UNITED NATIONS/AUSTRIA SYMPOSIUM:
"SPACE APPLICATIONS FOR FOOD SYSTEMS"
7-9 SEPTEMBER 2021.

MICROGRAVITY SIMULATIONS PLATFORMS FOR CROP FARMING BENEFITS

Funmilola Oluwafemi[1,2] and Omodele Ibraheem[2]

[1]National Space Research and Development Agency (NASRDA), Abuja, Nigeria

[2]Federal University Oye-Ekiti (FUOYE), Ekiti State, Nigeria

***Correspondence: oluwafemifunmilola@gmail.com; +2348065035799,**

https://orcid.Org/000-0001-7575-9992

INTRODUCTION

- **Space science and technology's role** in socio-economic growth and development to enhance the quality of life and living standard of people cannot be over-emphasized (Afolayan *et al*., 2019).

- **This is practically achieving the Sustainable Development Goals (SDGs).** For example, the Zero-hunger SDG encompass to:
  - end hunger
  - achieve food security
  - improve nutrition and to
  - promote sustainable agriculture.

- These are all achievable in diverse ways using space technologies.

The Sustainable Development Goals (SDGs)

SPACE FOOD AND NUTRITION

- Fulfillment of **space exploration mission is key**, but much more important are the **lives of the explorers**.

- A major contribution seems to be the food they eat. For **short-term space manned missions**, astronauts food could be taken along with them from Earth, but for **manned missions to the Moon, Mars and Venus** which are the current research destinations for long-term space missions, they must find a means for their nutrition such as growing plants and finding any other alternatives for their survival.

- Good food and nutrition for astronauts help to keep their **psychology and physiology** in good shape.

- In this project, the **benefits** to **Earth and benefits to space** research of planting and germinating crops under a simulated (mimicked) space environment is done.

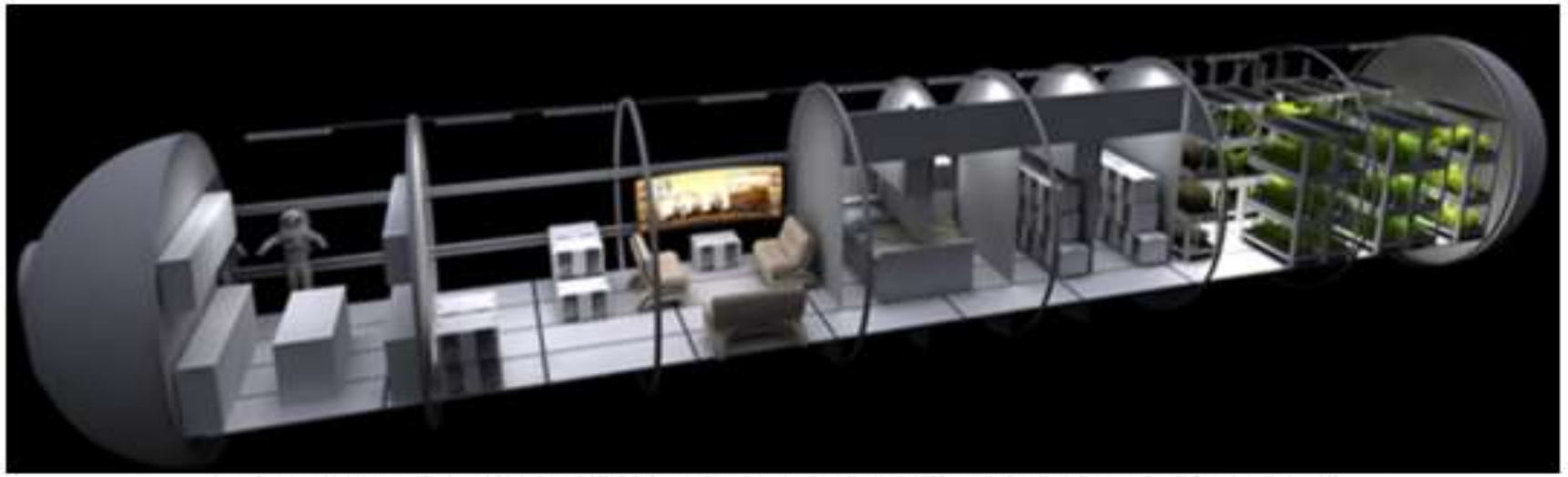
Food and Food Systems that are of high Nutrition to Astronauts

OTHER BENEFITS OF PLANTS IN LONG-TERM MANNED MISSION TO SPACE

- Human and plants are actually **ideal companions** for spaceflight; as plants breath in the carbon dioxide from humans, and humans breath in the oxygen from plants.

External view of the Mars One Habitat Concept after the first crew landing.

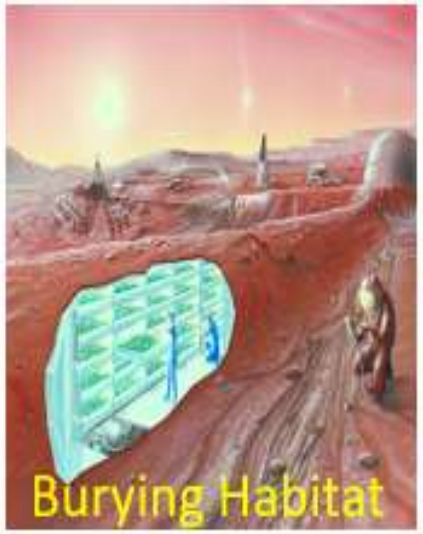
- Gardens could even, in the long-term, provide **building materials** such as wood and bamboo, and would **improve the morale and wellbeing** of the crew.



Internal view of one of the Mars One Habitat Housing Concept.

SPACE FARMING

- **Space farming** is equivalent to **agriculture on Earth**. Space farming simply refers to cultivation of food in space or on **off-Earth celestial bodies.**
- Space farming expands knowledge of agriculture on Earth, as **researchers transfer what have been learnt about growing food in inhospitable-climate of space to equally challenging and hostile-climate on Earth.**
- **Astrobotany** is studying plants in space. The space environment is characterized by **microgravity** and **space radiation,** which **could affect the germination, growth and development** of plants**.** In addition, **how gravity, light and atmospheric and other conditions affect** the plant's ability to grow needs to be **researched upon.**
- As on Earth, the method of planting seeds **require the same basic ingredients for the** plants to grow in space**.** It takes **nutrients, oxygen, water, and a good amount of light either if soil is used or not.**
- **Closed, controlled, or soil-less cultivation systems are used because of un-favourable environmental conditions.**
- **Some basic necessities:** Soil-simulation, Soil-less, In soil cultivations, Burying habitat, Genetic engineering of crops**.**
- **Specific methods for planting crops in space:** Plant pillows, Plant agar, Greenhouse, Aeroponics, Hydroponics, Aquaponics.



MICROGRAVITY

- The major **characteristics** of space environment are: **microgravity and radiation**.

- **Microgravity** is an experience in the outer space where the gravitational pull is very low. It is a state of **weightlessness**. Microgravity literally means very little gravity.

- **Impossible experiments** on the Earth can be conducted in space. Microgravity may impact how materials behave, how chemical reactions progress and how biology functions.

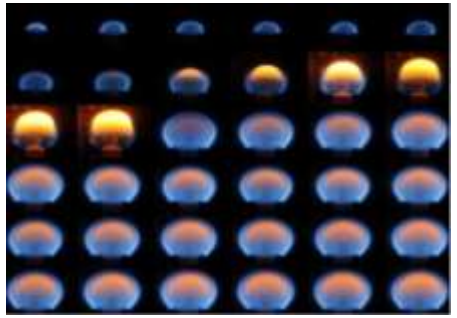
- As a result of finding **solutions** to some of the **major risks** in the space proposed manned mission and also for the Earth to get some **benefits** from the space exploration, **came the development of the science called "Microgravity Science"**.

MICROGRAVITY SCIENCE

Microgravity science is the knowledge or study of matter, material or a body under microgravity environment. As microgravity provides a unique environment for understanding the fundamental properties of matter (Rachel, 2018).

- Many **things behave differently** in microgravity environment.
- Without gravity, things sometimes behave unexpectedly and this knowledge can help spark innovations on Earth (Rachel, 2018).
- **Overall products manufactured in microgravity environments have key properties usually surpassing the best terrestrial counterparts.**
- **Commercially, these products have attractive features that facilitate marketing** (Oluwafemi, 2017).

On Earth, **flames** have a **teardrop shape** caused by hot air rising in a gravitational field. In microgravity, flames **break apart into little balls**.



They burn using **almost no fuel**. Something researchers would like to replicate in gas-saving auto engines (Mamta, 2019).

Flowers **even smell differently**; **new fragrance** is usually developed (Mamta, 2019).

MICROGRAVITY RESEARCH

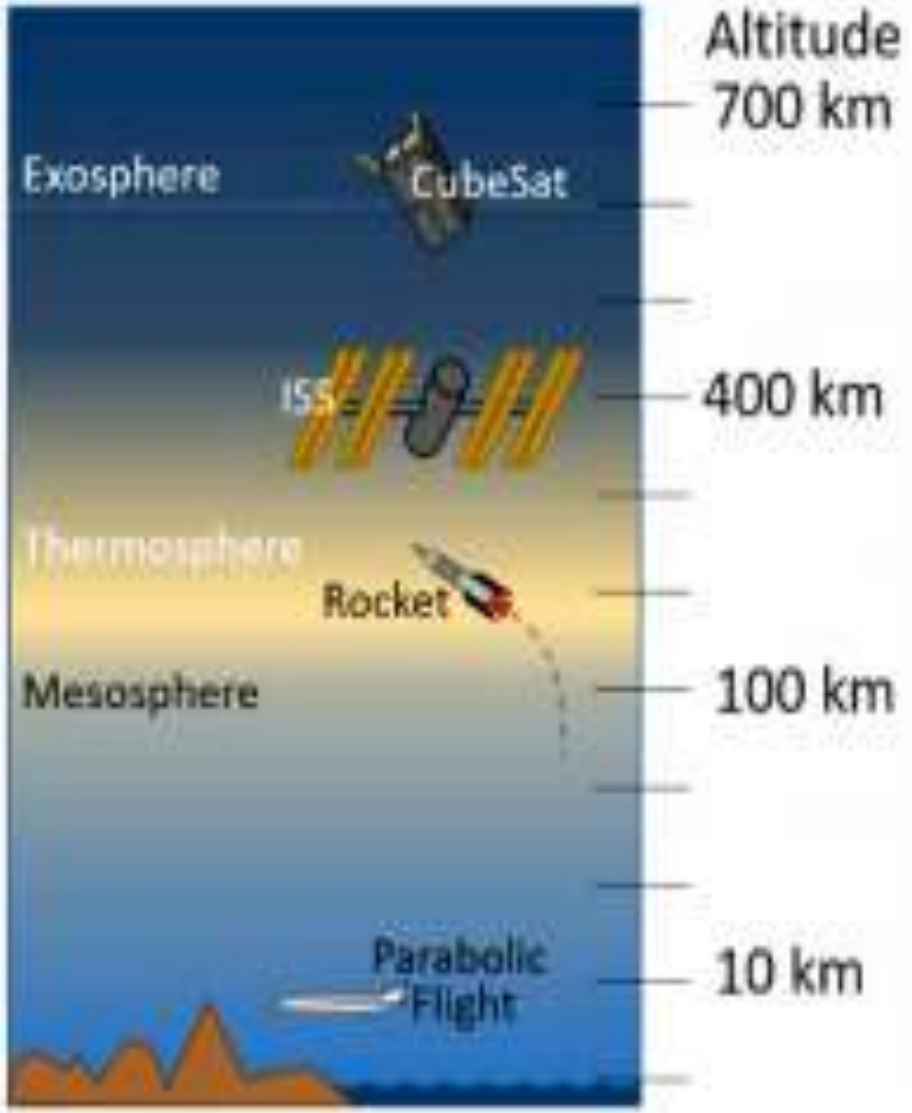
- **Microgravity research are those research conducted in low gravity environment**. Microgravity research can be done on the International Space Station (ISS), sounding rockets, parabolic flight etc.

- To carry out experiment in a real microgravity conditions in space is expensive and rare. Similar experiments are now being conducted on the Earth using equipment which provides **simulated microgravity conditions** such as clinostat, random positioning machine etc.

- Various microgravity simulators that are frequently used by gravitational researchers are based on **different physical principles**. **However, in plant biology, these simulators provide long enough period to assay growth and development effectively.**

2D Clinostat

Drop Tower



Ferranti *et al.*, 2021

SIGNIFICANCE OF MICROGRAVITY RESEARCH

- **Provides insight into certain processes and phenomena in microgravity research**.

- Broaden understanding of how organisms and matter react to gravity and this may lead to new applications of **benefit to man in food security and medical cures.**

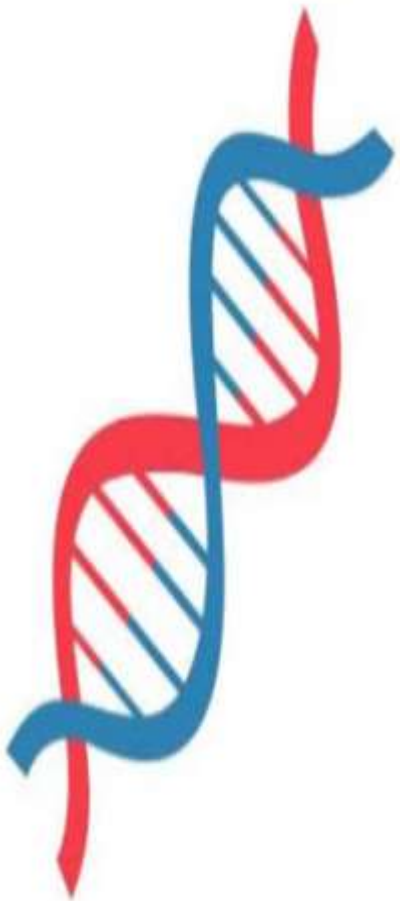
- **Reveals more information on molecular and cellular basis of some mechanisms in plants** in response to plant breeding and agriculture on Earth.

- **Provide more insights into growing plants in space (space farming)** and ensuring a supply of oxygen and food during long-term space missions.

- **Create a data set of experimental results in microgravity responses that could contribute to the design of future space experiments** and to the advancement of microgravity research.

BIOCHEMISTRY AND MICROGRAVITY

- **Not all life responds to microgravity in the same way.**



- Across species, the most consistent thing that is seen **altered is metabolism**. It basically manifests depending upon the species, which could either **increase** or **decrease** growth and development.

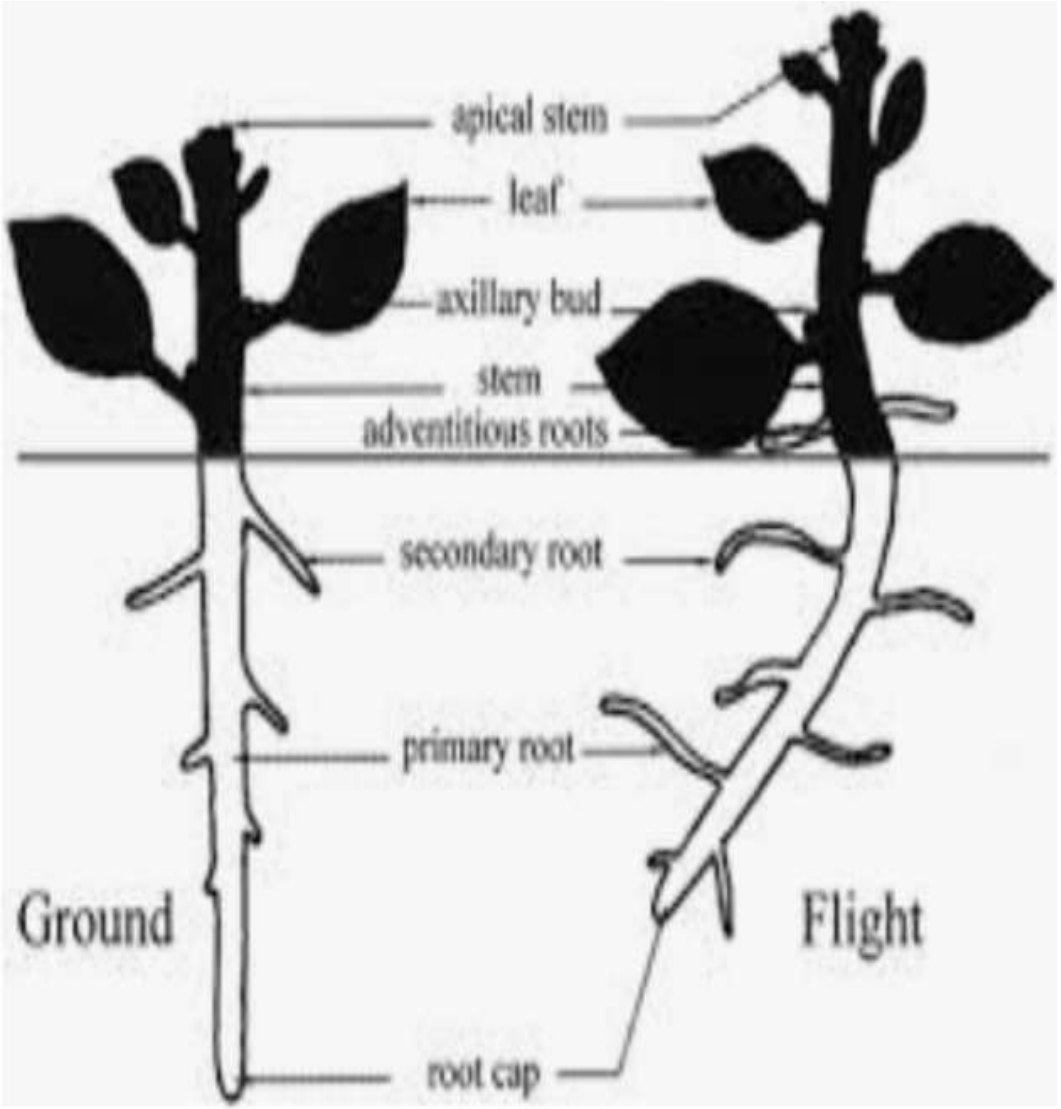
IMPORTANCE OF PLANTS ROOT

- Plants roots are structures specialized for **anchorage, storage, absorption and conduction.** Plants roots-anatomy is very important for gravi-responses and in plant physiology generally.

- In this project, the roots of the plants are the **focus**.

- Also, **biochemical make-up plays a major role during rooting process in plant.**

- **Root determines fruits. Without root no fruits; without fruits no food: no life; no existence; no future.**



MICROGRAVITY SIMULATION LABORATORY, NATIONAL SPACE RESEARCH AND DEVELOPMENT AGENCY (NASRDA), ABUJA, NIGERIA.

- Microgravity simulation equipment called clinostat is used in the Earth Laboratory to investigate the effects of microgravity environment on **plants, cells, micro-organisms and material samples.**
- A clinostat simulates or **mimic microgravity** environment.
- **Types** of clinostat are 1D, 2D and 3D (gravite).
- Different ways microgravity experiment can be performed using the 2D clinostat is **horizontal and vertical methods**.
- The basic principle behind the use of clinostat is that the **centrifugal and centripetal forces** are made equal.
- **Experimental variables:** Temperature, Humidity, Light Conditions. Rotation Speed, Rotation Direction, Rotational Axis Angle, Duration of Rotation **are specific for the Clinostat.**

SELECTED CROPS FOR MICROGRAVITY SIMULATIONS

- Some of the selected crops are **peanut, watermelon, corn, cucumber, carrot and tomato.**
- They are selected because of their **nutritional and economical values**. In this project, peanut is the focus.
- **Peanut** is an important **legume** in the world, and it is a dicot.

Peanut (*Arachis hypogae*)

AIM

- Using clinostat simulated microgravity model, to determine the effects of gravity variations on the root morphological developments and biochemical characterization of peanut.

SPECIFIC OBJECTIVES

1. To determine the **germination rate and seedlings growth rate** of peanut under gravity and simulated microgravity.

2. To ascertain the impact of microgravity on **plant's root biochemical characteristic components** in the developed roots samples by determining the **proximate composition of unstressed and chemical stressed** harvested seedling roots of peanut.

EXPERIMENTAL DESIGN

The steps necessary for preparing an experiment using the Clinostat with plants include:

- Preparation of **the substrate for seeds** in petri dishes.
- **Planting of seeds** into the substrate.
- **Cultivation inside a wet chamber**.
- **Placement of the seedlings on the Clinostat** (**source of simulated microgravity**).
- The **possible experimental variables** are humidity, temperature and light while on the Clinostat, **rotation-speed, rotational-axis angle, rotation-direction and duration of rotation** are the specific experimental variables.
- Possible methods for getting results is a further analysis of observed gravi-responses to compare the effect of **simulated microgravity on grown roots** of plants to those under **gravity response**.
- Observations were made for hours during the experiments on the samples and a **wide range of observational and measurement tools** (such as ImageJ) were used; also **biochemical characterization** were carried out.




OBJECTIVE 1

GERMINATION AND CLINOROTATION (MICROGRAVITY SIMULATIONS) OF THE PEANUT SEEDLINGS

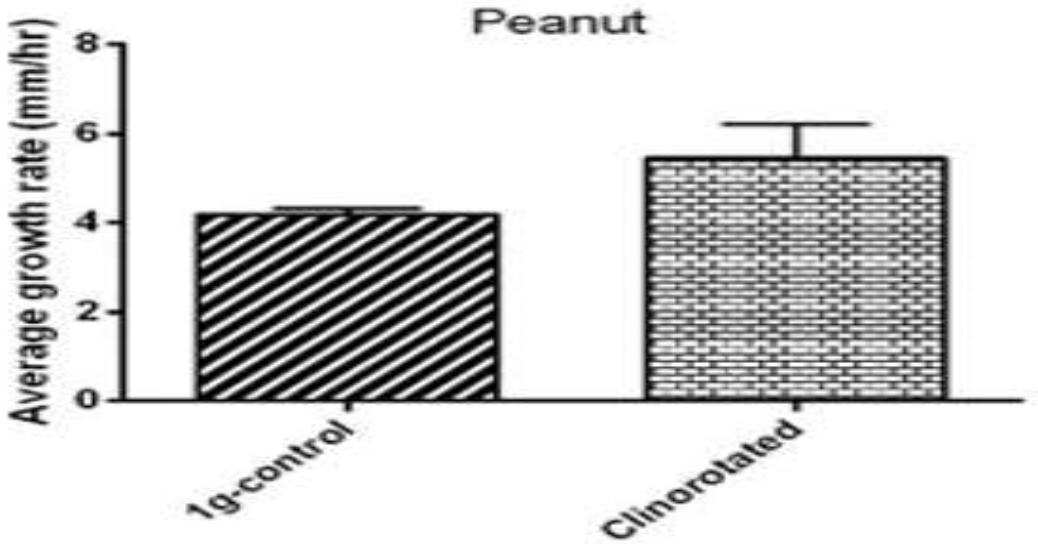
Growth Rate of the Seedlings

Earth's Gravity Sample (control)

Simulated Microgravity Sample

The root lengths of the Earth's gravity sample (control) and the simulated microgravity sample of peanut seedlings were measured by ImageJ software from their images taken every 30 minutes for 2 hours. Afterwards, their growth rates were calculated.

29.76% increased growth rate



Clinorotated had 29.76% higher root growth rate than the control

OBJECTIVE 2

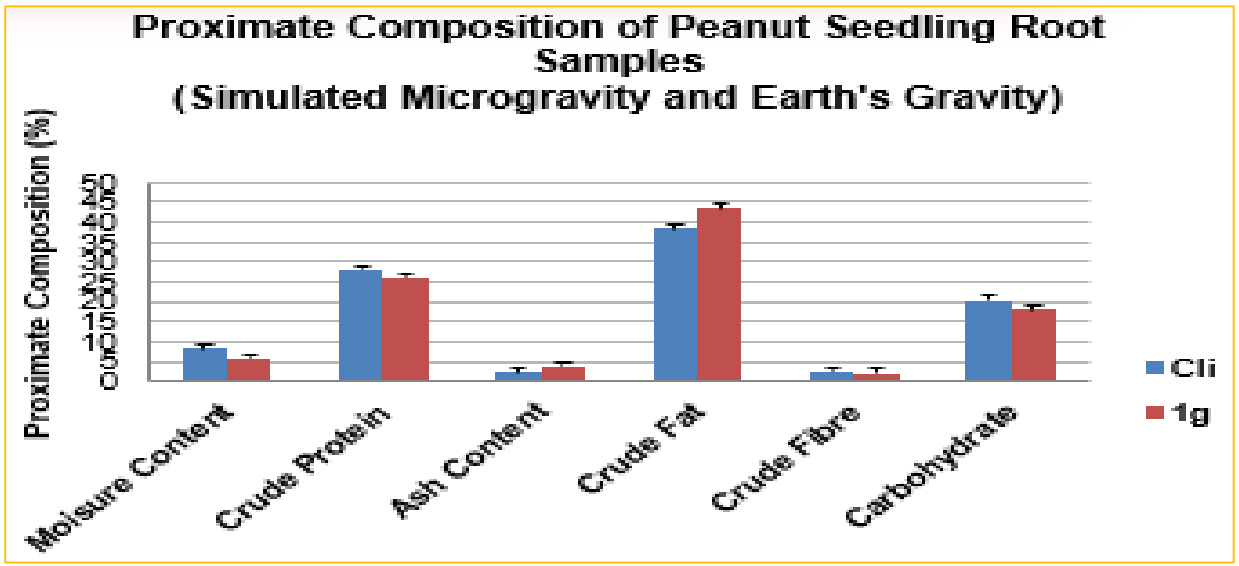
PROXIMATE COMPOSITION OF UNSTRESSED AND STRESSED HARVESTED SEEDLING ROOTS OF PEANUT SEEDLINGS ROOTS HARVESTED

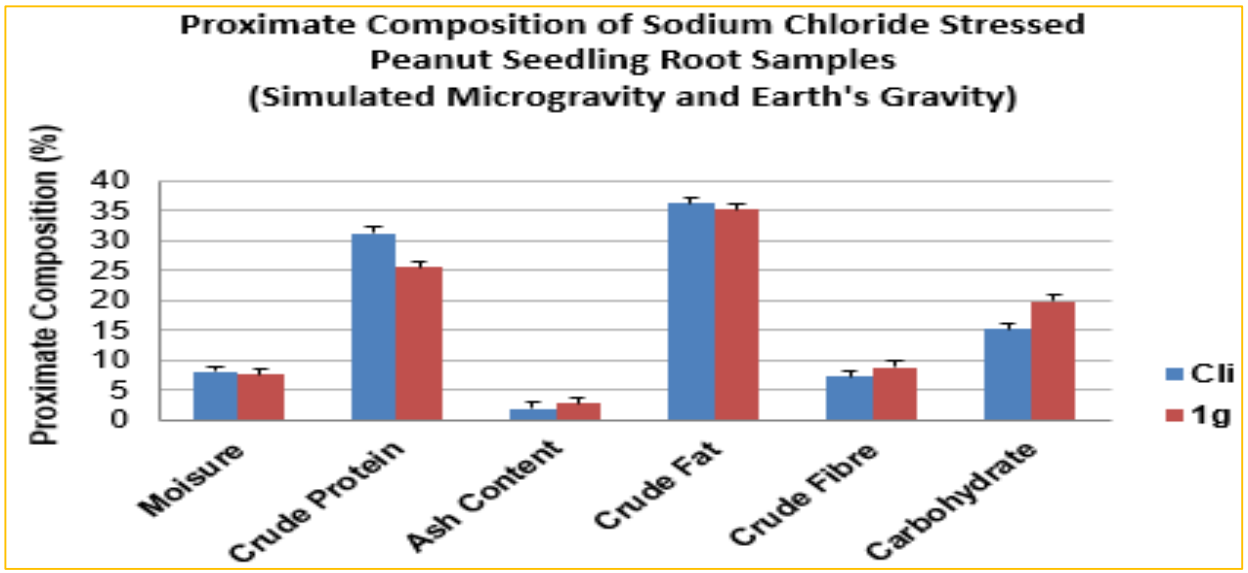
- **Proximate analyses** stand for a method, which determines the **values of the macronutrients** in food samples.
- **Sodium** is **both an electrolyte and mineral.** It helps keep the water (the amount of fluid inside and outside the body's cells) and electrolyte balance of the body.
- **The statistical significance levels were set at 5% (P<0.05).**

Unstressed - All the composition had significant differences (Moisture Content, Crude Protein, Crude Fibre, Carbohydrate are higher in the simulated microgravity sample).

Sodium chloride (NaCl) Stressed - All the composition had significant differences (Crude Protein, Crude Fat are higher in the simulated microgravity sample).

Harvested Peanut Seedlings Root





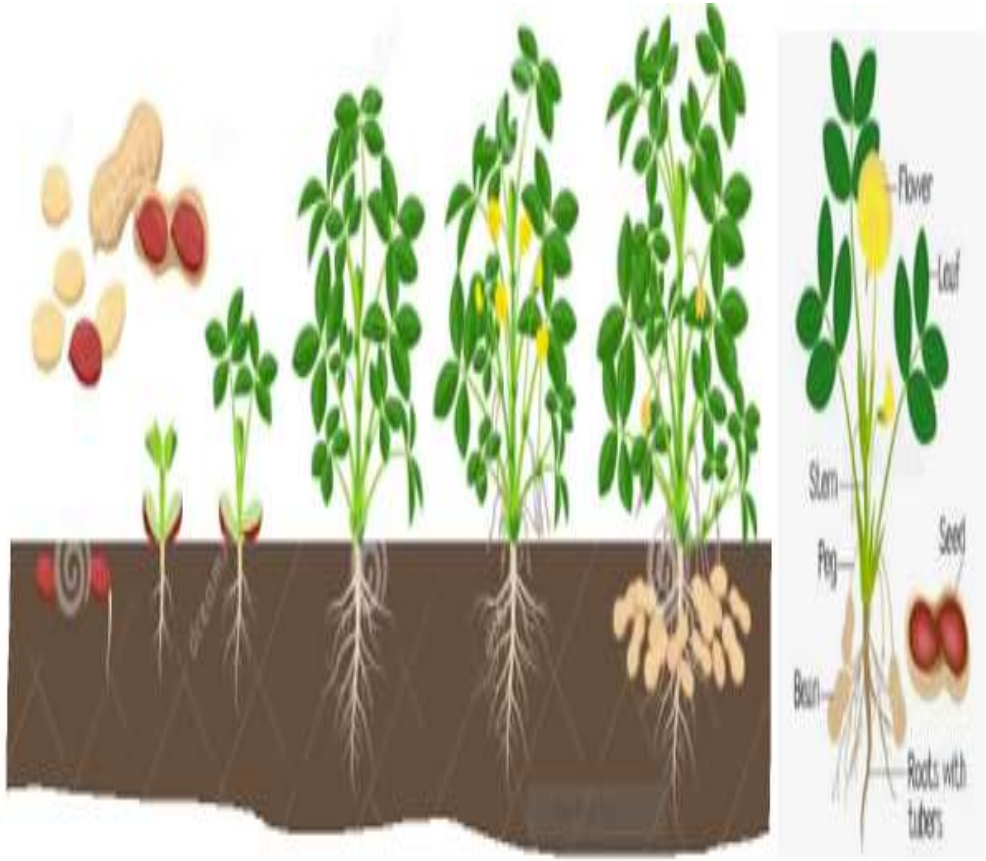
CONCLUSION

- **Plants account for the majority of human food**. Increasing **crop's yield** and **quality of crops** is quite important. The knowledge obtained from microgravity simulations of **crops** has been successfully applied to **bio-fortify**.

- Based on the work done, the **proximate composition** after **abiotic (chemical) stressing** of the seedling root of peanut still had good amount of nutrient in comparison to the control and having **ability to withstand the chemical stress**.

CONCLUSION CONT'D

- Microgravity effects ("space stress") on plants, kicks start/activate innate reaction mechanisms for surviving harsh environment, therefore when taken unto the field are proposed to **withstand or reverse environmental stresses.** Thus, **stressing the plant at the early stage** (pre-microgravity stressing of seedlings) is advantageous causing **better product yields and higher nutritional qualities than the normal conventional crops.**



- Due to these synergized efforts, **the agricultural sector** can have **improved crop breeds**, which can emanate survival/striving of crops very well in the **harsh/inhospitable environment and under unstable climate and weather extremes of the Earth** because of the enhanced characteristics for adaptation to extreme conditions under simulated microgravity.

- **Also space explorers may have improved crop breeds from this research that may strive well in the harsh environment of space**.


THANK YOU FOR YOUR
ACTIVE ATTENTION

FURTHER READING/REFERENCES

1. Afolayan, E.M., Oluwafemi, F.A., Jeff-Agboola, E.O., Oluwasegun, T., Ayankale, J.O. (2019). Socio-economic benefits of microgravity research. Arid Zone Journal of Engineering, Technology and Environment (AZOJETE), Centre for Satellite Technology Development Special Issue: Space Science and Technology for Sustainable Development 15, SP.i2: 57-74, Print ISSN: 1596-2490, Electron vic ISSN: 2545-5818.
2. Ferranti, F., Del Bianco, M., Pacelli, C. (2021). Advantages and Limitations of Current Microgravity Platforms for Space Biology Research. Appl. Sci. 11, 68. https://dx.doi.org/10.3390/app11010068.
3. Howard, G.L. (2010). The Influence of microgravity on plants. NASA Surface Systems Office, Space Life Sciences Laboratory, Mail Code NE-S-1, Kennedy Space Center, FL 32899. NASA ISS Research Academy and Pre-Application Meeting, South Shore Harbour Resort & Conference Center, League City, Texas.
4. Oluwafemi, F.A., Ibraheem, O., Fatoki, T.H. (2020). Clinostat microgravity impact on shoot morphology of selected nutritional and economic crops. Plant Cell Biotechnol Mol Biol. 21(43&44), 92-104. ISSN: 0972-2025.
5. Oluwafemi, F. (2018). Microgravity research applications in life sciences using clinostat. Lap Lambert Academic Publishing, trademark of International Book Market Service Limited, member of OmniScriptum Publishing Group, 17 Meldrum Street, Beau Bassin 71504, ISBN-13: 978-613-9-90145-6. ISBN-10: 6139901456. EAN: 9786139901456. 50pgs, Mauritius. <https://www.morebooks.de/store/gb/book/microgravity-research-applications-in-life-sciences-using-clinostat/isbn/978-613-9-90145-6>.
6. Oluwafemi, F., Olubiyi, R., Ibraheem, O. (2019). Space environment: A classical study for all research fields (Poster). Proceedings of the United Nations /Austria World Space Forum: 'Access to Space for All', Vienna, Austria, 18-22 November.
7. Oluwafemi, F.A., De La Torre, A., Afolayan, E.M., Olalekan-Ajayi, B.M., Dhital, B., Mora-Almanza, J.G., Potrivitu, G., Creech, J., Rivolta, A. (2018). Space food and nutrition in a long-term manned mission. Adv. Astronaut. Sci. Technol. 1, 1. Doi: 10.1007/s42423-018-0016-2.
8. Oluwafemi, F.A., Oke, A.B., Afolayan, E.M. (2018). Investigation of watermelon seeds growth under simulated microgravity and its advantages to agriculture sector. Monograph of Atmospheric Research, Centre for Atmospheric Research (CAR), Pp. 109-111, ISBN: 978-978-972-859-6, Anyigba, Nigeria. <https://carnasrda.com/2018monograph/>.
9. Oluwafemi, F.A., Olubiyi, R.A. (2019). Investigation of corn seeds growth under simulated microgravity, Arid Zone Journal of Engineering, Technology and Environment (AZOJETE), Centre for Satellite Technology Development Special Issue: Space Science and Technology for Sustainable Development 15, SP.i2:110-115, Print ISSN: 1596-2490, Electronic ISSN: 2545-5818.
10. Oluwafemi, F.A., Patal, D., Lakmal, Y., De La Torre, A., Kamaletdinova, G.R., Lousada, J. (2018). Microgravity Effects in a long-term manned mission, Monograph of Atmospheric Research, Centre for Atmospheric Research, ISBN: 978-978-972-859-6, Anyigba, Nigeria, Pp. 116-122. <https://carnasrda.com/2018monograph/>.
11. Oluwafemi, F.A., (2017). Microgravity research and applications: Roles in economic prosperity and poverty reduction. Conference proceedings of United Nations/United Arab Emirates high level forum: Space as a driver for socio-economic sustainable development, Dubai, United Arab Emirates.
12. Mamta Patel Nagaraja (2019). Science that can't be done on earth. https://science.nasa.gov/science-news/science-at-nasa/2003/16jan_sts107
13. Rachel Brazil (2018). Science in microgravity. https://www.chemistryworld.com/features/science-in-microgravity/3009826.article
14. Awika, M.J. (2011). Major cereal grains production and use around the world. ACS symposium series. 1089, pp. 1-13. DOI: 10.1021/bk-2011-1089.ch001.
15. United Nations. (2013). Teacher's guide to plant experiments in microgravity. Human Space Technology Initiative. United Nations Programme on Space Applications, Publishing and Library Section, United Nations Office, ST/SPACE/63, New York.