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Importance of Election of Species for Utilization of Tree in the Space Environment

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There are several utilization elements in the useful usage of tree in our daily life. Tree is also one of very important elements for space agriculture after the soil formation with some organisms including microbe in the artificial life system dome such as A'MED. The space agriculture is assumed of agriculture on Mars. Before our studying about tree related to the induction into the artificial space environment system, we investigated the importance of election of tree species and their shape for useful utilization of tree in space environment based on the results of experiments using two type of Japanese cherry trees, *Prunus* sp.. The inside uniformity of tree were analyzed with the two analysis, acoustic vibration and chemical analysis. Tree shape is deeply affected by gravity. The election of tree species and shape is important matter when we use the tree material in space environment. Weeping type of tree would be suitable for using it in the space environment because of their inside uniformity. In addition of tree shape, the useful functional substance was analyzed. Here, we will show an approach research of the importance of election of tree species for their induction into the closed bio-ecosystem space environment in our future.

Nomenclature

A'MED = *Arai's Mars ecosystem dome*

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CosmoBon = small bonsai for studies space experiment
P. = *Prunus*
Py-GC/MS = Pylolysis Gas Chromatography Mass spectrometry
SSR = simple sequence repeat

I. Introduction

There are several utilization elements in the usage of tree in our environment on earth. We can find easily that we are usually using the woody material in our daily life. The studies of woody plants under a space-environment in the vegetable kingdom have a high contribution to the study of various and exotic environmental responses, too. Woody plants can produce an excess oxygen, woody materials for the living cabin, and provide a biomass by cultivating crops and other species of creatures (Yamashita and Wheeler, 2014; Motohashi *et al*, 2012). Tree material would become to be a tool in closed bio-ecosystems (Fig 1). In the study related to space agriculture on Mars, tree material is an important element in the artificial closed ecosystem dome such as A'MED produced by Arai *et al*., 2008. Space agriculture is assumed of agriculture on Mars (Yamashita *et al*., 2005). The A'MED is a closed dome, which is one of models as installed on Mars as shown in Fig. 1 (Arai, *et al*., 2008a,b). Tree is an important element for space agriculture after the soil formation with some organisms, e.g. cyanobacteria (Fig. 1). After the soil formation and induction of grass plant for production of crops, we might be able to do the induction of woody plant as shown in Fig.1. Then, the election of tree species and their shape for useful utilization of tree in space environment will be a very important matter , e.g., because of their irregular genetic back ground by their cross-pollination. In addition, Tree shape is deeply affected by gravity.

We have been studying the proposal of utilization of trees in an outer space environment for our future space agriculture such as on Mars or other outer planets including that in a spacecraft (Motohashi *et al*., 2012; Tomita-Yokotani *et al*., 2010). Here, we show the importance of election of tree species by the results of experiments using *Prunus* sp., Japanese flowering cherry.

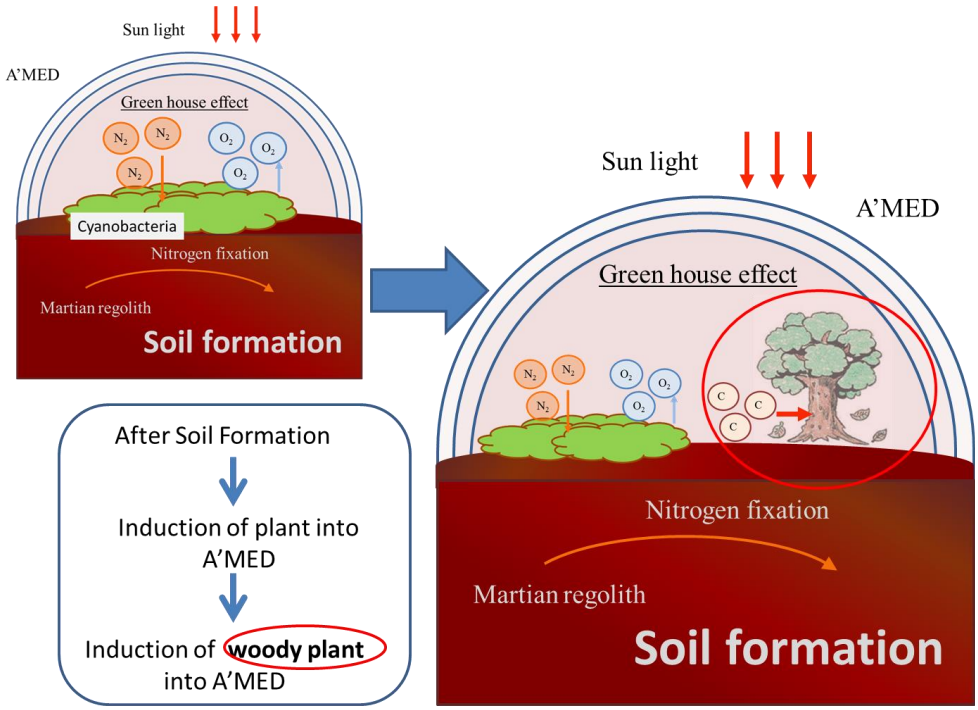

Fig. 1 Overall flow and each event for the preparation of space agriculture in A'MED (Arai' Mars Ecosystem Dome, 2008)

II. Useful tree shape as woody material for space environment

The tree shape is an important matter when we use the woody materials. In general, the biomass or whole size in woody plants is bigger than that in the grass plants. Then, woody plants form tension wood in order to maintain their shape and control their posture (Wilson and Archer, 1977 ; Baba *et al*., 2009, Motohashi *et al*, 2012). The tension wood in the case of woody angiosperms has a less lignin layer, the inner thick gelatinous layer, G-layer (Baba *et al*., 1995). Tension wood is generally described as containing of a higher cellulose and lower lignin content in comparison with normal wood. These substances would be related to carbon circulation in the closed ecosystem at the induction of woody plant into it. The composition profile of inner materials is need when the circulation of substances use in the closed bio-ecosystem. Furthermore, the uniformity of the tree inner composition is very important matter when we use the woody materials for several kinds of furniture or a dwelling because the wood materials formed tension wood is not suitable to them (Pilate *et al*., 2004). The inner uniformity of tree were analyzed in the two shape types of Japanese cherry tree, weeping and uplight types with the two analysis methods, vibration analysis and chemical analysis (Motohashi *et al*., 2012). The acoustic vibration analysis was used for this study (Fig.2 and 3). After the analysis, the statistical processing was done and the coefficient-of-variation (CV) of the sound speed was estimated. This method would be analyzed in the woody plant posture and inside composition with nondestructive method. (This method may be suitable in the very narrow laboratory such as a spacecraft in a space environments because it is possible that the several centimeter scale of branches of woody plant such as a "CosmoBon" can be used. We named the trees used as material for the experiment related to space environments "CosmoBon", small tree bonsai). The material and method are shown in Fig. 2.

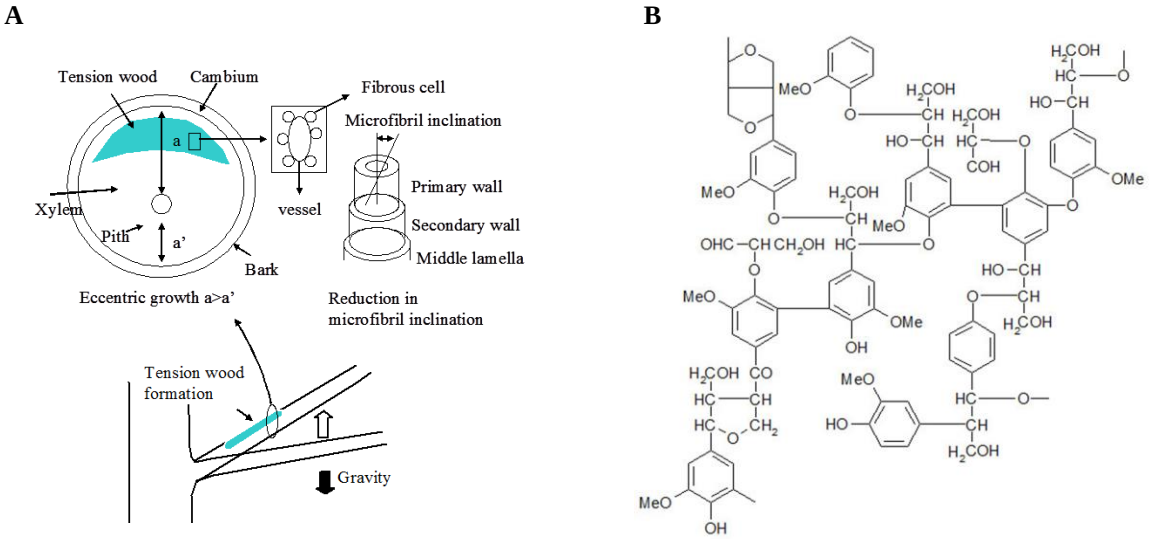

Fig. 2 Tension wood formation in angiosperm;A, and an example of the component of lignin;B.

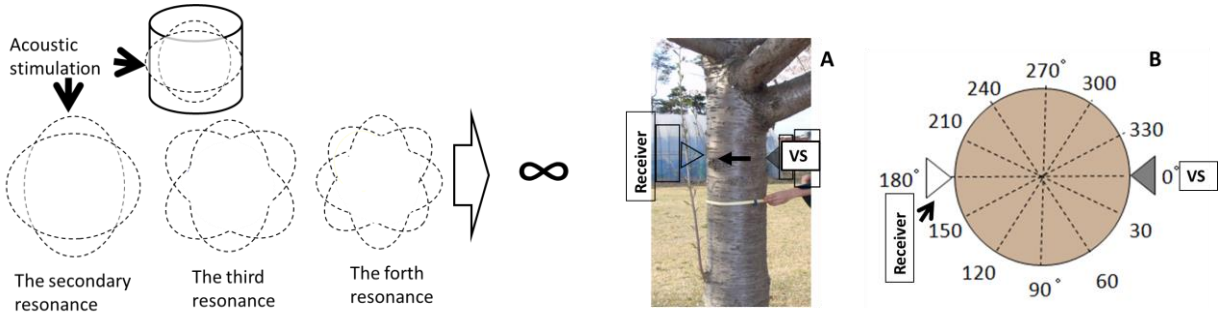

Fig. 3 The method of acoustic vibration analysis. The basic vibration track according to the theory in the case of the column shape object given an acoustic stimulation (Left side) and the method for the acoustic vibration analysis (A) and the position (B) in this study. An acoustic stimulation by vibration speaker (VS) is received by the receiver (Right side).

Table 1 The results of acoustic vibration analysis in upright and weeping types of *Prunus* sp.

Type and tested tree number		Tested part					
		Trunk			Branch		
		Speed of sound (m s^{-1})	SE*	CV(%)**	Speed of sound (m s^{-1})	SE*	CV(%)**
Straight	1	649.6	2.89	0.43	410.1	4.78	1.16
	2	618.9	1.94	0.31	437.0	1.80	0.41
	3	644.4	3.50	0.54	399.8	1.73	0.43
Weeping	1	711.3	1.66	0.23	450.7	0.66	0.15
	2	729.4	1.71	0.23	399.7	0.95	0.24
	3	708.2	1.64	0.23	410.0	0.50	0.12

(Motohashi et al, 2012) (n=12, *standard error of mean, **coefficient of variation)

Acceding to the results in Table 1(Motohashi *et al*., 2012), weeping type in both its trunks and branches had a uniform composition. In addition, the result of further detail chemical analysis by Py-GC/MS,Pylolysis Gas Chromatography Mass spectrometry, method indicated that the weeping type of tree is more stable than the upright type of tree, especially in the part of trunk. Tree shape is deeply related to gravity (Nakamura *et al*., 2002). Thus, the election of tree shape for the utilization in space agriculture is important matter.

III. Different production ability in functional substances

We can get some dietary from the crops in our food produced from agriculture. The fate of the food materials after our eating them are circulated in our environment. In the case of woody plant, they can maintain the carbonate for a long time. Furthermore, the components in their organ such as leaf or bark can be several medicine for us (Iwashina, 2003). In Fig. 4, it was shown the example of functional substances produced from trees (Nakatsubo *ed*, 2002). The secondary substances produced from plants or trees can be used for our human health (Chida *et al*, 2014). When we determine the species of organisms, especially woody plant, into closed bio-ecosystems, the election of species have to be severe. We have isolated a functional substance, a flavonoid, extracted from leaves in *Prunus* sp. (Chida *et al*, 2014). They extracted the same substance from the same species of trees identified by SSR (simple sequence repeat) method. In the several methods of biological activity tests, the production ability and their activity were not the same in the tested trees. Fig.5 showed the amount of isolated substance in the several strain of the same species of trees. Then, further detail profile will be needed at the induction of election of species of organ.

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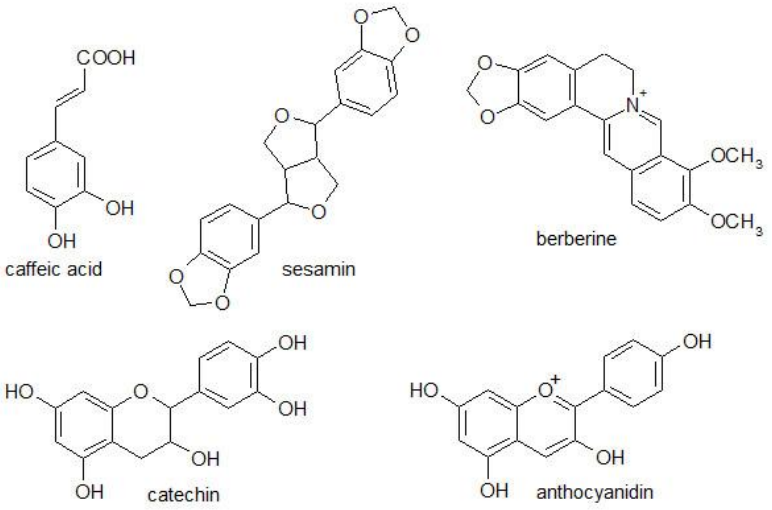

Fig. 4 Example of functional substances produced from trees.

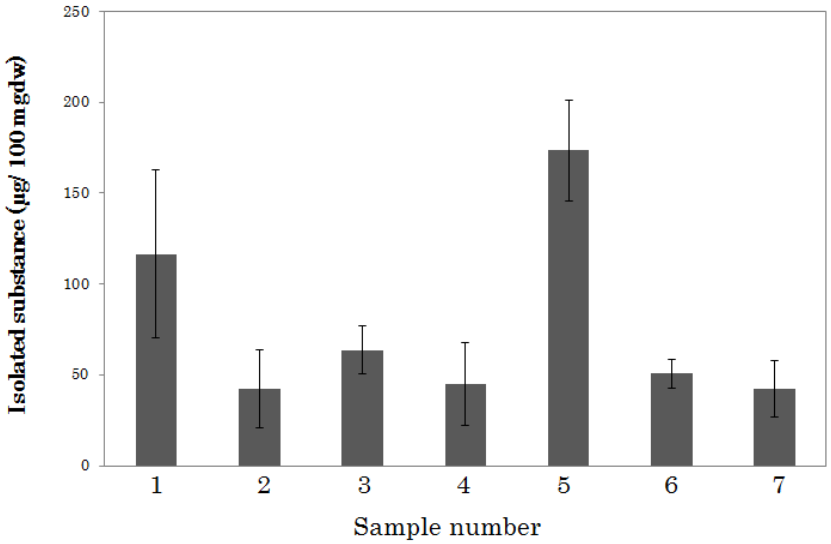

Fig.5 The amount of isolated active substance extracted from the dry leaves in the same species of *Prunus* sp.. Bars indicate average ± SE (n=3)

IV. Conclusion

We have been studying the proposal of utilization of tree in space environment for our future as space agriculture such as on Mars or other outer planet including in the spacecraft and space station. Tree produce excess oxygen, woody materials for living cabin, and provide biomass by cultivating crops and other species of creatures described above (Yamashita *et al*., 2005; Tomita-Yokotani *et al*., 2010). Japanese flowering cherry tree, *Prunus* sp., was used as woody plant material because of its high attention in Japan in this study. Furthermore, the studies of gravity and its morphological response has been accumulated using a Japanese flowering cherry tree for space experiments (Nakamura,T., *et al*., 2002; Funada, R. et al, 2008; Kokubo, S. and Sakurai., N., 2010; Motohashi, K., *et al*., 2012). One species of "Sakura", "Mamezakura, *Prunus incisa*", is not only lovely tree species, but also suitable tree for the model tree of our purpose. The species of *Prunus incisa* is originally grown in volcano environment. We will try to build the best utilization usage of woody plant under the space environment after our accumulating the results by using the model tree. In the future, it has a possibility that the bio - materials will be used together with mechanical technology, e.g. , a charcoal formation or separation of several elements by using several organic ability. Then, the election of organic material will be important matter. The detail analysis with the certain profiles related to chemical production and individual physiological matter would be needed in the selected bio-materials.

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