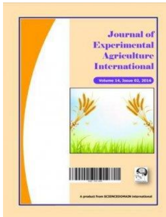

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Effect of Gravity Variation on the Growth of Wheat and Guinea Corn Seedlings

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Authors' contributions

This work was carried out in collaboration between both authors. Author OEA designed the study, involved in the laboratory work and data preparation, performed the statistical analysis, wrote the protocol and the first draft of the manuscript. Author MKO was involved in the laboratory work, managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

In this study, the impact of gravity on plant growths was studied to determine the orientation of the roots and shoots under simulated microgravity using the clinostat. The experiment was performed with two local seeds-wheat (*Triticum aestivum*) and guinea corn *(Sorghum bicolor*).

The agar-agar solution prepared was evenly distributed into the petri dishes where nine seeds each of wheat and guinea corn was planted on four petri dishes. The petri dishes containing the seeds were cultivated in the wet chamber for about 20-30 hours. Three petri dishes were selected in the following order, 1g, 90^o turned and clinorotated samples respectively. Five readings were taking at thirty minutes interval.

Data on plants growth were collected from photographs taken during the course of the experiments and analyzed using Image J software to measure the root curvature and growth rate.

The results show that the wheat has the longest root of about 4.2 cm at 90 minutes and Guinea corn

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2.58 cm at 120 minutes. The growth rate of clinorotated wheat is 1.88 times that of guinea corn at 90 minutes while that of 1g remained the same. The speed of clinorotation did not affect growth of clinorotated wheat and guinea corn but growth rate of guinea corn was about 23% lower than wheat. The higher value of angle indicates a more pronounced curvature of the root therefore; wheat germinates faster than guinea corn in simulated microgravity.

Keywords: Plant; microgravity; clinostat; agar-agar; curvature angle.

1. INTRODUCTION

Human exploration of space has provided numerous benefits to mankind and socioeconomic development of the nation. Recent developments about research in space flights have demonstrated the competences of space technology to increase the value of life on Earth through applications in agriculture, food security, medicine, biotechnology and environmental management [1-6].

Scientists have carried out ground-based research on the effect of gravity on the biological processes of plants and ample evidence of experiments conducted under microgravity in outer space has shown new perspectives and discoveries of potentially viable plants that may be beneficial to the Space Scientists and Astronauts, as it will provide a secure, sustainable and good quality of food in their quest to conquer space [7-11].

Numerous evidences abounds about the influence of microgravity on different aspect of the growth of plants and the space environment has provided a platform in which the essential life processes and mechanism responsible for the growth of plants in the absence of the effects of gravity can be studied [12-14].

Gravity as one of the dominant force on earth plays a significant role in the movement and growth directions of all plants (gravitropism). In outer space, the effect of gravitational force on the movement and growth directions of plant is minimized. This has provided a new research frontier to simulate microgravity using clinostat and its effect on the physiological variations of plant materials [15].

The Clinostat has been utilized for nearly 100 years to negate gravity and thus provide evidence on the importance of gravity to the growth of plants. This instrument has also been utilized to simulate or duplicate the weightless environment of space flight to provide understanding of possible growth effects upon plants in space stations and provide insights into how seedlings react in an environment of simulated microgravity during germination and early growth.

The success of any plant propagation program, among other things, hinges on a continuous supply of high quality seeds for the production of the desired quantity of seedlings. Several factors affect the production of high quality seeds, such as insect infestation, pollination failure and post-zygotic degeneration, infection by seed borne pathogens, environmental conditions during seed development as well as the genetic constitution [16-21].

The aim of this experiment was to observe the effects of gravity on seedlings of wheat (*Triticum aestivum*) and guinea corn (*Sorghum bicolor*) grown under microgravity condition simulated by clinostat and germinated seeds under normal gravity in the laboratory. Wheat and Guinea corn seeds were selected because of their nutritional and therapeutic values.

2. MATERIALS AND METHODS

Thirty-six viable seeds each was selected for wheat and guinea corn and were soaked separately in a beaker containing tap water for 24hours to aid faster germination. The substrate (agar-agar) which serves as the soil was prepared by dissolving 1.5g in 100ml of tap water and was heated in a beaker for about 2-3minutes to get a clear solution. The agar-agar solution was shared into four petri dishes equally and nine seeds were planted using the tweezers into the petri dishes containing the substrate. The seeds were arranged in such a way that the micropyle faces the same direction and along the gravity vector line. After planting, the lids were used to cover the petri dishes and were sealed with the parafilm to about two-third so as to allow air and water to pass into the seeds through the remaining unsealed one-third. The petri dishes were then arranged in the petri dish holders and placed in the wet chamber for about 20-30 hours with thermal hydrograph measuring the temperature and relative humidity respectively.

Fig. 1. Photograph of guinea corn seedlings in simulated microgravity and normal earth environments

After cultivation in the wet chamber, the petri dish holders containing the planted seeds of wheat and guinea corn were removed. Four petri dishes were selected for each of wheat and guinea corn and one of the petri dish was mounted on the clinostat with the aid of a double sided tape, the second petri dish was selected to represent the 90^o sample which was turned perpendicular to the gravity vector, the third was selected as 1g sample which was made parallel to the gravity vector and the last petri dish serves as back up.

Data on plants growth were collected from photographs (Fig. 1) taken at regular time interval of 30 minutes and the growth rate and curvature angle were measured using Image J software [7].

3. RESULTS AND DISCUSSION

The statistical summary of the lengths and growth rates of the roots for clinorotated and 1g samples of wheat (*Triticum aestivum*) and guinea corn (*Sorghum bicolor*) are given in Tables 1 and 2 respectively. The minimum and maximum root lengths of wheat seeds for clinorotated and 1g samples are 1.48 cm and 1.89 cm; 2.58 cm and 3.30 cm while that of guinea corn are 1.35cm and 1.59 cm; 1.91 cm and 2.83 cm respectively. The overall mean lengths of clinorotated samples of wheat and Guinea-corn in the microgravity environment are 1.69 cm and 1.53 cm and that of 1g samples are 3.09 cm and 2.55 cm respectively.

The results showed an increase in length of the roots for both 1g and clinorotated samples of wheat with increase in time but the average growth rate of clinorotated sample is more than 1g sample, this shows the importance of the clinostat as a device that helps in the cancelation of the gravity vector while gravity has a great effect on the growth rate of 1g sample. In guinea corn seedlings, the increase in length of roots

Table 1. Summary of the results obtained for clinorotated and 1g samples of wheat

Time (mins)	Clinorotated sample (n = 9)			1g sample (n = 9)		
	L (cm)	ΔL (cm)	GR	L (cm)	ΔL(cm)	GR
0	1.48	-	-	2.58	-	-
30	1.57	0.09	0.03	3.12	0.54	0.018
60	1.72	0.15	0.05	3.22	0.10	0.003
90	1.77	0.05	0.002	3.23	0.01	0.0003
120	1.89	0.12	0.004	3.30	0.07	0.002
Average Growth Rate = Total sum of Growth Rate/5			0.017			0.005

N.B: L= Length of the root as measured using Image J software, ΔL (cm) = Change in length and GR = Growth Rate = Change in Length/30 minutes interval, n = number of seeds show a slight variation in clinorotated samples while there is a much increase in the root lengths in 1g sample and the growth rate of guinea corn seeds exceed that of the wheat and it can be inferred that gravity play a major role in the growth of guinea corn.

In comparison, wheat seedlings has maximum root of about 0.5 cm in 1g sample and 0.3cm in clinorotated samples than that of guinea corn in the time interval considered. The average growth rate of wheat and guinea corn in microgravity environments are 1.88 cm h^{-1} and 1.70 cm h^{-1} and in the normal environment the growth rate was 3.43 cm h^{-1} and 2.83 cm h^{-1} respectively. Also the growth ratio of wheat to guinea corn is 1:2 in normal environment and 1:1 in microgravity environment.

The variation of clinorotated and 1g samples of wheat and guinea corn seedlings with time are shown in Figs. 2 and 3. The charts show that increase in length of clinorotated sample of wheat is about 1.1 times that of guinea corn while that of 1g is about 1.2 times that of guinea corn at 30 minutes interval.

Data on the curvature angles for both clinorotated samples of wheat and guinea corn are presented in Table 3. The least root curvature $(44.7°)$ was observed in guinea corn while the highest $112.94°$ was observed in wheat, this shows that clinorotation has a great effect on gravitropisms in roots.

The line graph of root curvatures angles for both wheat and guinea corn is shown in Fig. 4. The higher value of angle indicates an increase in the curvature of the root therefore, wheat germinated faster than guinea corn in a micro-gravity environments.

Table 2. Summary of the results obtained for clinorotated and 1g samples of guinea corn

Time (mins)	Clinorotated (n =9)			1g Sample (n = 9)		
	L (cm)	ΔL (cm)	GR	L (cm)	ΔL(cm)	GR
0	1.35	-	-	1.91	-	-
30	1.56	0.21	0.007	2.62	0.71	0.024
60	1.57	0.01	0.0003	2.70	0.08	0.003
90	1.58	0.01	0.0003	2.71	0.01	0.0003
120	1.59	0.01	0.0003	2.83	0.12	0.004
Average Growth Rate = Total sum of Growth Rate/5			0.002			0.006

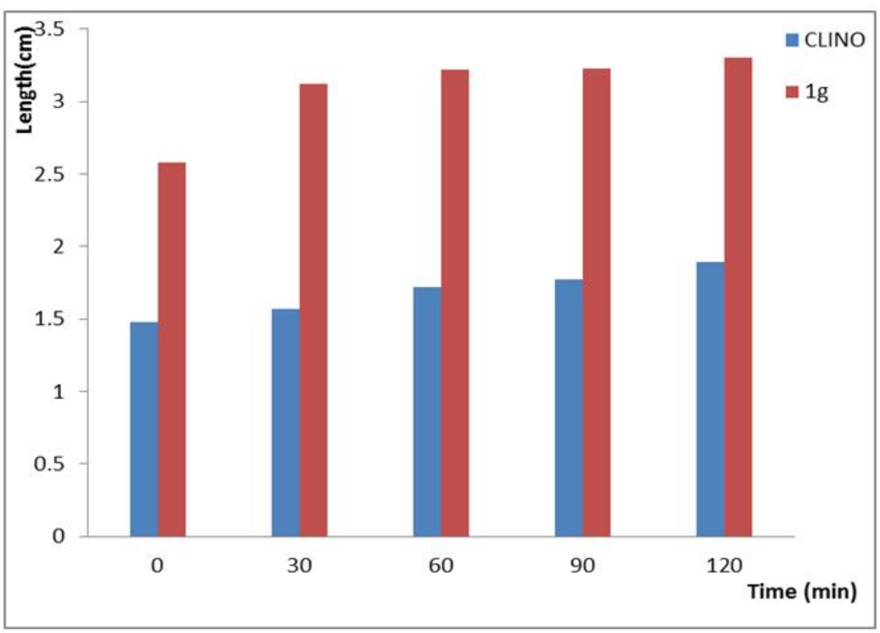

Fig. 2. The variation of clinorotated and 1g samples of wheat seeds

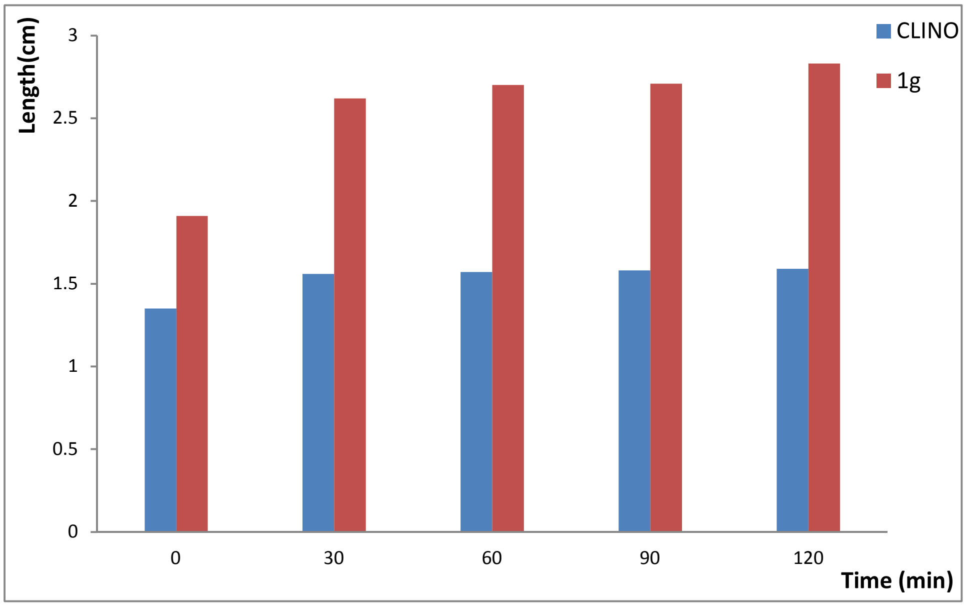

Fig. 3. The variation of clinorotated and 1g samples of Guinea corn

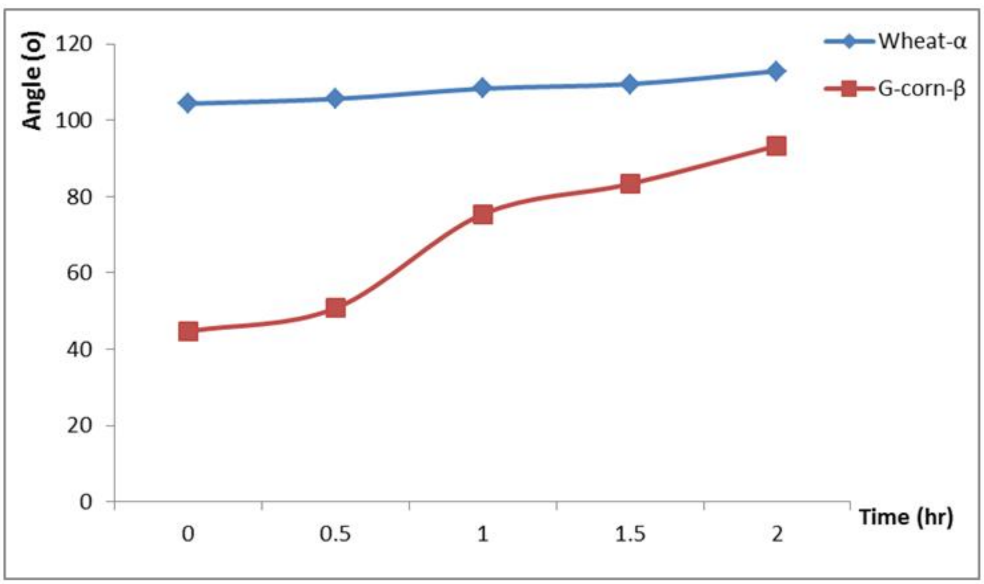

Fig. 4. Graph showing the curvature angle

Table 3. Summary of the results obtained for root curvature of wheat and guinea corn

Time (minutes)	Wheat-α° (n = 9)	Guinea-corn β° (n = 9)
0	104.41	44.70
30	105.66	50.79
60	108.35	75.41
90	109.53	83.35
120	112.94	93.37

3.1 Paired Samples *t*-Test

A paired samples *t*-test was conducted on the wheat and guinea corn seedlings to examine whether the difference between Clinorotated and 1g length and the growth rates of both clinorotated and 1g samples were significantly different from zero.

The result of the paired samples *t*-test on the length of wheat seedlings was significant, *t*(4) = -

17.68, $p < .001$, suggesting that the true difference in the means of Clinorotated and 1g was significantly different from zero (Table 4). The mean of Clinorotated sample (M = 1.69) was significantly lower than the mean of 1g (M = 3.09) (Fig. 5).

Table 4. Paired samples t-test for the difference between clinorotated and 1g length

Clinorotated		1g length		t	p	d
M	SD	M	SD			
1.69	0.16	3.09	0.29	-17.68	< .001	5.94

Note. Degrees of Freedom for the t-statistic = 4. d represents Cohen's d

The result of the paired samples *t*-test for the growth rate of wheat seedlings was not significant, $t(4) = 1.41$, $p = .230$, suggesting that the true difference in the means of Clinorotated growth rate and 1g was not significantly different from zero (Table 5). Fig. 6 presents the mean of Clinorotated and 1g growth rates.

The result of the paired samples *t*-test on the growth rate for the guinea corn seedlings was not significant, $t(4) = -1.48$, $p = .213$, suggesting that the true difference in the means of Clinorotated and 1g growth rate was not significantly different from zero (Table 6). Fig. 7 presents the mean of Clinorotated and 1g growth rate respectively.

Table 5. Paired samples t-test for the difference between clinorotated and 1g growth rates of wheat seedling

Clinonorotated growth rate		1g growth rate		*t*	*p*	*d*
M	*SD*	*M*	*SD*			
0.02	0.02	0.00	0.01	1.41	.230	0.76

Note. Degrees of Freedom for the t-statistic = 4. d represents Cohen's d.

Table 6. Paired samples t-test for the difference between clinorotated and 1g growth rate

Clinorotated		1g growth rate		t	p	d
M	SD	M	SD			
0.00	0.00	0.01	0.01	-1.48	.213	0.63

Note. Degrees of Freedom for the t-statistic = 4. d represents Cohen's d.

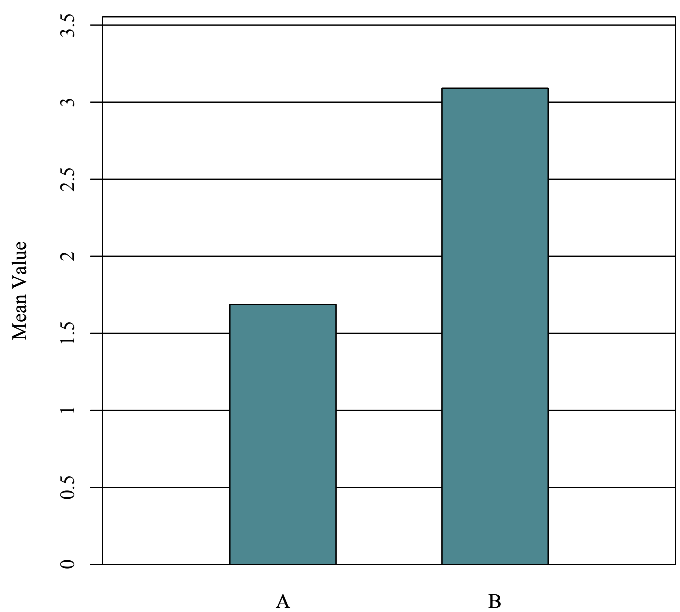

Fig. 5. The means of clinorotated (A) and 1g length (B) of wheat seedling

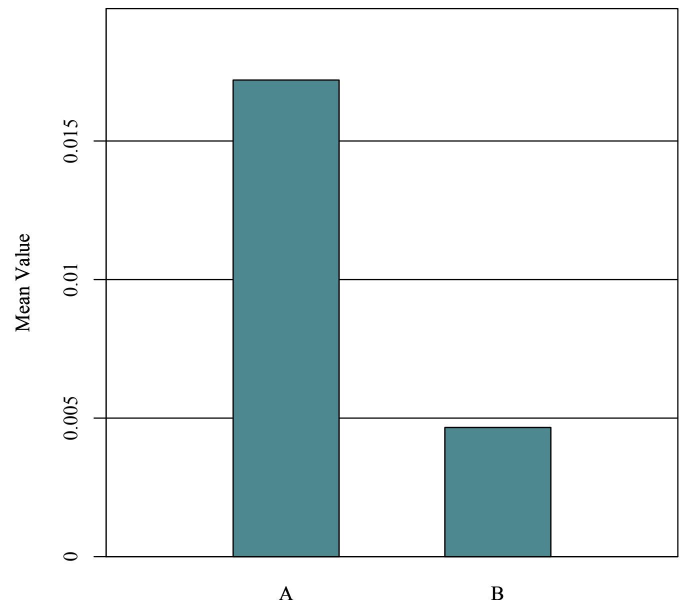

Fig. 6. The means of clinorotated (A) and 1g (B) growth rates of wheat seedling

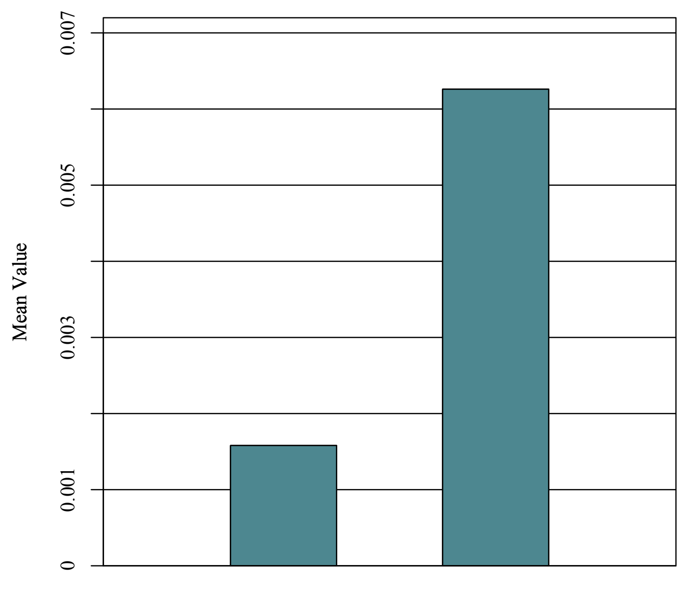

Fig. 7. The means of clinorotated (A) and 1g (B) growth rates

4. CONCLUSION

It was observed that the length of the roots of 1g and clinorotated wheat seedlings increases with time but the average growth rate of clinorotated roots is more than 1g roots, this shows the importance of the clinostat as a device that helps in the cancelation of the gravity vector while gravity has a great effect on the growth rate of 1g seeds. In guinea corn seedlings, the roots length show a slight increase in clinorotated samples while there is a considerable increase in the root lengths in 1g sample and the growth rate of guinea corn seeds exceed that of the wheat and it can be inferred that gravity play a major role in the growth of guinea corn.

The result of the paired samples *t*-test on the on the length of wheat seedlings was significant, suggesting that the true difference in the means of Clinorotated and 1g was significantly different from zero while the growth rate of both wheat and guinea corn seedlings was not significant, suggesting that the true difference in the means of Clinorotated and 1g growth rate was not significantly different from zero.

Therefore, it can be concluded that wheat germinated faster than guinea corn in simulated microgravity.

5. RECOMMENDATION

Government of Nigeria should provide financial assistance/grant to institution to promote further research on the effect of microgravity on food security as this will promote the cultivation of foods in outer space for the upkeep of the Astronauts instead of carrying food along with them while on a space mission.

This research has been found to be more interesting but the question that arises and needs to be answered is 'can microgravity environments support the cultivation of plants up to the stage of fruits bearing?' Further research is recommended in this area."

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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