 0.24 g cm^{-3}), as a bulk density between 0.2 to 0.4 g cm^{-3} is ideal for rooting substrate [27]. Among the various substrate combinations, 75 % SBP + 25 % CCP recorded higher water holding capacity (49.23 %) followed by 25 % SBP + 75 % CCP (49 %). The cations, Ca, Mg and K were increased and Na was reduced in all the substrate combinations. The content of plant nutrients (N, P, K, Ca, Mg and Na) were increased after the decomposition. Composting of organic residues has been shown to significant increase in the minerals including N, P, Ca, Mg and K [28]. Sugarcane bagasse pith is a good source of cellulose, hemi cellulose and lignin. With higher rate of sugar content, SBP when it is co-composted along with CCP becomes highly suitable substrate for microbial composting [29]. The microbial decomposition and mineralization of cellulose, hemi cellulose, lignin and bagasse protein releases more mineral nutrients in to the substrate, which was evidenced in our present study with recording higher amount of nutrients after decomposing the substrates.

In our present study, Reduction in organic carbon content and C/N ratio was noticed due to microbial decomposition. However, among the different substrate combinations, the C/N ratio was close to each other (28.67 to 29.29). The C/N ratio indicates the stability of the rooting substrate and rate of N availability. At low C/N ratio, the substrate decomposes very quickly and releases the N readily resulting in C and energy deficiency. In contrast, high C/N ratio will result in N immobilization, restricted microbial activity and N deficiency. A substrate with C/N ratio of 20-40 is best suitable for containerized plant production [4].

The rooting substrates CCP, SBP and their various combinations significantly influenced the rate of survival and growth parameters of casuarina and eucalyptus clones (Table 2 and Figure 1). Higher survival rate was recorded with the 100 % CCP, which is statistically on par with 50 % CCP + 50 % SBP ($p<0.05$). Reduced bulk density and optimized porosity / water holding capacity [26] of the substrates supported for the higher survival rate of the clonal plants. In addition to this, the stabilized C/N ratio of the substrates was also played greater role in improving the survival of clonal plants.

In casuarina, all the growth parameters *viz*. root volume, shoot length, root/ shoot ratio and number of new leaves were recorded with combinations of CCP + SBP than CCP alone. The substrate consisting 100% CCP excelled in registering higher root volume of eucalyptus clone ($p<0.05$). However, all other growth parameters like shoot length root/ shoot ratio and number of new leaves were recorded higher with the substrates containing both CCP and SBP. During the process of composting the conversion of organic wastes are maximized into simpler products and molecules that are useful for plant growth [30]. Further, many organic functional groups in SBP can absorb or loosely complex with mineral nutrients and to make them available to plant roots effectively [31]. As a result, inclusion of SBP in the rooting substrate along with CCP enhanced the survival and growth of casuarina and eucalyptus clonal plants.

4. Conclusion

The production of most of the containerized seedling/ clonal plants including pulpwood clones in India is being practiced using the organic substrate of partially decomposed coconut residue (coir pith) to a large extent. After microbial decomposition with fungal- bacterial consortia, the physicochemical and chemical properties of the decomposed sugarcane residue (bagasse pith) were comparable with decomposed coir pith and thus can be utilized as rooting substrate. The various combinations of co- composted coconut coir pith and sugarcane bagasse pith showed significant and positive effect on the survival and growth of pulpwood clonal plants (hybrids of *Casuarina* and *Eucalyptus* species). Based on the results of the present study, 50% or 25 % of coir pith can be substituted with bagasse pith for co-composting and utilization in the pulpwood clonal plants production.

Table 1. Physico-chemical properties and chemical composition of the substrates used in the study

Parameters	CCP		SBP		CCP + SBP (50:50)		CCP + SBP (75:25)		CCP + SBP (25:75)	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final	Initial	Final
A. Physico-chemical properties										
pH	6.45	7.12	5.72	6.45	6.43	6.66	6.27	6.58	5.94	6.15
EC (dS m^{-1})	0.89	0.99	0.18	0.23	0.41	0.43	0.72	0.75	0.54	0.57
Bulk density (g cm^{-3})	0.44	0.21	0.58	0.24	0.45	0.22	0.35	0.22	0.36	0.24
Water Holding Capacity (%)	74.26	57.63	80.49	58.45	65.33	46.50	71.23	49.23	65.63	49.00
Exchangeable Ca (C mol kg^{-1})	9.56	10.80	8.78	9.20	6.43	7.20	7.56	8.33	8.79	9.56
Exchangeable Mg (C mol kg^{-1})	0.14	0.20	2.96	3.80	2.06	2.40	1.37	1.86	0.96	1.23
Exchangeable Na (C mol kg^{-1})	223.54	201.90	20.28	23.70	94.57	84.70	118.17	102.50	157.00	136.63
Exchangeable K (C mol kg^{-1})	8.79	9.52	4.94	5.30	7.04	7.26	4.02	4.95	6.21	6.73
B. Chemical properties										
Organic carbon (mg kg^{-1})	28.56	15.9	23.26	14.8	25.64	12.04	23.53	12.56	24.86	13.36
Nitrogen (mg kg^{-1})	0.27	0.63	0.21	0.56	0.25	0.42	0.23	0.43	0.22	0.46
Phosphorus (mg kg^{-1})	0.02	0.07	0.03	0.08	0.02	0.05	0.03	0.05	0.02	0.06
Potassium (mg kg^{-1})	0.79	1.26	0.59	1.18	0.58	1.03	0.63	1.21	0.54	1.15
Calcium (mg kg^{-1})	0.41	0.52	0.37	0.48	0.38	0.5	0.40	0.51	0.36	0.48
Magnesium (mg kg^{-1})	0.36	0.48	0.72	0.89	0.68	0.83	0.43	0.59	0.70	0.85
Sodium (mg kg^{-1})	1.23	0.57	0.21	0.25	0.43	0.44	0.66	0.73	0.41	0.44
C/N ratio	105.78	25.24	110.76	26.43	102.56	28.67	102.30	29.21	113.00	29.04

All the values represents mean of three replications
CCP- coconut coir pith; SBP- sugarcane bagasse pith;
Initial- before the start of composting; Final- after decomposing the substrates

Table 2. Effect of various rooting substrates on the performance of casuarina and eucalyptus pulpwood clonal plants

Substrate	Survival %				Root volume				Shoot length				Root/ shoot ratio				No of new leaves			
	CHC	SD	EHC	SD	CHC	SD	EHC	SD	CHC	SD	EHC	SD	CHC	SD	EHC	SD	CHC	SD	EHC	SD
100 % CCP	92.08	± 1.49	94.31	±2.01	1.07	±0.02	1.33	±0.02	35.28	±1.77	33.33	±0.92	0.27	±0.02	0.52	±0.02	2.44	±0.04	0.78	±0.14
25 % SBP	83.06	± 2.39	85.28	±1.17	0.81	±0.02	1.04	±0.03	33.33	±2.07	33.22	±0.39	0.28	±0.01	0.53	±0.02	2.11	±0.10	1.67	±0.06
50 % SBP	90.83	± 0.92	92.47	±1.52	1.12	±0.02	1.07	±0.02	32.78	±2.27	38.56	±1.07	0.29	±0.01	0.41	±0.03	3.11	±0.12	1.67	±0.05
75 % SBP	87.36	± 2.63	89.53	±1.92	0.98	±0.03	1.07	±0.02	35.71	±1.21	33.39	±0.34	0.25	±0.02	0.47	±0.02	3.67	±0.06	0.67	±0.07
100 % SBP	54.31	± 2.36	55.56	±0.7	0.74	±0.02	0.98	±0.02	31.42	±0.44	33.06	±0.32	0.37	±0.02	0.54	±0.01	0.89	±0.02	0.56	±0.02
LSD (<0.05)	8.40		4.07		0.07		0.06		0.98		0.98		0.02		0.03		0.46		0.24	

All value represents mean of three replications with standard deviation (±SD)
LSD - Least significant difference at p <0.05
CCP- Coconut coir pith; SBP- Sugarcane bagasse pith; CHC- Casuarina hybrid clone; EHC- Eucalyptus hybrid clone

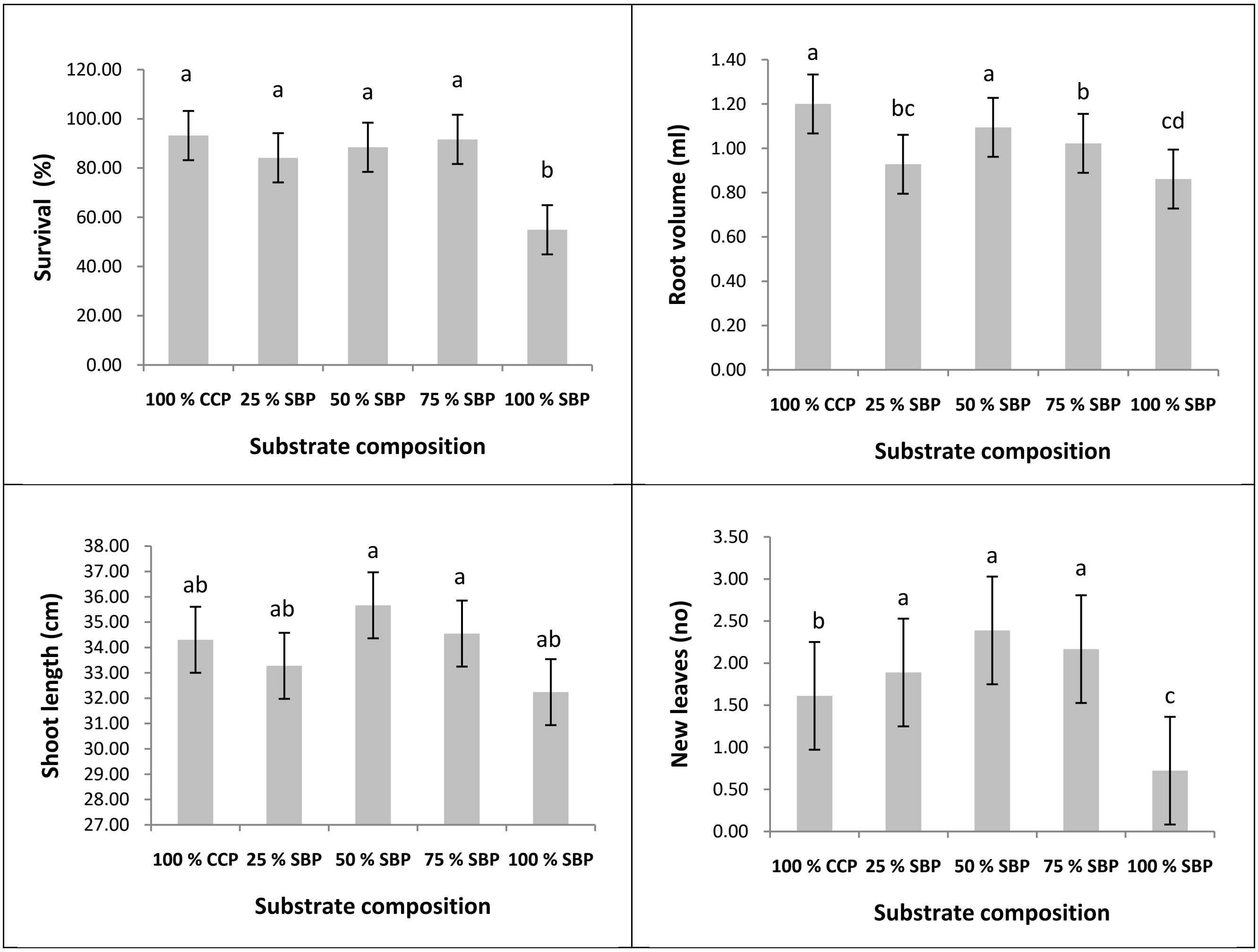

Figure 2. Survival and some growth parameters of pulpwood plants grown in various rooting substrates (mean of casuarina and eucalyptus clones). Error bars indicate the standard deviation (±) of mean. Bars indicating same letters are not significantly different according to DMRT ($p < 0.05$).

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