Preliminary Investigation on the Effect of Centrifugal Force on Germination and Early Growth of Maize (*Zea mays* L.)

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ABSTRACT This study aimed to investigate the effect of centrifugal force on the growth of maize, an important cereal crop in Nigeria. The maize seeds were subjected to centrifugation for three revolutions (1000g, 5000g, and 10000g) for 2, 4 and 6 hours. The seeds were planted and observed for germination and early growth for seven days. Results revealed that seeds treated with 1000g centrifugal force for 4hrs had the highest germination percentage (70%), while 50% of the control seeds germinated at the end of the 7th day. The radicle length in the 10,000g/2hrs treatment was also the highest (24 cm). However, the highest shoot length was observed in the control plants. This showed that though centrifugal force triggered a rapid and higher germination rate in the treated maize plants, it still did not result in higher shoot length in those plants. The experiment should be extended until the yield or maturity stage in order to have more profound observation on this centrifugal force effect on the maize plants.

KEYWORDS: Centrifugal; germination; hypergravity; maize; mutant
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INTRODUCTION

Centrifugal force has been known to affect the physiology, morphology, differentiation and other metabolic activities in biological systems (Boonsirichai *et al.*, 2002; Strohm *et al.*, 2014; Sugimoto *et al.*, 2014). The centrifugal force can be generated in microgravity condition, which means the condition of weightlessness and zero-gravity. This shows that the gravitational force is minimized, but not completely eradicated. Several kinds of researches have been carried out with microgravity simulators such as clinostat or centrifuges (Herranz *et al.*, 2013). Knowledge of the mechanisms of growth and other metabolic activities of plants under the influence of centrifugal force is very necessary when preparing for other planets such as Mars. Plants can discover and respond to the direction of gravity through the possession of some special organelles called statoliths (Chebli *et al.*, 2013).

Many researchers have based their studies on understanding the effects of hypergravity on cell rigidity, signal perception, and resistance of cells. But, very few have focused on the possible influence this centrifugal force, as a mechanical stressor can have on the growth of plants (Jost *et al.*, 2015). The effect of centrifugal force as a stressor in a plant is usually first noticed during germination, and it reduces the growth of some plants such as *Oryza sativa* and *Zea mays* (Kordyum, 2014; Matía *et al.*, 2010; Vandenbrink & Kiss, 2016). The shorter periods (few hours) exposures of plant cells to centrifugal force has been reported to produce oxidative stress which leads to the formation of reactive oxygen species (ROS) (Carman *et al.*, 2015; Xiong & Sheen, 2014).

However, plants are known to overcome this oxidative stress and acclimatized to the condition after being exposed for a long time (many days) to centrifugal force (Hausmann *et al.*, 2014). Maize is a very important cereal crop especially around the savannah region in Nigeria. It is the most important cereal crop after sorghum and millet. Propagated from seeds, there are many cultivars varying in grain size, shape color, maturity rates and resistance to pests and diseases. Modern varieties have upright leaves that help the plant to capture sunlight energy under crowded conditions (Olaniyan & Lucas, 2004). The aim of this research is to investigate the effect of centrifugal force on the germination and early growth of maize.

METHODOLOGY

Study Area

This research work was carried out at the Biological laboratory of American University of Nigeria and agricultural garden of the Federal College of Education (FCE), Yola, Adamawa State, Nigeria. Yola South local government area falls within the Sudan savannah belt of Nigeria vegetation zone. The vegetation is made up of grasses, valleys and dry land weed interspaced by scrubs and woody plants. Grasses collectively make up about 70% of the entire vegetation. The temperature is relatively hot throughout the year. The average annual rainfall ranges between 700 mm to 1000 mm.

Sample Collection and Treatment

The seeds of maize (Samaru yellow maize) were bought from Jimeta Modern Market, Yola. The seeds were tested for viability by using the flotation method. The viable seeds were thereafter removed and sundried. The seeds were centrifuged at three different revolutions (1000g, 5000g, and 10000g). Three different hours were used for each treatment (2, 4 and 6 hours).

Field Experiment

The land to be used was properly cleared and well irrigated. Two plots were used, both having a size of 3 m^2. The experimental design was complete randomized block design with three replicates. The plots were watered twice daily (morning and Evening). There were nine different treatments with control, each having three (3) replicates. Five seeds of maize were planted in each replicate thereby making 15 seeds per each treatment. The treatments include the followings; 1000g (2hours) was denoted by A1, A2, A3; 1000g (4hours) was denoted by B1, B2, B3; 1000g (6hours) was denoted by C1, C2, C3; 5000g (2hours) was denoted by D1, D2, D3; 5000g (4hours) was denoted by E1, E2, E3; 5000g (6hours) was denoted by F1, F2, F3; 10000g (2hours) was denoted by G1, G2, G3; 10000g (4hours) was denoted by H1, H2, H3; 10000g (6hours) was denoted by I1, I2, I3; control.

The following preliminary growth parameters were determined: germination rate, shoot length (seeding height), stem diameter (girth). Measurements of plant height and stem diameter were taken daily starting from the first day after germination. Data were subjected to analysis of variance to determine the difference between the treatment means at $P \leq 0.05$ for each parameter measured.

RESULT AND DISCUSSION

The effect of centrifugal force treatment on the germination percentage of the maize plant is shown in Figure 1. Twenty percent (20%) of the seeds sown in the 1000g/2hrs treatment germinated immediately after the first day, compared with 10000g/6hrs, 5000g/2hrs treatment and 5000g/4hrs which had 0% and 10% germination respectively. However, at the end of the first day, only 4000g/4hrs treatment produced 40% germination among the treatments. At the seventh day after germination, the highest percent germination was obtained in the 1000g/4hrs (70%) as against 1000g/2hrs treatment which was 40% only. Fifty percent (50%) of the control germinated at the end of the 7^{th} day. The results show that higher centrifugation forces have no negative effect on the germination of the maize seeds, except for the lowest force where germination rate was very low when compared with control. This agrees with Waldron and Brett (1990) who observed that seeds of *Pisum sativum* subjected to increasing centrifugation were able to germinate successfully compared with control. Seeds of *Phaseolus vulgaris* subjected to clinorotation also germinated faster and better than those of the control (Aronne *et al.*, 2003). The germination and growth of some wheat cultivars subjected to clinorotation were also observed to increase than the control ones (Akomolafe *et al.*, 2016). The reverse was observed in the germination of tomato seeds which was higher under normal gravity than under clinorotation (Akomolafe *et al.*, 2017).

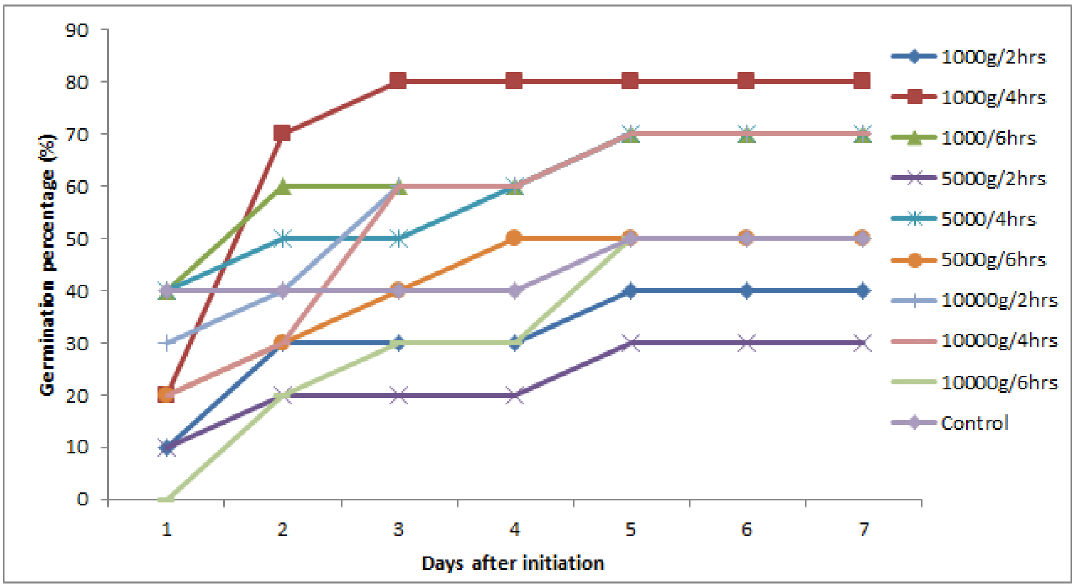

Figure 1. Effects of centrifugal force on the germination percentage of the maize plant

From Figure 2, it can be seen that the radicle length on the 7th day ranged from 7.0 cm in 1000g/4hrs treatment to 24 cm in the 10,000g/2hrs treatment. This is contrary to that of *Pisum sativum* where the radicle lengths of the plants subjected to high centrifugation force were lower compared with the ones subjected to lower force (Waldron & Brett, 1990).

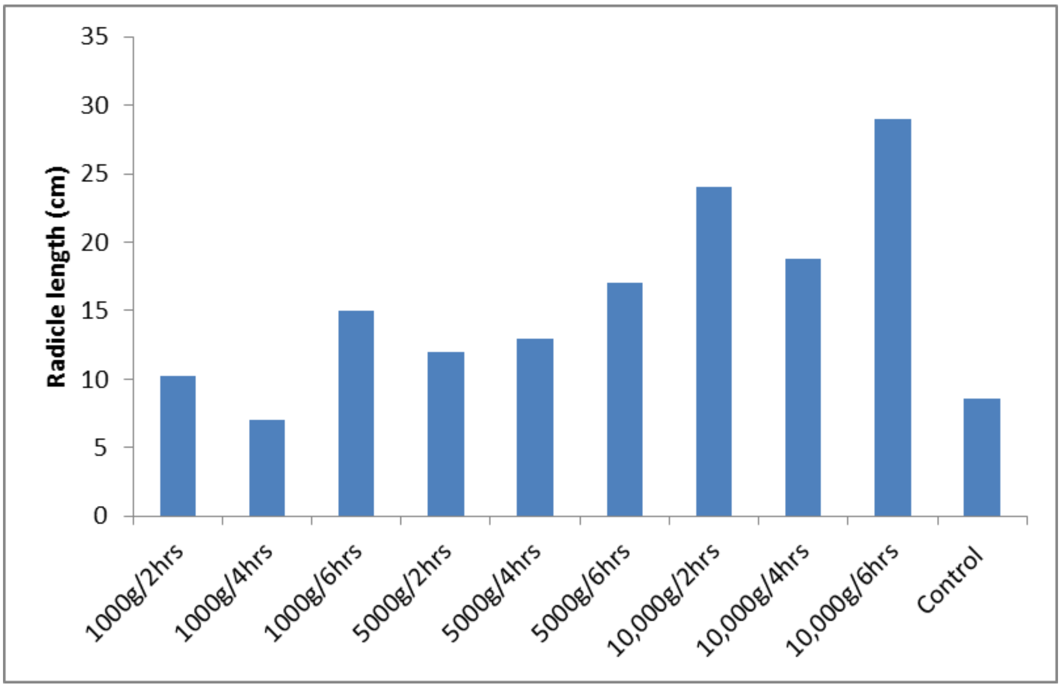

Figure 2. Effects of centrifugal force treatment on the radicle length

The shoot length at the 7th day of germination initiation ranged from 8.9 cm in 5000g/4hrs treatment to 17.8 cm in the control (Figure 3). The increasing shoot length observed in the control as compared with other plants subjected to centrifugation buttressed the report on *Camellia japonica* where the growth rate of the plant under hypergravity condition was low compared with the control plant which had higher growth rate (Chebli *et al.*, 2013). This observation could be as a result of the abiotic stress created by the hypergravity forces on the plants, thereby reducing the growth rates. As reported by Carman *et al.* (2015) that short time exposures of plants to centrifugal forces usually triggered production of reactive oxygen species which eventually affect the metabolic processes in plants.

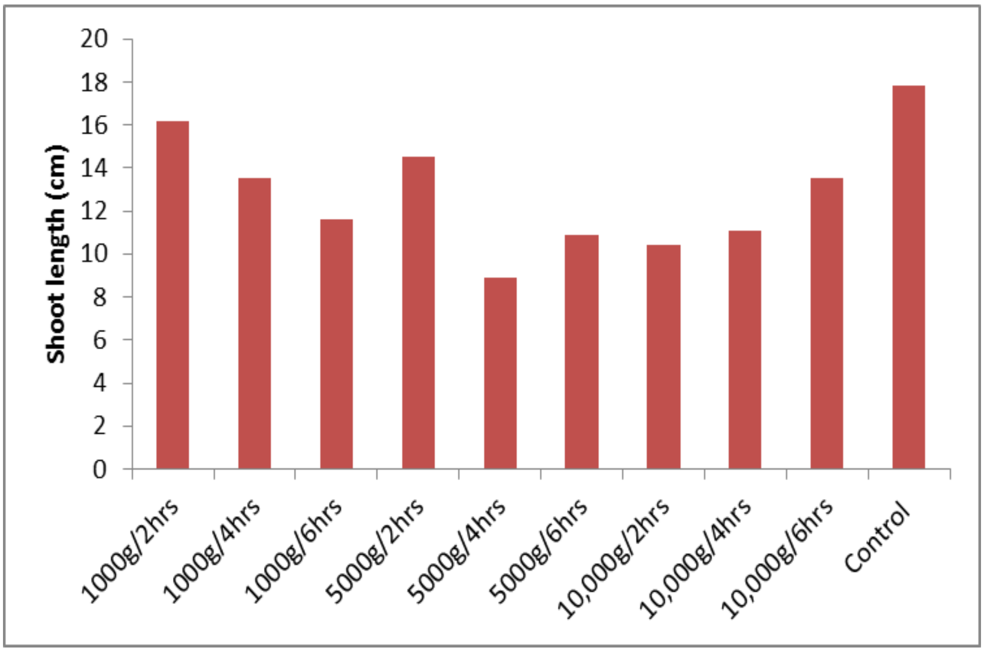

Figure 3. Effects of centrifugal force treatment on the shoot length

As for the stem girth (Figure 4), 5000g/4hrs still had the lowest (0.9 cm) while the control plants had the highest (1.8 cm). This can also be linked to the effect of oxidative stress in the maize plants caused by the centrifugal forces.

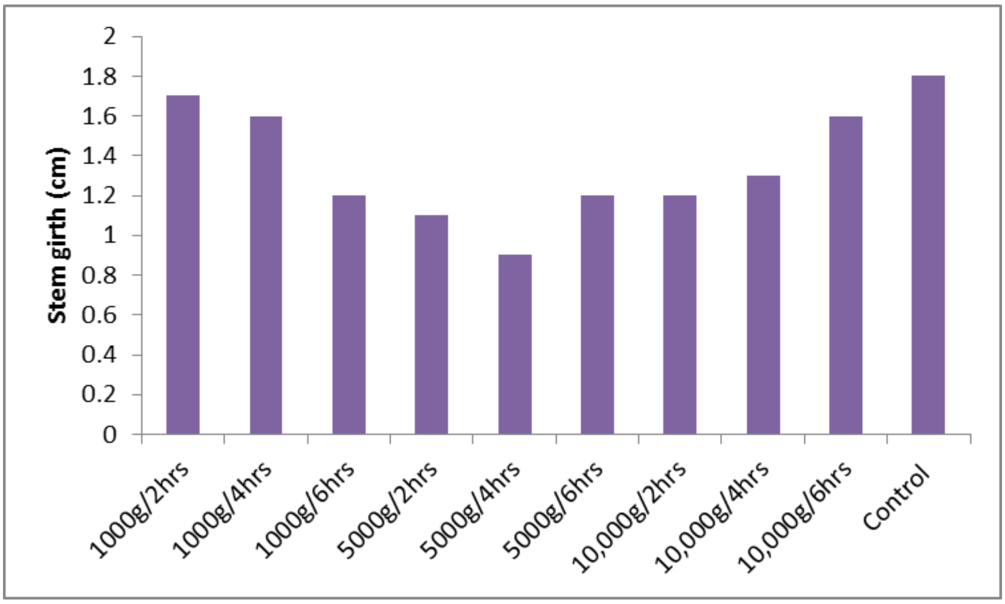

Figure 4. Effects of centrifugal force treatment on the stem girth

CONCLUSION

It can be concluded that the higher centrifugal force stimulated better and faster germination in maize compared with the control ones. However, the centrifugal force did not contribute to an increasing growth rate of the maize plants. It could be possible to have a different observation in the growth rate of the maize seedlings if the experiment was observed till yield period, hence our recommendation for further research.

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