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ORIGINAL RESEARCH ARTICLE

INVESTIGATION OF CORN SEEDS GROWTH UNDER SIMULATED MICROGRAVITY

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ABSTRACT

Living organisms are made-up of cells, while cells are made-up of several macromolecules such as proteins, carbohydrates, nucleic-acids, lipids, which have individual functions. The role and impact of light on plant metabolism including photosynthesis cannot be overemphasized. Corn seeds were planted in two petri-dishes using plant-agar after standard-preparation. The plant-agar served as soil and as source of nutrient. The two petri-dishes containing the seeds, had equal treatment by receiving 50lux of light and humidity of 60-100%. These are the essential conditions for photosynthesis. After 3days, germination of the seeds was observed. One of the petri-dishes was labelled terrestrial-control while the other was labelled clinorotated. The clinorotated was mounted on clinostat, a microgravity-simulating equipment for 4 hours. The two petri-dishes for the 4 hours received 50lux of light. Observations and analysis were carried out using ImageJ software on pictures taken periodically from the two samples. The quantitative result of the analysis showed that the clinorotated sample had 9.73mm/h growth-rate while terrestrial-control sample had 7.54mm/h growth-rate. The two samples received equal lux of light, but the interaction of the light for conversion into chemical-energy for plant-activities was different after subjection to simulated-microgravity for 4 h. It could be deduced that: the light dependent reactions, which take place in the thylakoid-membrane, that use light-energy to make ATP (chemical) and NADPH was speed-up under simulated-microgravity and that photosynthetic functions were impacted positively by the space-environment. Therefore, role of light on plants is complex and this is a function of the role of complex light interactions on individual cells of plant.

1.0 Introduction

Plants respond to environmental stimuli such as gravity, light, water, wind and touch. The gravitropic response is often – cited example of biological signal perception, processing and response. Signal perception is attributed to sedimenting or moving amyloplasts. The physical process is then converted into a biochemical signal (through signal transduction mechanism) that elicits a growth response in the shoot and roots, where differential elongation on the top and bottom flank reestablishes the gravitropic set-point angle. The curvature is the final step in a series of complex processes (Susan and Karl, 2011).

Corn (*Zea mays*) is an important grain used for food, animal fodder, the production of alcoholic beverages, and biofuels. Corn's usefulness makes research on corn quite important (AGDHSA, 2008). All living things need energy to grow. Humans get energy from plants by eating them. Plants get energy from light through a process called photosynthesis. Without light, a plant would not be able to produce the energy it needs to grow (Heather, 2018). Living organisms are made-up of cells. Cells on the other hand are made-up of several macromolecules such as proteins, carbohydrates, nucleic-acids, lipids etc. which have individual functions (Geoffrey, 2000). The role and impact of light on plant metabolism including photosynthesis cannot be overemphasized (Howard, 2010). Photosynthesis is the process by which green plants and some other organisms use sunlight to synthesize nutrients from carbon dioxide and water. Photosynthesis in plants generally involves the green pigment chlorophyll and generates oxygen as a by-product (RSC, 2019).

Corn seeds were bought and authenticated to be the actual seeds sought after. Experimental sample of corn seeds were allowed to grow under simulated microgravity using clinostat for 4h. The experimental and the control samples had equal treatment by receiving 50lux of light and humidity of 60-100%. These are essential for photosynthesis. Observations and analysis were done using ImageJ software on the pictures taken periodically on the two samples for the period of the four hours. Haven received equal light treatment, the quantitative analytical result on the growth gives information on the light interactions on the individual samples from their photosynthesis. This is according to the Teacher's Guide to Plant Experiments by United Nations Office for Outer Space Affairs (UNOOSA) of the Programme on Space Applications (United Nations, 2013).

Several researches such as those of Raghad et al. (2016) and Emmanuel et al. (1996) have shown that microgravity impact on plants usually results in positive influence on plant biochemicals. Therefore, the objective of this research was to investigate if equal light impact on the sample mounted on clinostat and the control sample under normal Earth gravity gives the same growth rates in these samples.

2.0 Materials and Methods

The substrate of seeds called plant-agar was prepared in 2 petri-dishes following the standard preparation method (Oluwafemi et al., 2018a). The plant-agar (seeds substrate) served as the soil and as source of nutrient. Then the corn seeds were planted into the substrate and it was cultivated inside a wet chamber in vertical positions. This is because plants grow vertically under normal Earth gravity (terrestrial). The light intensity reaching the samples for growth was measured using lux meter (Figure 1). After 3 days, germination of the seeds with short roots was observed. The 2 petri-dishes were then taken and labeled "terrestrial-control", and "clinorotated" (Figures 2 and 3). The terrestrial-control sample was left in the vertical position while the clinorotated sample was placed at the centre of the clinostat using double-sided tape. The photos of the 2 petri-dishes were taken every 30 min with very short stopping time of the clinorotated in order to avoid the effect of gravity (the clinorotated sample mounted on the clinostat was stopped from rotation for some seconds to snap it. During this short period to

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snap, negligible gravity will act on this sample). These observations were done for 4h under the following conditions; light of 50lux, humidity was between 60% to 100% and temperature was 23ºC. In addition to these, the clinorotated sample had the following conditions, rotation speed of 75rpm, horizontal rotational-axis angle of 90° and the direction of rotation was clockwise. This is because the clinostat is an equipment and needs to be set at specified experimental variables at the discretion of the experimental. The rotation speed ranges from 1 to 90°; the position of the clinostat could be maintained from horizontal to vertical; and the direction of rotation could be clockwise or counter-clockwise (anti-clockwise) (United Nations, 2013).

At the end of observation, the analysis of growth-rate was carried out. The data obtained were the two sets of photos of the roots which show the "terrestrial-control" and "clinorotated" roots. An image-processing application soft-ware called ImageJ was used to analyze the photos. The difference between the two cases was analyzed by measuring the length of the roots, which thereby allowed their growth-rate to be determined. The length of the roots was measured by drawing a line which is exactly 10mm long on each petri-dish. This line was used to standardize 10mm length on the ImageJ software serving as a fixed length in the photos of the roots (such as Figures 2 and 3). After standardization, the length measurement tool of the ImageJ software was used to measure the length (in mm) of each of the roots in each photo. This yielded data-set of experimental-results in gravity and simulated microgravity responses whose grand average was calculated in mm/h and used to plot graph (Oluwafemi et al., 2018b).

Figure 1: Lux Meter

3.0 Results and Discussion

The average (in mm) growth-rate of the roots of the seeds of corn for the terrestrial-control sample was 7.54mm/h while that of the clinorotated sample was 9.73mm/h. Table 1 shows the growth-rate analysis using the root length of the terrestrial-control and clinorotated samples; table 2 shows the grand averages of the values in Table 1; while the graph was plotted using these grand averages.

Figure 2: The Clinorotated-Sample

Figure 3: The Terrestrial-Control Sample

Table 1: Growth Rate Analysis for Terrestrial-control and Clinorotated Samples

TERRESTRIAL-CONTROL	**TIME OF GROWTH DURING OBSERVATION**				
	0 h	0.5 h	1 h	1.5 h	2 h
Seed1 (mm)	11.035	12.862	12.999	11.998	12.010
Seed2 (mm)	2.122	2.001	2.186	2.205	2.590
Seed3 (mm)	18.848	22.000	22.071	21.567	22.971
Seed4 (mm)	11.519	14.564	14.564	14.302	14.879
Seed5 (mm)	13.306	15.421	15.701	15.163	15.814
Seed6 (mm)	17.869	20.471	20.942	19.430	21.000
Seed7 (mm)	22.755	23.571	24.431	23.578	24.100
Seed8 (mm)	4.394	6.720	6.140	5.806	6.123
Seed9 (mm)	17.909	21.223	23.105	21.611	22.844
Average (mm)	13.306333	15.425889	15.793222	15.073333	15.814556
CLINOROTATED					
	0 h	0.5 h	1 h	1.5 h	2 h
Seed1 (mm)	33.895	37.225	34.673	36.035	36.980
Seed2 (mm)	22.003	27.430	22.559	24.047	25.000
Seed3 (mm)	5.419	6.584	5.441	5.564	5.941
Seed4 (mm)	15.623	17.372	16.724	17.688	17.999
Seed5 (mm)	23.201	26.660	23.382	25.610	26.151
Seed6 (mm)	28.737	30.078	26.191	25.717	26.210
Seed7 (mm)	3.841	5.000	4.469	4.743	4.976
Seed8 (mm)	22.832	23.455	21.549	21.554	21.842
Seed9 (mm)	11.976	13.425	12.486	13.080	14.001
Average (mm)	18.614111	20.803222	18.608222	19.337556	19.900000

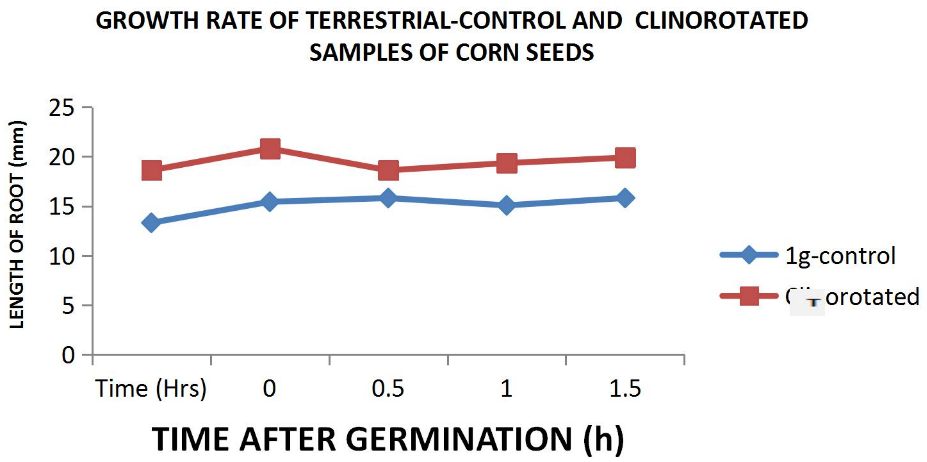

Figure 4: The Length of the Terrestrial-control Sample Roots and the Clinorotated-Sample Roots Versus the Time After Germination

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The experiment carried out by Emmanuel et al. (1996) under clinorotation showed doubling of the root length of seeds compared to the stationary control in similar experiment to this one. The result gotten in this project is also in conformity with the result of Raghad et al. (2016) which concluded that clinostat rotation can affect the biochemicals in plants tissue positively and that this technique can be used to enhance plant germination. Raghad et al. (2016) specifically investigated that gravistimulation produced on corn using clinostat showed enhanced amino acid concentration more than the control.

The experiment of Oluwafemi et al. (2018b) on watermelon seeds growth under simulated microgravity using clinostat showed that there was an increased growth rate of the clinorotated sample than the terrestrial control sample. Another study of Oluwafemi (2017) reports that reduction of gravity causes significant changes on the chosen samples during experiments. These samples could be plants, animal cells, micro-organisms and nanoparticles. The changes that occur as a result of the effect of microgravity have led to discoveries that have been found to be of socio-economic benefits.

Therefore, in this project, the same light intensity on terrestrial and clinorotated samples resulted in different growth rates of the two samples.

4.0 Conclusions

The quantitative result of the average growth-rate of the roots of the corn indicated an increased growth-rate of corn under simulated microgravity by 29.05%. The two samples received equal lux of light, but the interaction of the light for conversion into chemical-energy for plant-activities was different after subjection to simulated-microgravity for 2 hours. It could be deduced that: the light dependent reactions, which takes place in the thylakoid membrane, that use light energy to make ATP (chemical) and NADPH was speed-up under simulated-microgravity and that photosynthetic functions were impacted positively by the space environment. Therefore, role of light on plants is complex and this is a function of the role of complex light interactions on individual cells of the plant. Clinostat rotation can therefore be said to impact the biochemicals in plants tissue positively and this technique can be used to enhance plant germination, growth and ultimately, productivity in agricultural sector.

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