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Research Paper

Early Growth Performances of Different Cultivars of *Triticum aestivum* L. (Wheat) as Influenced by Microgravity Condition

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ABSTRACT

Wheat production had contributed to the world agriculture and increased resilience of global food system against food insecurity. Following the trend of increase in global human population, space biology is an aspect of science that deals with survival of mankind in space. The research was conducted to study the influence of microgravity on growth rate and root curvature of Nigerian wheat cultivars Seri M82, Norman Bourgluk 2008 and Atila. The seedlings of each cultivar were set on a one-axis clinostat at the speed of 20 rpm for 3 h following standard methods. Positive gravitropism of the wheat cultivars Seri M82, Norman Bourgluk 2008 and Atila were maintained under microgravity. Hence, growth of wheat cultivars was faster under mirogravity than the normal gravity condition. However, wheat cultivar Seri M82 grows faster than the other cultivars. These emphasized the fact that growth of wheat is enhanced in microgravity condition which may result in higher growth and yield than the normal gravity condition.

Key words: Wheat cultivars, gravitropism, microgravity, one axis clinostat.

INTRODUCTION

Wheat (*Triticum* aestivum) family Poaceae is a world most widely cultivated food crop. It is the second important staple cereal food. Wheat contains more protein [8 to 15% (grain), 8 to 13% (flour)] than other cereals (Gooding, 2009). Besides their significance in nutrition, wheat straw is a good source of feed for livestock. Adverse changes in global climate especially in parts of sub-Saharan Africa are spreading fast beyond limitation. Similarly, overuses of renewable sources are growing faster due to increase in demand from growing populations (Zimmer et al., 2003; ACB, 2009). Population growth is leading to increasing demands for food and hence claiming more land for food production. This process has thrown many developing countries into a poverty trap characterized by expansion of agriculture into marginal lands, land degradation and declining yield (de Bie et al., 2008). Nations interested in prolong space voyage has triggered the cultivation of plants in space environment because there are needs to secure higher productivity of food crops and survival of mankind in space.

In recent time, various experiments are performed to investigate plant growth and root curvature in microgravity condition using microgravity platforms such as International space station (NASA, 1997). In order to understand plants static gravistimulation and responses, various mechanisms were employed to simulate microgravity condition. Microgravity condition in this case is one in which the apparent weight of a plant root and shoot is drastically reduced as compared to its actual weight due to gravity when subjected to clinorotation. As interest and opportunities for prolong space flight became available, microgravity research in plants also grew in importance (UNOOSA, 2013) especially in preparation for missions to Mars. Clinostat has been proven to be an invaluable tool in the understanding of plants response to gravistimulation (Moore and Cogoli, 1996).

Plants contain specific cells (called statocytes) responsible for sensing gravity (Kiss, 2000; Saito et al., 2005). In flowering plants, the gravitropic response mechanism is localized primarily in two tissue types. In roots, specialized gravity sensing cells reside in the columella of the root cap, whereas evidences show that plant shoots sense gravity through endodermal cells (MacCleery and Kiss, 1999). These two specialized tissues are responsible for sensing the direction of the gravity vector and transmitting the information to other parts of the plant for responses. The alteration of gravity was identified as important in modulating the activity of meristematic cells and some of the results obtained in space experiments have shown that cell proliferation parameters are modified in plants grown in space (Medina and Herranz, 2010; Barmicheva et al., 1989; Matía et al., 2010)). Therefore, it is evident that microgravity induces some distresses in plant development (Ana et al., 2012).

The effects of altered gravity on plant development have also been discovered in plant seedlings grown in microgravity simulators in earlier researches. Similarly, decoupling of cell proliferation and growth in the meristems was observed in both real and simulated (RPM) microgravity conditions (Matía et al., 2010). The growth rates of various plant organs were also investigated in space and it was discovered that some external environmental factors such as temperature, light, water, gaseous parameters and sample storage conditions must be held constant in order to make the effects of mircrogravity pronounced (Hoson and Soga, 2003). Light causes similar changes in cell wall properties as gravity thereby acting as a substitute for gravity in growth regulation (Hoson, 1999). Therefore, this study was aimed at evaluating the growth rate and orientation of the root curvature of three Nigerian cultivars of wheat (*T. aestivum*) under simulated microgravity condition using one axis clinostat.

MATERIALS AND METHODS

Collection of seeds

Seeds of three Nigerian cultivars of *T. aestivum* (wheat) were used for this study. Wheat plants are suitable plants for this research since they possess short germination period, easy to handle and are fast growing. The seeds were collected from the Lake Chad Research Institute, Maiduguri, Borno State, Nigeria. The names of the varieties are Seri M82, Norman bourgluk 2008 and Atila.

Germination of seeds

The seeds of each cultivar were sown inside Petri dishes each containing 10 ml of 1.5% Duchefa Biochemie plant Agar-Agar. The Agar-Agar was prepared according to standard method (UNOOSA, 2013). Vertical lines were drawn on the top of each Petri dish to indicate the direction of the gravity vector. Then, the petri dishes were placed in vertical positions parallel to the gravity vector. A wet chamber was prepared in a plastic box with a size of 40 cm × 40 cm with a humidity of about 60 to 100%. After 20 to 30 h, the petri dishes with short roots of about 1 cm were separated into three classes. One which is rotated through 90°, one left in the normal position towards gravity (1 g) and one mounted on the one-axis clinostat. The clinostat was set at the speed of 20 rpm for 3 h and the pictures of the petri dishes taken at every 30 min using a good digital camera.

Root curvature and growth rate analysis

The root curvatures of the 90° turned and clinorotated roots were measured using an open-source image-processing application called imajeJ software. Out of the nine seedlings in each petri dish, three uniformly germinated ones were selected for measurement and analysis. The pictures containing roots to be measured were opened using the software and an angle measurement tool used to measure the curvature angles at each time point that is, every 30 min for 3 h. The angle measurement tool was placed at the middle of the root tip and followed along the root until the curvature begins. A click was made and followed with a second line parallel to the upper root part. After obtaining the curvature angle of the roots, the real curvature angle was calculated by subtracting the measured angle from 180°. The curvature angles of both 90° turned and clinorotated roots of each cultivars of wheat were then compared. Each result represents an average of three replicates.

To determine the growth rates of the three cultivars, the pictures of 1 g control and clinorotated were used for analysis. Their lengths were measured using length measurement tool in the application and used to calculate the respective growth rate. The length measurement tool was placed at the initial measurement point and then dragged to the end measurement point on each root. Just like in the curvature angle, the root length was also measured for every 30 min. Each result represents an average of three replicates. Both root curvature angles and growth rates were determined using standard methods (UNOOSA, 2013).

RESULTS

The early growth of the root curvature angle of Seri M82, Norman bourgluk 2008 and Atila rotated at 90° were significantly higher than the ones subjected to microgravity (Figure 1). The growth rates of wheat cultivar Seri M82 and Atila were higher under clinostat as compared to normal gravity conditions (1 g). Norman

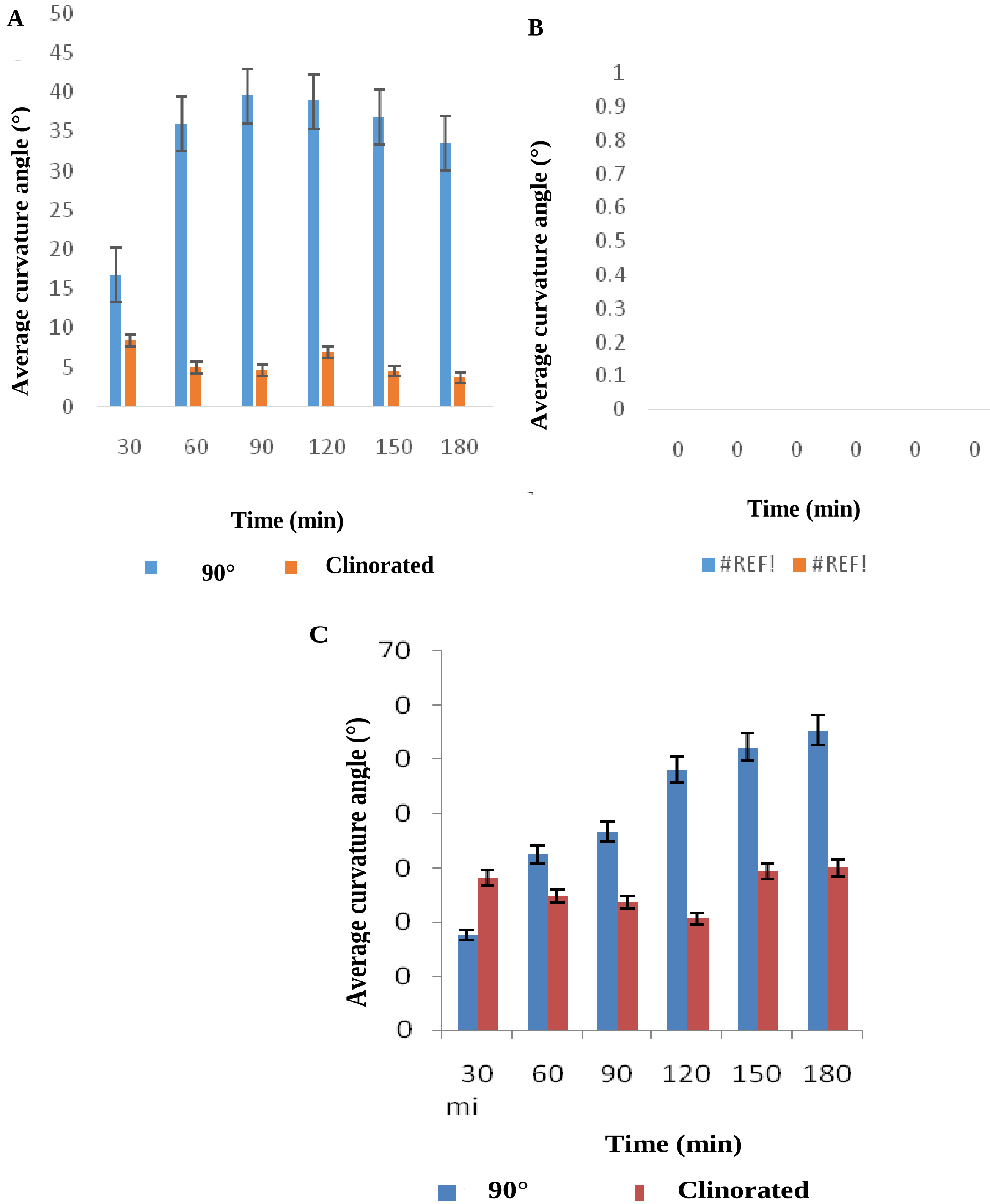

Figure 1. Root curvature angle of wheat cultivar; (a) Seri M82; (b) Norman Bourgluk, 2008 and (c) Atila.

bourgluk 2008 showed no significant difference in growth rate under clinostat and normal gravity condition (1 g) (Figure 2). The growth rate of clinorotated Seri M82 and Norman bourgluk 2008 increased with time though, growth rate of Seri M82 (33.43 mm/min) was higher than Atila (29.99 mm/min) and Norman bourgluk 2008 (24.02 mm/min) after 3 h of study (Figure 2).

DISCUSSION

The root of Seri M82, Norman bourgluk 2008 and Atila had a greater angle of curvature as a result of change in the orientation (90°) which made the root to bend towards the direction of gravity. This agrees with the report of Pickard (1973) that a plant is expected to react to gravity if the

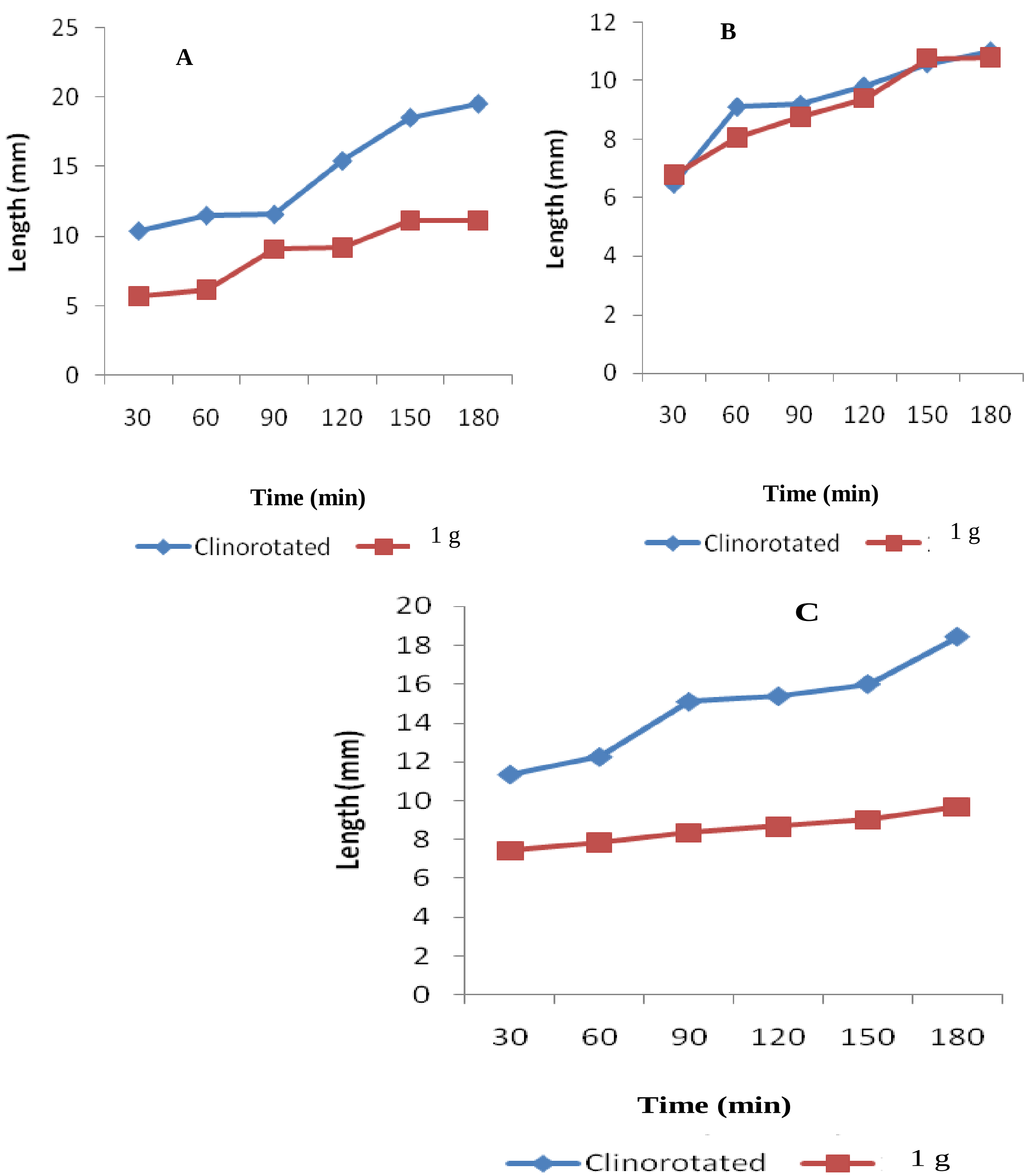

Figure 2. Root growth rate of wheat cultivar (a) Seri M82; (b) Norman Bourgluk, 2008 and (c) Atila under normal gravity and microgravity conditions.

gravistimulation is maintained for longer than a critical amount of time, called the minimal presentation time (MPT) which lies somewhere between 10 and 200 s. On the contrary, downward root growth (positive geotropism) of Seri M82, Norman bourgluk 2008 and Atila towards direction of gravity was not disrupted by the clinostat that is, the positive gravitropism of the root was maintained. This may be due to the fact that the roots could not sense any direction of gravity due to the clinorotation thereby maintaining the original orientation. This is an evidence that clinorotation confused the wheat roots and created simulated microgravity conditions for them that is, they showed no response to gravity (UNOOSA, 2013).

Root curvature of the wheat cultivars studied behaved almost the same way (that is, no definite pattern across the given time) under microgravity. This agrees with the result of Hoson (1994) who reported that clinorotated roots shows automorphic curvature which occurs in random directions without any dorsiventrality. Microgravity affected the settling of statoliths, a specialized form of amyloplast involved in graviperception by plant roots. In

90° turned roots, statoliths settled by gravity to the bottom of cells in the root regulated and redistributed by movement of the plant hormone auxin known as polar auxin transporter.

The result of growth rates observed for cultivars Seri M82 and Atila and Norman bourgluk 2008 is similar to earlier reports by Hoson (2014) indicating that elongation growth of the shoot organs and roots are stimulated under true microgravity conditions in space. This also agrees with Hilaire et al. (1996) who observed an increased growth rate of primary and lateral roots and an earlier initiation of secondary roots in some seedlings grown in microgravity simulators leading to an increase in biomass. Since the growth rate of clinorotated Seri M82 increased with time and higher than the others, it can be said that wheat cultivar Seri M82 grew faster than the other cultivars on simulated microgravity. This may be as a result of cell wall loosening in the roots according to the report of Hoson (2014) that stimulation of elongation growth in space was attributed to cell wall loosening, which is brought about by diverse changes in the metabolic turn-over of cell wall constituents (Hoson, 2014). This implies that Seri M82 may grow to maturity and reproduce faster than other cultivars in space environment.

Conclusively, these results showed that growth of wheat cultivars on microgravity was higher than the normal gravity condition. Hence, wheat plants still grew toward positive gravitropism. The authors hereby recommended that the wheat cultivars be exposed to long hours of clinorotation and different speed of clinostat to further understand the influences.

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