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Research article

In situ study on the settlement of biofoulers employing wooden test panels

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Abstract

The aim of this study is to analyze the antifouling properties of different timbers, and thus to identify the wood which shows the most antifouling activity. The chemical component present in that wood which is responsible for its antifouling property can be extracted and used in the manufacture of natural antifouling paints, thus saving the marine environment from the effects of heavy metal antifouling paints. Wood species used in this study were, 1) *Tectona grandis* 2) *Prosopis juliflora* 3)*Strychnos nux-vomica* 4) *Lagerstroemia microcarpa* 5) *Mangifera indica* 6) *Artocarpus hirsutus* 7) *Milicia excelsa* 8) *Swietenia mahagoni* 9) *Anigre* 10) *Terminalia arjuna* 11) *Artocarpus heterophyllus* 12) *Albizia lebbeck* 13) *Acacia mangium.* Four sets of panels were exposed for a period of 1 month and 20 days. The identification of fouling organisms obtained from wooden panels revealed the presence of 5 species belonging to Barnacles, Tubeworms, Bivalves, Bryozoans, and Hydroids. The study showed promising results, out of the thirteen species of wood used in the study, it was found that *Albizia lebbeck* and *Lagerstroemia microcarpa* showed the most biofouling resistance. The chemical extracts from these wood can be used in the preparation of environmental friendly antifouling coatings.

Introduction

Marine biofouling is the undesired accumulation of organic molecules, microorganisms, plants, animals, and their by-products on an ocean-submerged surface. The biofouling community consists of sessile species that adhere to surfaces of solid substrata. In the marine environment, natural and artificial surfaces, when contact with the marine water, are quickly colonized by microfoulers like bacteria, algae, protozoa and macrofoulers like barnacles, bryozoans and tubeworms [1-3]. The colonization of a substratum in the aquatic realm has been viewed as going through a four step process, viz. Biochemically conditioning the surfaces, bacterial colonization, diatom and protozoan colonization and settlement of invertebrate larvae and algal spores. Biofouling results in an increase in roughness on ship's hulls, which leads to an increase in hydrodynamic drag as the vessel moves through water. Increased fuel consumption, hull cleaning, paint removal and repainting, and associated environmental compliance measures all contribute to the costs of biofouling. Antifouling is the ability of specifically designed coatings to remove or prevent biofouling by any number of organisms on wet surfaces [4-6]. Antifouling paints are formulated with copper, organo tin compounds and other biocides-special chemicals which impede growth of barnacles, algae, and marine organisms. Antifouling paints have a profound effect on the environment [7]. The majority of antifouling paints are pigmented with copper, as cuprous oxide (Cu_2O). The self-polishing copolymer (SPC) paints give 'polishing' effect as the polymer dissolves away during normal vessel operation, releasing tributyltin (TBT). TBT kills settling fouling organisms and the surface becomes smoother. The SPC system was extremely successful, but TBT was shown to effect non-target organisms, including a number of shellfish, at levels much lower than ever envisaged. The most sensitive invertebrate species, the dog whelk, *Nucella lapillus*, exhibits imposex (imposition of male sexual characters on the female)and its disappearance from rocky shores in areas of high boating activity has been attributed to the presence of TBT from antifouling paints. Thus, there is intense research activity to seek novel, environmentally benign methods of fouling control. New, effective, and environmentally compatible options are needed to control fouling [8-10]. The objective of this study is to find an alternative environmental antifouling strategy by conducting *in situ* studies using panels of different timbers. Wood species used in this study are: 1) *Tectona grandis* 2) *Prosopis juliflora* 3) *Strychnos nux-vomica* 4)*Lagerstroemia microcarpa* 5) *Mangifera indica* 6) *Artocarpus hirsutus* 7) *Milicia excelsaa* 8) *Swietenia mahagoni* 9) *Anigre* 10)*Terminalia arjuna* 11) *Artocarpus heterophyllus* 12) *Albizia lebbeck* 13) *Acacia mangium*.

Experimental

The experiment was designed as per Wright (1991). This in situ study on the settlement of biofoulers employing settlement was carried out for a period of 1 month and 15 days during 2015-2016.This study aims to investigate the natural antifouling properties of 13 different timbers. Trials were carried out at a boat jetty situated in the Ernakulam Channel, adjacent to the Marine Science Campus of Cochin University of Science and Technology in Ernakulam. This is nearly 4.5 km away from the bar mouth .Four replicates each of thirteen varieties of Various Indian tropical wood samples were hanged down at depths of 0.5 meter and one meters in the estuary for two periods of 30 days and 50 days .Wood species used in this study are 1)*Tectona grandis* 2)*Prosopis juliflora* 3)*Strychnos nux-vomica* 4)*Lagerstroemia microcarpa* 5) *Mangifera indica* 6)*Artocarpus hirsutusb* 7)*Milicia excelsaa* 8)*Swietenia mahagoni* 9) *Anigre* 10) *Terminalia arjuna* 11)*Artocarpus heterophyllus* 12)*Albizia lebbeck* 13) *Acacia mangium* .The wood materials used were 20x20 cm in dimension. The wooden panels were then hanged down, during 2 December 2015 to 29 January 2016 at the study station. Two sets of short term panels were exposed for a period of 30days and two sets of long term panels were exposed for a period of 50 days. The identification of fouling organisms obtained from wooden panels revealed the presence of 5 species belonging to Barnacles, Tubeworms, Bivalves, Bryozoans, and Hydroids. On retrieval after the respective time periods, the panels were analyzed for the number/percentage coverage of fouling organisms. Fouling cover in percentage was expressed by calculating area covered by the foulers versus total surface area of the panel.

Results and Discussion

Result

TThe results of the in situ studies on antifouling activity of thirteen species of wood exposed in water of Cochin boat jetty, Ernakulam has been presented. Fouling fauna comprised of barnacles, tubeworms, bivalves and hydroids. The study brings out the antifouling properties exhibited by some of these Indian antifouling timbers. Minimum fouling was recorded on *Albizzia lebbeck* and maximum on *Strychnos nux-vomica*. Comparatively low fouling values were recorded on *Lagerstroemia microcarpa, Mangifera indica* and *Artocarpushirsut.* There are no earlier reports on fouling on timber panels from this station. The Minimum number of barnacles was recorded on *Lagerstroemia microcarpa*and the maximum number was on *Milicia excelsa*. Minimum tubeworm coverage was noticed on *Albizia lebbeck* and *Acacia mangium*. Maximum tubeworm coverage was seen on *Anigre*. *Swietenia mahagoni* and *Tectona grandis* was completely devoid of bivalve coverage. Maximum bivalve coverage was noticed on *Anigre*. *Strychnos nux-vomica* was completely devoid of bryozoan coverage .Maximum bryozoan coverage was noticed on *Anigre*. *Tectona grandis* was partially devoid of hydroid coverage .Maximum hydroid coverage was noticed on *Acacia mangium*. Maximum barnacle attachment was exhibited by the wooden panels immersed at the lower depth of 0.5m.In case of tubeworm attachment, the maximum was exhibited on the wooden panels which were immersed at a deeper depth of 1m.

Hydrographic Studies

Water quality status at the near shore waters remained stable. Temperature, salinity and pH fluctuations in waters of Cochin boat jetty were minimum during the two months of study.

Table 1. Hydrographic Studies

S. No.	Parameters	Values
1	Salinity	23
2	pH	7

The result of in situ studies on the settlement of biofoulers employing wooden test panels are presented in table no 1-6.

Discussion

The study on the in situ settlement of biofoulers employing wooden test panels gave promising results. It was found that two wood species out of the thirteen showed resistance against bio-fouling [11-13]. Through further detailed studies, biochemical assays, the chemical composition of these wood species can be found and the compound responsible for the antifouling action of the wood can be extracted and used in the preparation of antifouling coatings to be used on ships and other objects immersed in water. And so, their likely impact on the settlement of marine fouling organisms has not yet received much attention. In this regard in our research we made a preliminary attempt to elucidate the possible effect of different species of wood on the settlement of marine fouling organism as a result of which are presented here. The Minimum number of barnacles was recorded on *Lagerstroemia microcarpa*andis believed to be due to the presence of sseveral classes of phytochemicals like alkaloids, glycosides, saponins, steroids, flavonoids, proteins and carbohydrates [14-17]. Minimum tubeworm coverage was noticed on *Albizialebbeck* might be due to the presence of steroids, Terpenoids, alkaloids, flavonoids, phenols, and saponins[18]. *Swietenia mahagoni* and *Tectona grandis* was nearly devoid of bivalve coverage [19].

Table 2. Antifouling activity of various timbers on the settlement of larvae of different biofoules

S. No.	**Name of Timbers**	**Branches**		**Tubeworms**		**Bivalves**		**Bryozoans**		**Hydroids**	
		Depth		Depth		Depth		Depth		Depth	
		0.5m	1m	0.5m	1m	0.5m	1m	0.5m	1m	0.5m	1m
1	Teak	8	3	0	0	0	0	6	3	2	2
	(Tectona grandis)	11	9	0	11	1	1	17	10	15	10
2	Karuvelakam	2	1	0	5	4	1	0	10	1	0
	(Prosopis juliflora)	17	7	10	46	9	5	17	27	60	16
3	Eetti	3	0	2	0	7	0	2	6	0	0
	(Strychnos nux-vomica)	47	10	17	77	7	27	52	0	55	8
4	Ben Teak	4	1	4	10	3	0	0	2	40	0
	(Lagerstroemia microcarpa)	7	7	12	22	9	0	18	13	85	15
5	Mango	1	2	1	3	0	0	2	6	5	2
	(Mangifera indica)	12	5	11	7	1	2	32	1	80	90
6	Aanjili	7	2	0	2	0	0	5	1	12	0
	(Artocarpus hirsutus)	12	9	4	22	1	3	7	7	88	70
7	African teak	15	3	2	3	0	0	1	0	1	2
	(Milicia excelsaa)	44	14	8	16	4	6	1	17	75	70
8	Mahagoni	0	0	0	2	0	1	0	0	10	0
	(Swietenia mahagoni)	51	1	1	56	1	0	3	8	70	60
9	Plywood	2	1	0	56	0	0	4	7	0	0
	(Anigre)	26	5	2	84	28	32	13	44	85	50
10	Marudha	2	4	2	10	2	1	0	0	0	0
	(Terminalia arjuna)	23	4	6	47	0	9	8	33	70	90
11	Jackfruit Tree	8	0	5	9	0	3	0	1	25	40
	(Artocarpus heterophyllus)	40	16	27	34	8	5	1	11	65	60
12	Indian siris	1	0	0	2	1	0	0	0	2	0
	(Albizia lebbeck)	23	1	0	1	0	5	4	2	90	50
13	Mangium	5	0	1	1	0	0	0	7	10	0
	(Acacia mangium)	11	17	0	4	6	1	9	0	100	85

Table 3. Attechment of branches on wooden panels

Sr. No.	**Name of timbers**	**Number of biofoulers attached**
1	Teak	
	(Tectona grandis)	7.75
2	Karuvelakam	
	(Prosopis juliflora)	6.75
3	Eetti	
	(Strychnos nux-vomica)	15
4	Ben Teak	
	(Lagerstroemia microcarpa)	4.75
5	Mango	
	(Mangifera indica)	5
6	Aanjili	
	(Artocarpus hirsutus)	7.5
7	African teak	
	(Milicia excelsaa)	19
8	Mahagoni	
	(Swietenia mahagoni)	13
9	Plywood	
	(Anigre)	8.5
10	Marudha	
	(Terminalia arjuna)	8.25
11	Jackfruit Tree	
	(Artocarpus heterophyllus)	16
12	Indian siris	
	(Albizia lebbeck)	6.25
13	Mangium	
	(Acacia mangium)	8.25

Table 4. Attechment of Tubeworms on wooden panels

Sr. No.	**Name of timbers**	**Number of biofoulers attached**
1	Teak	
	(Tectona grandis)	0.25
2	Karuvelakam	
	(Prosopis juliflora)	4
3	Eetti	
	(Strychnos nux-vomica)	12
4	Ben Teak	
	(Lagerstroemia microcarpa)	4
5	Mango	
	(Mangifera indica)	2.5
6	Aanjili	
	(Artocarpus hirsutus)	1.75
7	African teak	
	(Milicia excelsaa)	4
8	Mahagoni	
	(Swietenia mahagoni)	0.5
9	Plywood	
	(Anigre)	8.5
10	Marudha	
	(Terminalia arjuna)	4.5
11	Jackfruit Tree	
	(Artocarpus heterophyllus)	10
12	Indian siris	
	(Albizia lebbeck)	1.5
13	Mangium	
	(Acacia mangium)	0.5

Table 5. Attechment of Bivalves on wooden panels

S. No.	Name of timbers	Number of biofoulers attached
1	Teak *(Tectona grandis)*	0.5
2	Karuvelakam *(Prosopis juliflora)*	4.75
3	Eetti *(Strychnos nux-vomica)*	10.25
4	Ben Teak *(Lagerstroemia microcarpa)*	3
5	Mango *(Mangifera indica)*	0.75
6	Aanjili *(Artocarpus hirsutus)*	1
7	African teak *(Milicia excelsaa)*	2.5
8	Mahagoni *(Swietenia mahagoni)*	6.5
9	Plywood *(Anigre)*	15
10	Marudha *(Terminalia arjuna)*	3
11	Jackfruit Tree *(Artocarpus heterophyllus)*	4
12	Indian siris *(Albizia lebbeck)*	1.5
13	Mangium *(Acacia mangium)*	1.75

Table 6. Attechment of Bryozoans on wooden panels

Sr. No.	Name of timbers	Number of biofoulers attached
1	Teak *(Tectona grandis)*	9
2	Karuvelakam *(Prosopis juliflora)*	13.5
3	Eetti *(Strychnos nux-vomica)*	15
4	Ben Teak *(Lagerstroemia microcarpa)*	8.25
5	Mango *(Mangifera indica)*	10.25
6	Aanjili *(Artocarpus hirsutus)*	5
7	African teak *(Milicia excelsaa)*	4.75
8	Mahagoni *(Swietenia mahagoni)*	2.75
9	Plywood *(Anigre)*	17
10	Marudha *(Terminalia arjuna)*	10.25
11	Jackfruit Tree *(Artocarpus heterophyllus)*	3.25
12	Indian siris *(Albizia lebbeck)*	1.5
13	Mangium *(Acacia mangium)*	4

Table 7. Attechment of Hydroids on wooden panels

S. No.	Name of timbers	Number of biofoulers attached
1	Teak *(Tectona grandis)*	7.25
2	Karuvelakam *(Prosopis juliflora)*	19.25
3	Eetti *(Strychnos nux-vomica)*	15.75
4	Ben Teak *(Lagerstroemia microcarpa)*	35
5	Mango *(Mangifera indica)*	44.25
6	Aanjili *(Artocarpus hirsutus)*	42.5
7	African teak *(Milicia excelsaa)*	37
8	Mahagoni *(Swietenia mahagoni)*	35
9	Plywood *(Anigre)*	33.75
10	Marudha *(Terminalia arjuna)*	40
11	Jackfruit Tree *(Artocarpus heterophyllus)*	47.5
12	Indian siris *(Albizia lebbeck)*	35.5
13	Mangium *(Acacia mangium)*	48.75

Absence of attachment on *Swietenia mahagoni* is believed to be due to the presence of swiete macrophyllain while in case of *Tectona grandis* might be due to the presence of several classes of phytochemicals like alkaloids, glycosides, saponins, steroids, flavonoids, proteins and carbohydrates (Goswami, 2010). *Strychnos nux-vomica* was practically devoid of bryozoan coverage. Absence of Bryozoan coverage on *Strychnos nux-vomica* might be due to the presence of intensely bitter alkaloids strychnine and brucine.Hydroid coverage was expressed in percent coverage on the wooden panels. *Tectona grandis* was partially devoid of hydroid coverage. Attachment pattern on *Tectona grandis* is believed to be due to the presence of sseveral classes of phytochemicals like alkaloids, glycosides, saponins, steroids, flavonoids, proteins and carbohydrates .It also contains secondary metabolites such as tectoquinone, 5-hydroxylapachol, tectol, betulinic acid, betulinic aldehyde, squalene, lapachol etc.Out of the thirteen species of wood used in this study, *Albizia lebbeck* and *Lagerstroemia microcarpa* exhibited the most antifouling resistance. Maximum barnacle attachment was exhibited by the wooden panels immersed at the lower depth of 0.5m. In case of tubeworm attachment, the maximum was exhibited on the wooden panels which were immersed at a deeper depth of 1m [20, 21].Conventional antifouling technology involves continuous release of toxicants into marine environment [22-24]. With the day to day increasing environmental awareness there is an increasing tendency to evolve a natural nontoxic means of fouling control. In this regard, research for antifouling compounds from marine organisms has already been initiated all over the world. Antifouling properties exhibited by selected Indian timbers may prove beneficial in this context.

Conclusion

In situ study on the settlement of biofoulers employing wooden test panels shows that *Albizia lebbeck* and *Tectona grandis* are the wood species in the study that shows maximum fouling resistance. The results show that the wood species involved are not very effective against hydroids, but few of them were effective against certain fouling organisms. This throws light on the future prospects of these woods as a potential source for natural antifouling coatings. Minimum attachment of barnacles was recorded on *Lagerstroemia microcarpa; Strychnos nux-vomica* was practically devoid of bryozoan coverage; *Swietenia mahagoni* and *Tectona grandis* was nearly devoid of bivalve coverage; Minimum tubeworm coverage was noticed on *Albizia lebbeck* and *Acacia mangium;* and Hydroid coverage in general was the high on all test panels. *Tectona grandis* was partially devoid of hydroid coverage. Maximum barnacle attachment was exhibited by the wooden panels immersed at the lower depth of 0.5m. In case of tubeworm attachment, the maximum was exhibited on the wooden panels which were immersed at a deeper depth of 1m. There has not been much research done in this area. Recently biogenic compounds produced by the microorganisms, especially marine microbes are most promising against of marine fouling. Many marine organisms microalgae and marine invertebrates produced biogenic agents with antibacterial, antifungal, antialgal, antiprotozoan, larvaicidal and molluscidal properties to defend themselves against settlement in the marine environment. Some of these secondary metabolites possess potent antifouling activity also, but their antifouling activity under laboratory and field conditions are unknown. Through further detailed studies, biochemical assays, the chemical composition of these wood species can be found, thus the chemical compound responsible for the antifouling effect of *Albizia lebbeck* and *Tectona grandis* can be identified. This compound then can be extracted and used in the manufacture of natural antifouling paints, which will not cause threat to the environment.

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