Bamboo (*Bambusa bambos*) on Mars and Moon Soils;

The germination and growth of bamboo (*B. bambos*) on Mars and moon regolith simulants

Figure 1; Impression of a bamboo plant on Mars

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1 Objectives and Aims

While the possibility of growing certain plants in Mars and moon regolith simulants has already been researched [1-4], this has mainly concerned crops and other plants that can serve as food. The possibility of growing plants that can be used as building material has not yet been investigated. This experiment will test how well bamboo (*Bambusa bambos*) can grow on Mars and Moon regolith simulants. This will be done by planting bamboo seeds in regolith simulants and close observation of the germination and development of the plant. The aim of this experiment is to test bamboo as a possible building material to grow on other solar bodies.

2 Introduction

If at some point we as humans want to be able to live on other planets or moons medium to long term, relying only on food and materials that are brought on arrival or during resupply missions is not a sustainable solution. Preferably, an extra-terrestrial base is self-sufficient. A more sustainable way to fulfil this need is to produce food and grow building materials on site. This is referred to as In Situ Resource Utilisation (ISRU), also called Space Resource Utilisation (SRU) [5]. ISRU is the generation of products using local resources and materials. While often used to talk about oxygen generation on site, using regolith present on the solar bodies in question to produce plants is also ISRU. While the possibility of growing plants that can be used as food on Mars and moon regolith simulants has already been researched, no scientific research has been done on growing plants on these soils that can be used as building material. A possible contender for this building material grown on site is bamboo. Bamboo has been used as a construction material for centuries on Earth, grows fast and is stronger than normal structural woods [6]. Bamboo can serve as an addition to glass, metal and bricks made from regolith or rocks on Mars [7, 8]. This experiment will investigate if bamboo (*B. bambos*) can grow on Mars and moon regolith simulants.

2.1 Mars and moon regolith simulants

Regolith (loose dust on the surface or informally, soils) simulants are soils collected on Earth and manipulated so that they possess qualities similar to regolith found on other solar bodies. These qualities include, amongst others, compositional and geomechanical characteristics of these extra-terrestrial soils [9]. These collected soils are made by, for example, crushing and sieving basalt found in the Mojave desert, as is the case with MMS-1, the Mars regolith simulant to be used in this experiment [10]. The moon regolith simulant that will be used is basaltic and comes from the Miriam Crater in the United States. This regolith simulant is also milled and sieved [11]. Because of their origin, both of these simulants are almost entirely free of organics.

2.2 Bamboo as a building material

For centuries bamboo has already been used as a building material, especially in Asian countries. *B. bambos* in particular is used as a construction material [12]. According to a 2018 study *B. bambos* has a tensile strength and specific tensile strength greater than that of A36 steel in specimens without nodes, while all specimens of *B. bambos* are stronger than commonly used structural woods [6]. Additionally, *B. bambos* has the advantage of being an edible type of bamboo [12]. In other words, if taken to Mars or the moon, seeds can be used to grow building materials as well as food.

2.3 Plant germination and growth on Mars and moon regolith simulants

While a relatively new research area, a few experiments have been conducted to test the possibility of growing plants on Mars and moon regoliths. Model plants like *Tagetes patula* successfully grow in lunar regolith simulants [2, 4]. In 2014 Wamelink et al. investigated the possibility of growing certain crops and wild plants on Mars and moon regolith simulants [1]. These experiments have proven that this is indeed possible, although moon regolith simulant is noticeably worse soil to grow on than Earth soil.

2.4 Aim of experiment

This experiment aims to answer the following research questions:

Do *B. bambos* seeds germinate in Mars and moon regolith simulant?

How does *B. bambos* grow on Mars and moon regolith simulant compared to Earth soil?

3 Materials and Methods

3.1 Materials to be studied

Bamboo seeds of the species *Bambusa bambos* will be studied. 200 seeds are ordered from Zadengigant.nl [13]. They will be planted in moon regolith simulant produced by NASA's Jet Propulsion Lab (JPL) for their Mars Phoenix mission, ordered from Sierra Nevada Corporations (named ORBITEC at the time of purchase) (type JSC1-1A) [11] and Mars regolith simulant ordered from the Martian Garden (type MMS-1) [10]. A control group will consist of *B. bambos* seeds planted in Earth soil purchased from Horticoop (type Lentsepotgrond) [3].

3.2 Growth conditions

B. bambos seeds will germinate in plastic pots or petri dishes with damp paper towels. Plants will grow in the Nergena glasshouse on the campus of Wageningen University (51.9961° N, 5.6575° E). The temperature will be maintained at around 20°C during the day and 15°C during the night. HS2000 Hortilux Schréder lamps will be used (80 µmol m-2s-1) in the case sunlight intensity is below 150 watt/m². Ambient CO_2 is available (400 ppm as of 2015 in De Bilt, The Netherland). Temperature, relative humidity and day length will be recorded during the experiment.

3.3 Methods

Experimental design was partially based on 2014 and 2019 research into growing plants on Moon and Mars regolith simulant by Wamelink et al. [1, 3].

90 seeds will be brought to germination on petri dishes in between damp paper towels. Tissues will be kept damp until germination.

Plastic pots with a diameter of 10,5 cm will be filled with 270mL soil. Each pot will be supplemented with 30mL of organic matter (Earth soil), as it has been proven that addition of organic matter significantly improves plant growth [3]. Additionally, the addition of organic matter increases the nutrient availability, water retention and hydraulic conductivity

[14]. 25mL water and 50mL nutrient solution will be added to each pot. Nutrient solution is needed since the soil simulations do not contain enough nutrients themselves [10, 11]. In each pot a filter will be placed to prevent leaking of the soil. 3 seeds will be planted per pot and 10 replicas will be used per soil type. This means 30 seeds will be used per soil type and in total 90 seeds will be planted directly into soil.

Seeds will be watered with tap water triweekly with the same amount of water per seed (pots with multiple germinated seeds will receive multiple doses of water). On Mondays the watering will include nutrient solution (100mL in the second week and then as needed). During the experiment germination will be monitored first. If germinated, plant height will be measured and amount of sprouts will be counted before watering on Mondays. Greenness of the leaves (as a proxy for chlorophyll content) will be measured after four weeks, eight weeks and at the end of the experiment with a SPAD-502 meter. After a growing period of 10 weeks wet weight will be measured. After drying in the ovens at 70℃ for 48 hours, dry weight will be measured.

Seeds will be scored on germination, growth in mm (and eventual height in mm), amount of sprouts, chlorophyll content, wet weight and dry weight.

Double sided student t-tests will be conducted with the collected data.

3.4 Estimation of amount of data to be collected

Data on all planted seeds can be collected. For these seeds planted directly in the soil estimated is that at least one in three seeds will germinate. If this is not the case, seeds germinated in petri dishes will be planted in the soil. Thus, information on germination of 90 (3x10x3; seeds per pot x replicas x soil types) seeds will be available.

Estimated is that for the seeds germinating in petri dishes 60% will germinate**.** If used, this amounts to data on the growth of at least 10 seeds in the Mars regolith simulation group, 10 seeds in the moon regolith simulation group and 10 seeds in the control group. Together this amounts to data on the growth of 30 plants.

Seeds will have 10 weeks to germinate and grow. Plants will be watered and observed three times a week and measurements will be done on Mondays. This means that information on 10 measurements plus the final weighing of 30 plants is expected to be collected.

3.5 Presentation of results

Results on the germination of seeds and the amount of sprouts will be presented in tables. Results on the growth of the germinated plants and chlorophyll content will be presented in graphs. Wet weight and dry weight will be presented in tables.

4 Project planning

4.1 Planning of activities

Table 1: Planning of BSc thesis

Date	Activity
Phase 1: Writing of research plan	
March 20, 2023	First meeting with supervisor
March 22, 2023	First meeting with second supervisor

March 20-24, 2023	Literature research, writing of research plan and ordering of seeds
March 24, 2023	Handing in draft research plan
March 26-30, 2023	Implementing feedback on research plan and preparation of presentation research plan
March 30, 2023	Handing in final research plan
March 31, 2023	Presentation research plan
Phase 2: Performing of experiment	
April 4-May 12, 2023	Performing research project part 1
June 13-June 16, 2023	Performing research project part 2
Phase 3: Writing of article	
June 19-June 27, 2023	Writing draft article
June 27, 2023	Handing in draft article
June 30-July 5, 2023	Implementing feedback on article
June 5, 2023	Handing in final article
June 30-July 6, 2023	Preparation of presentation BSc thesis
July 7, 2023	Presentation BSc thesis

4.2 Detailed planning of performance of research project

Table 2: Planning of research project; Phase 2

Date	Activity
April 4, 2023	Planting of bamboo seeds and start germination in petri dishes
April 5-May 1, 2023	Performing of phase 2
May 2-May 5, 2023	Think Tank University of Twente
May 8-May 12, 2023	Performing of phase 2
May 13-June 12, 2023	Triweekly watering and measuring of plants (period 6A)
June 13, 2023	Last day of growing
June 14, 2023	Weighing of bamboo shoots and drying of bamboo shoots
June 15, 2023	Finishing Capita Selecta
June 16, 2023	Weighing of dried bamboo shoots

Phase 2 extra information

Mornings:

Observations/measurements (Mondays) and watering of plants (Mondays, Wednesdays, and Fridays), article (Tuesdays and Fridays)

Afternoons:

Thesis extension project/Capita selecta

5 Back-up strategies

Table 3: Back-up strategies for possible problems with proposed research plan

Problem	Solution
Seeds do not get delivered	Seeds can be ordered from a different supplier, bamboo can be bought from de Oude Tol or collected from Supervisor’s garden

Less than 5 of the seeds planted directly into the soil germinate after 2 weeks	Seeds germinated in petri dishes can be used
Seeds in petri dishes do not germinate	Bamboo can be bought from de Oude Tol or collected from Supervisor's garden
Control group bamboo does not grow	Try to figure out why and redo experiment if time permits
Plants die due to unforeseen circumstances (fungal infection, etc.)	Redo experiment if time permits

6 Literature references

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