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FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCE

DEPARTMENT OF CROP SCIENCE

The effects of sprouting agents and environmental conditions on the sprouting of potatoes (*Solannum tuberosum*).

by

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A research project submitted in partial fulfilment of the requirements of a Bachelor of Agricultural Science Honours Degree (Crop Science).

DECLARATION BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENT SCIENCE

The undersigned certify that they have read and recommended to the Department of Crop Science, this thesis entitled:

The effects of sprouting agents and environmental conditions on the sprouting of potatoes (Solannum tuberosum).

Supervisor……..

Date……..

Project coordinator ……...

Date……

Chairperson ……

Date……..

ABSTRACT

Irish potato production in Zimbabwe is low under smallholder farming sector due to high cost of synthetic plant growth regulators. The main aim of this study was to assess a natural organic bio-stimulant that is effective and able to be used in future as a plant growth regulator among other synthetic plant regulators. This was done by examining the effect of giberellic acid, calcium carbide, aloe vera and environment in a four-week period. The findings were obtained by measuring sprouts length, diameter, sprouting percentage and number of sprouts per tuber in a complete randomized design with a 2x4 factorial arrangement. The trial had 4 treatments in continuous darkness and 4 in diffuse day light environment. It was replicated twice to make a total of 16 treatments for both light and darkness. Data was collected in the second and fourth week. Under continuous dark conditions, giberellic acid, aloe vera, calcium carbide and control recorded 90%, 65%, 45% and 8% sprouting percentage respectively. Sprout lengths were 10.5mm, 4.3mm, 5.5mm, and 0.36mm respectively. Under diffuse light conditions, the results were 20%, 25%, 5% and 0% respectively. Sprouts length in dissenting order of giberellic acid, aloe vera, calcium carbide and control under diffuse light conditions were 3.3mm, 1mm, 0.5mm and 0,5mm respectively. Among these, aloe vera data was statistically significant with p-value of ($p<0.05$). The results were analysed using Genstat 18th Edition for analysis of variance (ANOVA). From the data collected, there were significant differences ($P<0.05$) in different sprouting agents and environment on potato sprouting. The interaction of factors on sprouting percentage, (A and B) was ($P<0.05$) meaning that the interaction of sprouting agents and environment was statistically significant.

Keywords: Irish potato, sprouting agent, smallholder farmer, bio-stimulant, dormancy, growth regulators, factorial arrangement.

DEDICATION

I would like to dedicate this project to my wife Memory Tinapi and my mother. These people have been supportive throughout my degree program. Above all, the praise goes to the almighty God whose name is Jehovah.

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CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the study

Globally, potato demand is on the rise due to its nutritional value and many uses in the food processing industries. In Zimbabwe, there has been a significant exponential increase in potato production from 52 000 tonnes in 2010 to 534 543 tonnes in 2022 season according to Herald Zimpaper report (The Herald, 2023). Statistics from Zimbabwe National Statistics Agency (ZimStats, 2023) show that fresh or chilled potato imports increased 392 percent from US$2,6 million in 2019 to US$12,9 million in 2022 (The Herald, 2023). However, by looking at percentage of imports, the increase in production from the said years is not sufficient to meet local demand as well as global contribution to food and nutrition security. This is a result of low adoption of potato production by most smallholder farmers who are resource constrained and afraid of using modern plant regulators in fear of unknown health consequences (Mukasa et al, 2017).

The main challenges facing most communal smallholder farmers are poor yields due to lack of finance, poor sprouting techniques and many other factors (Mukasa et al, 2017). The issues such as unavailability and inaccessibility of the synthetic sprouting agents in smallholder farming communities, has been a menace, hence it is crucial to proffer a solution to these challenges with innovative researches. Furthermore, it is very important to increase adoption and production of potatoes by smallholders despite financial constraints. This should be aimed both at national and global level.

Recent studies by Alkuwayti et al, (2022) have revealed that the aloe vera can be used safely and has the potentially to act as substitute for synthetic plant growth regulators in sustainable agriculture. This is because of several potentially active chemical constituents of which the main important ones that gives it the potential to be used as sprouting agents are notably the, IAA, a group of Auxins. Alkuwayti et al, (2022) have reported that auxins are found in aloe vera leaf extracts (ALE) at the concentration of (0.63 mg/100 g) and can enhance cell elongation and the

stem growth. Meanwhile, gibberellins at (16 mg/100 g) enhances plant height. Substituting synthetic agro chemicals with organic biochemical sources is now the main focus of most companies, both at national and global level to avert health problems and side effects caused by use of synthetic agrochemicals in the long run.

Giberellic acid, a commercial plant hormone, has been widely studied for its ability to promote plant growth and development. According to Algul et al, (2016) when applied to potatoes, it is believed to enhance the sprouting process by stimulating cell elongation and division in the tuber but its use has been limited due to its expensiveness and strong health side effects (Santa, 2009). On the other hand, aloe vera, a succulent plant known for its medicinal properties, has been suggested to have a contribution to roots and shoot initiation effects on dragon fruit plant (Ahamad et al, 2016). This can be a major background and a reason for trying it on the sprouting of potatoes due to its chemical properties like auxins and gibberellins. Calcium carbide which was banned in the past was oftenly used as a ripening agent for fruits. It has also been found to influence sprouting by releasing ethylene gas (Maman, 2022). This gas can either promote or delay the sprouting process depending on the concentration used.

In addition to the sprouting agents, environmental conditions also play a crucial role in the sprouting process. Darkness is known to be a favorable condition for sprouting, as it promotes the accumulation of carbohydrates, which are required for the growth of sprouts (Kabira and Lemaga, 2003). On the other hand, exposure to light has been found to inhibit sprouting by reducing the carbohydrate content and inducing a phenomenon known as greening in potatoes (CIP, 1997). However, issues on whether light or dark environmental condition would initiate sprouting is still under debate (SimplySeed, 2023). Understanding the interactions between sprouting agents and environmental conditions is of utmost importance in the agriculture industry. By examining the effects of sprouting agents and environment on potato sprouting, there is a possibility of gaining valuable insights into improving potato dormancy breaking methods and enhancing crop yields.

1.2 Problem Statement

Aloe vera is a readily available alternative to synthetic sprouting hormones, however its effectiveness has not been well explored hence the need to assess its viability compared to generally used synthetic hormones like Giberrelic Acid and Calcium Carbide.

1.3 Justification

Since the study of sprouting agents and environment effects on potato production enhances productivity in Zimbabwe agriculture system, the justification for this study lies in its agricultural significance, economic implications, environment and waste reduction, and scientific curiosity. The agricultural significance involves the importance of helping farmers, especially the smallholder sector and agricultural researchers to optimize the sprouting and yield of potato crops. This knowledge can be used to develop better storage and handling techniques, which are crucial for food security and sustainable farming practices. It is also going to improve local knowledge system base which will boost commercial production of bio stimulants and increased potato production country wide as well as promotion of export marketing. In addition, there are economic importance such as increase in production and demand for bio-stimulants such as aloe vera leaf extracts which will lead to growth in agriculture industry and bio- chemical industry as well as employment creation. The social aspect cannot be ignored. This involves enhancement of local and global food security, diverse source of carbohydrates for a well-balanced diet to eliminate poverty. This will bring out a product that is user friendly, less expensive in terms of cost, reduces production cost and improve adoption by smallholder farmers and change their lives.

Furthermore, it is crucial to safeguard the environmental by reduction of waste. Curbing ecological damage that is as a result of chemicals that pollute environment and affect living organisms is very important. Due to widespread demand of harmless agriculture chemical products, the project can be an asset in research and promotion for the use of bio-stimulants organic compounds in the breaking of dormancy in potatoes.

1.4.0 Objectives

1.4.1 Main objective

To determine the effects of giberellic acid, calcium carbide as well as aloe vera leaf extracts in the sprouting of potatoes under the influence of light and dark environmental conditions by the end of the experiment.

1.4.2 Specific objectives

- To measure the length and diameter of the shoots from the second week after treatment until the fourth week.
- To determine the average number of sprouts per tuber per treatment and sprouting percentage at the end of the fourth week.
- To compare the number of days to maximum sprouting in all treatment levels by the end of the experiment.

1.5 Hypothesis

H_1: Sprouting agents and environment have an effect on sprouts length and diameter.

H_1: Sprouting agents and environment have an effect on the number of sprouts per tuber.

H_1: Sprouting agents and environment have an effect on sprouting percentage.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Global trend of potato production.

According to the FAO data, a total of 376 million tonnes of potatoes were produced worldwide, with China (94 million tonnes) and India (54 million tonnes) being the largest potato producing countries in 2021. FAO figures indicate that the total area harvested globally in 2021 was 18,132,694 hectares, a world average of about 21 tonnes per hectare (FaoStat, 2023). The leading countries in top 5 include:

Table 1. Global trend of potato production.

1. China	94,362,175t/ha
2. India	54,230,000
3. Ukraine	21,356,320
4. USA	18,582,370
5. Russian Federation	18,295,535

Source: (FaoStat, 2023).

2.2 Potato Production in Zimbabwe

In Zimbabwe, there has been a significant exponential increase in potato production from 52 000 tonnes in 2010 to 534 543 tonnes in 2022 season but the result is mainly by large scale commercial farmers. Statistics from Zimbabwe National Statistics Agency (ZimStats, 2023) show that fresh or chilled potato imports increased 392 percent from US$2,6 million in 2019 to US$12,9 million in 2022 (The Herald, 2023). However, by looking at percentage of imports, the increase in production from the said years is not sufficient to meet local demand as well as global contribution to food and nutrition security. This is a result of low adoption of potato production by most smallholder farmers who are resource constrained. Most challenges are poor yields due to poor seed tuber sprouting as a result of many underlying factors. This is the reason why this study is necessary to focus on the investigation into the effects of sprouting agents that are synthetic (giberellic acid, calcium carbide) as well as those that are derived from organic

compounds (Aloe vera leaf extracts). This is going to lessen the burden of financial constraints affecting smallholder farmer to adoption production.

2.3 The effects of giberellic acid on breaking dormancy in potatoes.

Holmes et al, (1970) reported that giberellic acid treatment immediately after harvesting reduced the duration of tuber dormancy by 38-42 days. These authors indicated that giberellic acid is involved in breakage of dormancy and growth stimulation. In addition, Alexopoulos et al, (2006) found that post-harvest application of giberellic acid to tubers grown from seed potatoes promotes the breaking of dormancy. Coleman (1987) also explained that exogenous giberellic acid generally terminate dormancy in potatoes and may play important roles as endogenous regulators of bud dormancy and development. Uncut tubers which were dipped in a solution of 16 ml gibberellic acid per 100 l water for 2 mins proved to be successful from previous researches. It is supposed to be harmless to humans.

But, in recent research on lab rats there was a decrease in sperm count and fertility rates over prolonged exposure (Armelle, 2014). This material can cause eye irritation and damage in some persons. The persons who have respiratory system that is impaired, conditions such as emphysema or chronic bronchitis and airway diseases, were observed to end up with problems like disability if excessive concentrations of particulate are inhaled (Santa Cruz, 2009). These health problems can be alternatively addressed by use of organic derived compounds that can be extracted in the aloe vera plant for the breaking of dormancy in potatoes. This necessitates the research in order to come up with a sprouting agent that is ecological friendly and cost effective to smallholder potato farmers.

2.4 The effects of calcium carbide on potato sprouting (breaking dormancy) and associated health issues that led to its ban.

The second exogenous growth promoter is the calcium carbide. Once dissolved in water, the carbide produces acetylene gas. Calcium carbide is rich source of acetylene (nitrification inhibitor) and ethylene (plant hormone). Ethylene is a unique plant growth regulator that is involved in almost all the phases of plant growth and development, which ranges from seed germination to organs senescence in potato (Coleman, 1987). The use of ethylene as an exogenous application has been reported to increase the agricultural production through plant

growth improvement (Dogonadze *et al*, 2000). Better performance of calcium carbide treatments for tuber sprouting percentage might be due to the dual effects of ethylene produced from calcium carbide which increased the respiration rate resulting in the breakdown of dormancy in potato tuber (Daniels-Lake et al., 2005b) as well as by reducing the concentration of sprout inhibiting hormone (ABA) produced in dormant potato (Lei. 2023). Acetyline at a rate of 0.1 % of acetylene gas in an airtight room between 21 to 27 ^{0}C was found to initiate sprouting. A quantity of 30 g of calcium carbide will generate sufficient gas for 2 m^3 for heaped potatoes. Immersing the tubers in an acetylene solution for 4-6 hours results in sprouting and the mixture should be 45 litres of water to 230 g of calcium carbide added slowly.

Calcium carbide was also favored by most farmers for fruit ripening but its usage rate has decreased due to some common toxic issues and generally, it was banned in some countries. In terms of health effects, the acetylene gas released from the CaC_2 reaction contains phosphine at a concentration of 95 ppm (Bingham et al, 2001) and this concentration exceeds the life and health value that was set by NIOSH which is 50 ppm (National Institute of Occupational Safety and Health, 2003). Generally, acetylene gas is not considered to be a major contributor to a serious toxic hazard to human but the association of the impurities, like phosphine contained in it causes health problems (Public Health England, 2009) especially to pulmonary system and cardiovascular system (Agency for Toxic Substances and Disease Registry, 2002). The inhalation of phosphine by farmers was found to cause cough, chess tightness and may lead to lung damage (Agency for Toxic Substances and Disease Registry, 2002). Also, an excessive exposure may cause pulmonary edema (New Jersey Department of Health, 2013). These researched results show that there is need to make more researches in to sprouting agents that are environmentally friendly and poses no threat to human and animal health issues. However, a cost benefit analysis needs to be weighed efficiently in order to come up with a sprouting agent that fit for all conditions, reduced toxicity and usable by the smallholder farmers. This was the reason why the aloe vera plant was included in the research in order to run away from these negative issues.

2.5 The aloe vera and its associated benefits in breaking dormancy in potato tubers.

The third and natural exogenous growth promoter is the aloe vera leaf extract. The botanical name of Aloe vera is *Aloe barbadensis*. It belongs to Asphodelaceae (Liliaceae) family, and is a shrubby or arborescent, perennial, xerophytic, succulent, pea-green color plant. The aloe plant has long (up to 42.5 cm long and 12.5 wide), triangular, fleshy leaves that have spikes along the edges. The fresh parenchymal gel from the center of the leaf is clear; this part is sometimes dried to form aloe vera concentrate or diluted with water to create aloe juice products (Sharrif and Sandeep, 2011).

The aloe vera has several potentially active chemical constituents but the main important ones that gives it the potential to be used as sprouting agents are notably the, IAA, a group of Auxins. Alkuwayti et al, (2022) have reported that auxins which was found in aloe vera leaf extracts (ALE) at the concentration (0.63 mg/100 g) plays an important role in cell elongation and the promotion of the stem growth, while gibberellins (16 mg/100 g) enhance plant height. Also, it has several macro-elements that were found on the ALE after the analysis of its contents of the leaves. Similarly, ALE enhancement of plant growth and yield has been well documented in several plants, with ALE increasing the photosynthetic pigments and the potassium, phosphorus, and nitrogen contents in S. marianum leaves, compared with control plants (Alkuwayti et al, 2022).

In an experiment conducted by (Sujata et al, 2022) on the effect of indole-3-butyric acid (IBA) and aloe vera on the establishment of stem cuttings and to determine the best rooting and shooting substance option for better growth of cuttings of dragon fruit, the results showed that the *Aloe vera* treatment produced the highest number of shoots (2.2) and roots (9.9), similarly to the IBA treatment. The aloe vera treatment considerably increased shoots (30.35 cm) and roots (25.92 cm) length, coinciding with an increase in root (4.55 g) and shoot (102.6 g) weights compared to the other treatments. However, there were no significant differences in shoot diameter in all the treatments. It was also observed that natural substances that are locally available, such as *Aloe vera* gel, could be used as an efficient root and shoot promoting agent (Sujata et al, 2022).

Auxin which is also found in aloe vera is produced by IBA manufactured chemical and it impacts the hypocotyls and branching of shoots (Starder et al, 2011). In terms of root number, the findings revealed that treating cuttings had a considerable effect on the average number of roots per cutting. The aloe vera and IBA treatments were significantly different from the control. The aloe vera treatment had the highest average number of roots (9.9) per cutting, while the control had the lowest average number of roots (8.7). The cuttings treated with exogenous auxin performed similarly to aloe vera. There is a correlation between primordia division and endogenous or exogenous auxin in root initiation. Fathi and Ismailpor (2000) backed up this claim, claiming that auxin promotes root development in cuttings. According to El-Sherif (2017), auxin (IAA), aloe vera helps to stimulate the root in a populous plant. IBA was reported to be promising for increasing the number of roots in dragon fruit by Ahamad et al, (2016).

2.6 Environmental aspect for sprouting potatoes.

Another important aspect of this literature review is the light effects to the sprouting of potatoes in conjunction with the previously mentioned sprouting agents. Healthy green potato sprouts need light to grow properly. Potatoes that are left to sprout in the dark give off a white, unhealthy growth. The seed potatoes are pre-sprouted 2 to 3 weeks before planting in the ground (Suzie, 2017). The debate over whether seed potatoes should be placed in dark or light conditions has been ongoing for decades (SimplySeed, 2023). Use of diffused light storage (DLS) which is a low-cost storage involving storing the potatoes in thin layers on shelves or trays in natural, diffused (indirect) light with good ventilation has been developed by the International Potato Centre and accepted worldwide (CIP, 1997). A study done in Mount Kenya region indicated that 48 % of potato growing farmers were not even aware of the improved DLS for potato seed tubers (Walingo et al., 2001).

The most common method is the use of dark rooms which result in excessive sprouting, thus desprouting has to be done prior to planting (Kabira and Lemaga, 2003). This traditional method have resulted to loss in seed quality through weight loss, excessive sprouting, and pest and disease attacks. Kabira and Lemaga (2003) estimated weight loss caused by evaporation and sprouting to be 90%, and respiration 10%. Storage in DSL has been found to delay the physiological ageing of potato seed tubers, reduce apical dominance, resulting in an increased

number of stems per tuber, short and firm sprouts (Demo et al., 2004). These reported weaknesses and strengths led to the research of the existing sprouting agents along with aloe vera under the influence of the environment in order to see their combined effect to the process of breaking dormancy and enhancing sprouting in potatoes for increased production by both, particularly the smallholder farmers and followed by large scale commercial farmers.

It is also important to note that the specific effects of sprouting agents and environmental conditions may vary depending on potato varieties, storage duration, and other factors. Therefore, further research is needed to establish optimal concentrations and application methods for these sprouting agents, as well as to determine the most suitable environmental conditions for potato sprouting control.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Description of The Study Area

The place where the experiment was conducted is in Kadoma at cotton research institute residential area which is located at latitude -18º 32" 47 and longitude 29º 9" 18 inside Zimbabwe. It is located 3km from Kadoma town along Sanyati road. The soils are light red clay with some portions having clay loamy soils that are well drained and rich in soil nutrients. The average annual precipitation is around 125.43mm (Weather and Climate, 2023) and mean monthly temperature of 27.77^0C. The altitude is 1185m (Maplogs, 2023). It is also under region IIb which receives annual rainfall that ranges from 500 to 700mm with relatively high temperatures (Vincent and Thomas 1961).

3.2 Experimental Design.

The experimental design used was Complete Randomized Design (CRD) with a factorial arrangement (A * B). The arrangement is a 2*4 factorial with 'A' two factor levels of environment, (darkness and light) and 'B' four levels of sprouting agents (giberellic acid, calcium carbide and aloe vera) and a control. A probability sampling method of simple random sampling was used to assign treatment groups to the experiment layout. The treatments were replicated twice for each treatment to reduce noise.

3.3.0 Treatment Groups:

Dividing the potatoes into different treatment groups:

- Control group: No sprouting agent, kept in darkness
  - Giberellic acid group: Sprouting agent applied, kept in darkness
  - Aloe vera group: Sprouting agent applied, kept in darkness
  - Calcium carbide group: Sprouting agent applied, kept in darkness
- Light group: No sprouting agent applied, exposed to light
  - Gibberellic acid + Light group: Sprouting agent applied, exposed to light

- Aloe vera + Light group: Sprouting agent applied, exposed to light
- Calcium carbide + Light group: Sprouting agent applied, exposed to light

3.3.1 Preparation and Application of Sprouting Agents

The treatments were exposed to different environmental conditions that are darkness and light exposure. They were dipped in the chemical solutions in samples of ten tubers in 15,63L solution of GA32 at a rate of 16ml/100L of water, ten tubers in 19.6L Calcium carbide at a rate of 230g/45L, ten tubers in 5L, aloe vera dilute leaf extracts solution at rate of 60ml juice/1L and the last ten have received a placebo treatment (control). Under darkness environment, there were also ten tubers dipped in GA32, ten tubers in Calcium carbide, ten tubers in aloe vera leaf extracts. The placebo treatment (dipped in water only and place in darkness) acted as a control treatment. For those tubers that were treated with aloe vera leaf extracts, the leaves were collected and a 310ml juice was extracted, of which 300ml juice was diluted to 5L of water.

The leaves were crushed using a traditional perforated mortar and pestle and the crushed material was put in a potato sack which was then put inside a perforated mortar. The material was pressed hard to forcefully squeeze out the aloe juice from the leaf material. The juice content was then put into 5 litres of water and stirred well to mix. The potato tubers were then dipped in the solution for 5 minutes and placed on open air and light environment to dry. This was done for about 15 minutes before going to the final trial or sprouting area to avoid fungal infection and rotting. The dark condition treatments were covered with black polythene plastic paper. Eight treatments after replication were placed in the shade where diffuse daylight reaches to avoid direct sunlight radiation and the other eight treatments were placed in the dark, covered with black plastic paper to promote dark conditions. The experiment did not involve light control measures in order to imitate natural environment where smallholder farmers usually use naturally occurring light without manipulating it because of limited resources.

Meanwhile, all sixteen treatments after replication were observed closely and the records were taken after every week, in the morning to monitor for changes. The average length and diameter of the sprouted shoots per treatment was measured using a ruler and a string and venier caliper. The average number of shoots per tuber per treatment and sprouting percentage were recorded.

3.4 DATA COLLECTION

3.4.0 Sprout Length and diameter

The length in millimeters of the sprouts was measured at the end of the project using a string and a ruler. The sprouts were measured from the base to the tip end of the shoot from second week on weekly interval up to the end of the project. Sprout diameter was measured using a venier caliper at the end of the fourth week of the project. The measurements were collected by placing a venier caliper at the base of the shoot and then recorded in millimeters from each shoot that was successfully sprouted.

3.4.1 Number of Sprouts per tuber

The number of sprouts per tuber was counted and recorded. The tubers were considered sprouted whenever the eye was observed even though not measurable. The average number of sprouts per tuber was calculated as this is important in determining the yield per hectare of the potato plants.

3.4.2 Sprouting Percentage

In order to determine the effectiveness of each and every sprouting agent, number of sprouted tubers was recorded and expressed as a percentage. This also helps to ascertain the germination percentage of the seed tubers after planting and in achieving the required optimum plant population as well as evenness of the crop in the field.

3.5. ANALYSIS OF RESULTS

The results of the project were analyzed using Genstat version 18th Edition statistical package to perform Analysis of variance. The least significance difference (L.S.D) of $P<0.05$ was used to separate means.

CHAPTER 4

4.0. RESULTS

Table 2. Effects of different sprouting agents on the sprouting of potatoes.

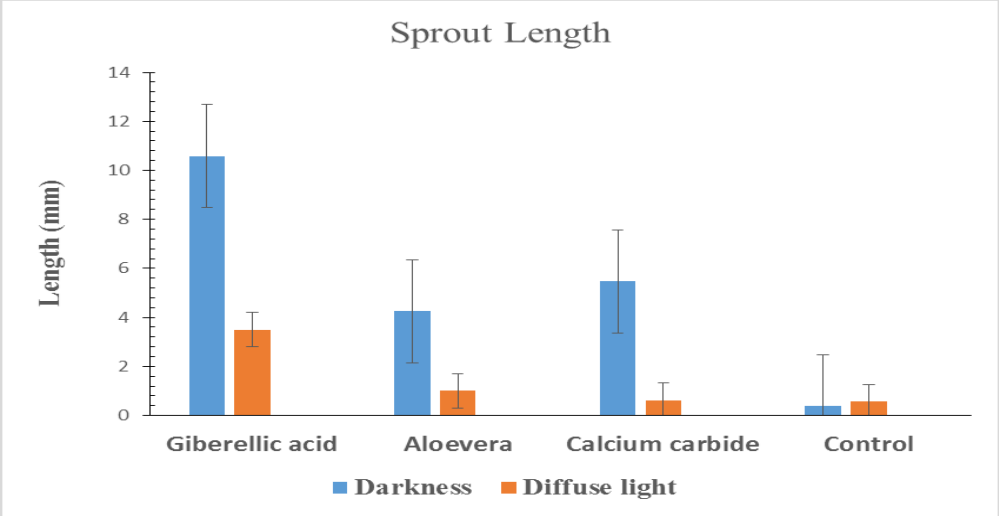
Treatment	At Week 4			
	Sprouts Length	Sprouts Diameter	Sprouting Percentage	Number of Sprouts per Tuber
Giberellic acid 16ml/100L	6.875[a]	3.380[a]	0.5750[a]	2.416[a]
Aloe vera 60ml/1L	2.625[b]	1.587[ab]	0.4500[ab]	1.072[ab]
Calcium carbonate 230g/45L	3.045[b]	2.028[ab]	0.2750[b]	1.115[ab]
Control	0.467[b]	0.095[b]	0.0625[c]	0.035[b]
Grand mean	3.25	1.77	0.341	1.16
P- Value (P<0.05)	0.018	0.042	<0.001	0.030
LSD (0.05)	3.517	2.103	0.1879	1.416
S.E.D	1.525	0.912	0.0815	0.614
CV (%)	6.63	7.28	3.38	7.49

*Means that are followed by the same letters are not significantly different.

4.1. Effects of sprouting agents and environment on sprout length of the potato seed tubers.

The length of the sprouts varied significantly due to the difference in sprouting agents used at (P<0.05). The sprout length of tubers treated with giberellic acid, aloe vera leaf extracts and calcium carbide under dark conditions showed a significant difference compared to those treated and exposed to diffuse light conditions. Most importantly, it also provides evidence that aloe vera has got high ability of breaking dormancy and resulting in sprouting in potatoes according to the bar-graph information below.

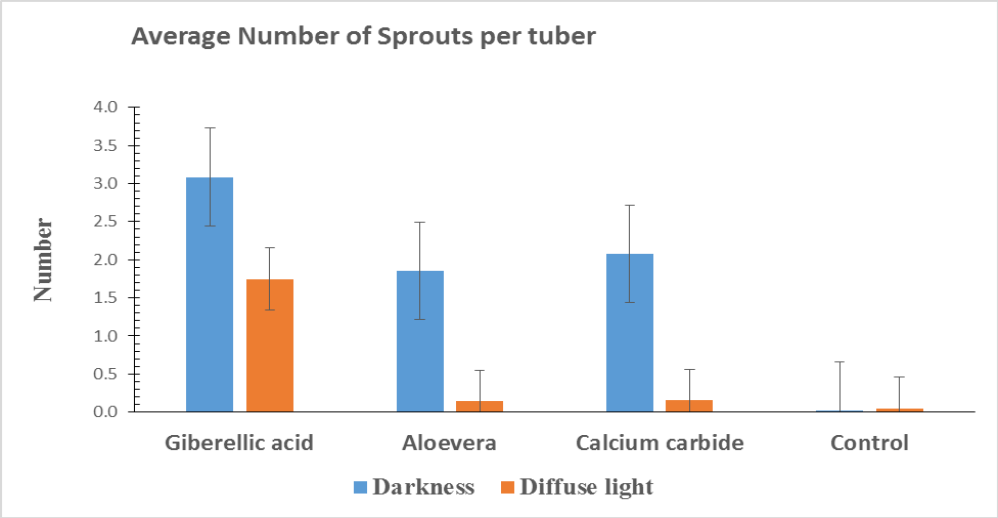
Effects of sprouting agents and environment on sprout length of the potato seed tubers.



4.2. Effects of sprouting agents and environment on the number of sprouts per tuber.

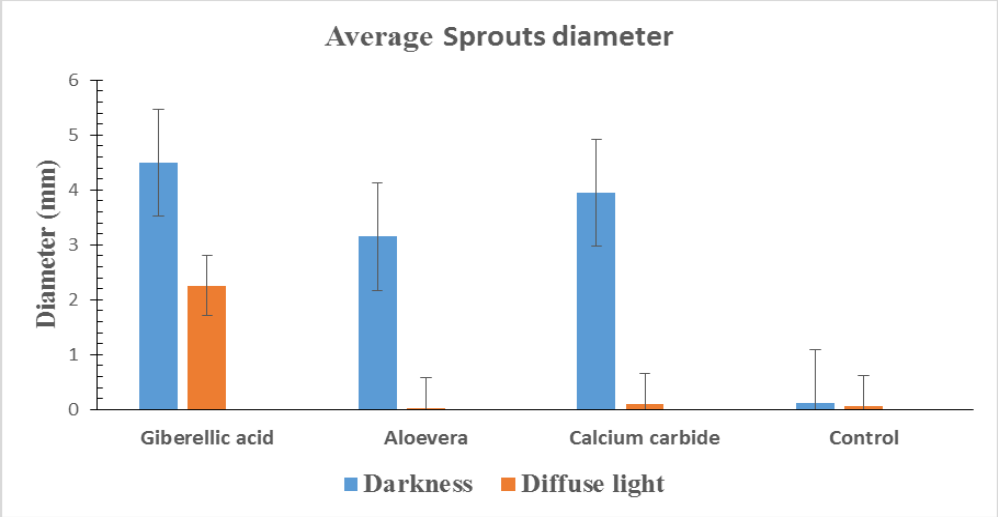
The effect of environment was significant at the (0.019) less than alpha ($p<0.05$). This means there is an interaction, a statistical difference between the means of the treatments that were exposed to the diffuse light and darkness conditions. The treatments in dark conditions had a high number of sprouts per tuber across all treatments except for the control which barely sprouted with more than one sprout. The null hypothesis under this condition was rejected giving the evidence that sprouting of potatoes happens successfully under darkness environmental conditions since hormones like auxins and gibberellins do not do well in light conditions.

Effects of sprouting agents and environment on the number of sprouts per tuber.



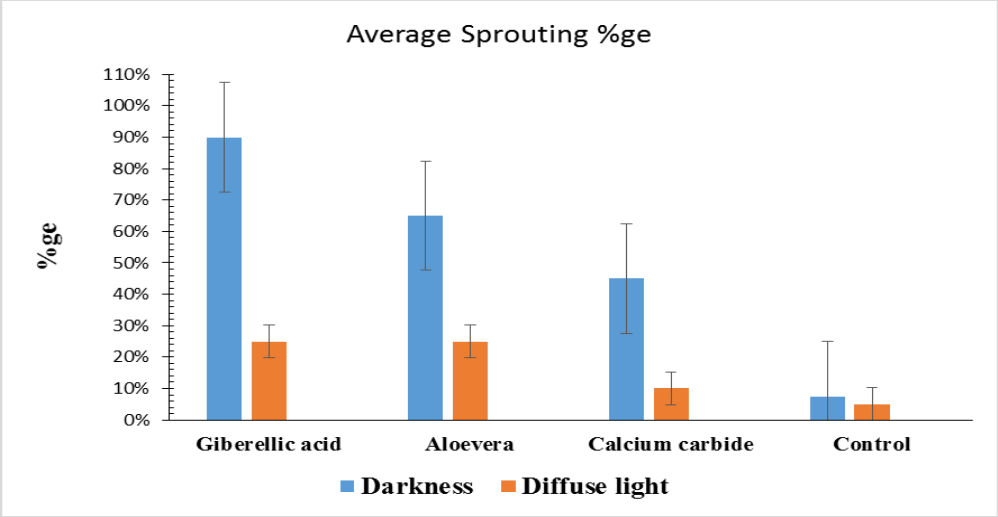
4.3 Effects of sprouting agents and environment on the diameter of sprouts.

The $p<0.05$ value of the main factor B (Sprouting agent) was at p 0.042. This indicated that sprouts diameter varied significantly due to the difference in sprouting agents used. Sprout stem diameter of tubers treated with giberellic acid, aloe vera leaf extracts and calcium carbide under dark conditions showed a significant difference compared to those treated and exposed to diffuse light conditions.



4.4 Effects of sprouting agents and environment on sprouting percentage.

Sprouting percentage of potato tubers is almost equally the same as germination percentage. The sprouting percentage varied with the type of sprouting agent used for treatment with the environment prevailing. Based on the P-values, it shows that the factors "Environment", "Sprouting agent" and "Interaction" have statistically significant effects on the sprouting percentage. The p-values for these factors are below the typical significance level of 0.05 ($p<0.05$). The source of variation mainly occurred as a result of treatments that were exposed to dark conditions. As shown in the bar-graph, giberellic acid at 90% has shown evidence to effect sprouting to a big number of tubers under its treatment, followed by aloe vera that averaged to 65% and lastly is calcium carbide that failed to compete fairly with aloe vera extracts and giberellic acid at 45%.



CHAPTER 5

5.0. DISCUSSION

The present study on the effect of three sprouting agents and environment on potato sprouting was carried out in a room storage environment that had darkness initiated by black polythene plastic paper and the other one condition that allowed diffuse light penetration. All treatments had a control trial on both dark and light conditions. The results from this experiment means that there was an interaction between sprouting agents and environment. The treatments of sprouting agents gave no significant effect under light conditions which means diffuse light is not efficient in sprouting of potatoes (Crissman et al., 1993). Good sprouting effect was observed under continuous dark conditions with giberellic acid recording long sprout length, high average number of sprouts per tuber and high sprouting percentage than control of the same environment. This concurs with the findings made by Esther et al (2019) in their journal that the length of sprouts can reach about 46.25mm at 12 weeks. However, this experiment lasted for only four weeks but still proved the point by a record of 4.25mm from aloe vera, 10.58mm from giberellic acid and 5.47mm from calcium carbide.

Post treatment results from dark condition on sprout diameter resulted in almost similar diameter though different. This showed that the diameter was not affected too much under dark conditions while on diffuse light all treatments completely failed to give sprouts with observable diameter. Aloe vera leaf extracts treatments showed that the project was a success on achieving its goals on coming up with a bio-stimulant that is ecological sound, cost effective, convenient and usable by smallholder farmers. This agrees with a discovery made by Jamal et al (2020) who found that aloe vera is more promising than synthetic hormones as a rooting and shooting substance.

The solution of 60ml juice per litre of aloe vera leaf extracts gave above average results of 65% sprouting percentage, good average number of sprouts per tuber and a length that is 4.25mm sprouts that are firm and strong. Aloe vera proved to be more effective than calcium carbide that is difficult to prepare and not reliable which led to its removal on the market. Aloe vera (*Aloe zebrine)* also showed that the hormones found in its leaves such as auxins and giberellins are

good organic sprouting compounds that can be extracted and used as sprouting agents as cited by Sujata et al (2022). Hamouda et al (2012) also came up with results which revealed that aloe vera treatments had a significant effect on the number of shoots as a result of gibberellins and salicylic acid, which promote and increase growth. These gibberellins have similar effect with the synthetic plant growth regulators.

Kabira and Lemaga, (2003) observed that dark storage condition results in excessive sprouting and reduced sprout strength that requires desprouting prior to planting. In addition there is need for hardening the sprouts for few days depending on light strength before planting to aid quality and strengthen the sprouts that were exposed to dark conditions. According to Smith (1968), proline which is the only amino acid that moves freely from the tuber to the sprout tends to accumulate in sprouts grown in the dark but disappears when they are exposed to light. These observations concur with those of Crissman et al. (1993) who reported that light has an inhibition effect on elongation of sprout internodes. However, in the present investigation, this suggest to the reason why all the treatments exposed to diffuse light condition failed to sprout post treatment during this experiment.

CHAPTER 6

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusion

The study that was conducted for four weeks on the effects of sprouting agents and environment has shown that the use of aloe vera as a sprouting agent at a rate of 60ml per liter of aloe vera leaf extracts has proved to be effective. Under dark environment conditions with a record of 65 % sprouting percentage and an average of 1.85mm number of sprouts per tuber, aloe vera can potentially be used as a sprouting agent. Gibberellic acid proved to be the most efficient with 90% sprouting percentage and 3.1mm average number of sprouts per tuber, at a rate of 16ml/100L of water owing to its wide spread adoption under commercial farming. Calcium carbide was the least effective on sprouting percentage with 45% and physically malformed sprouts with a mass of tissues. All the results were environmental dependent with the continuous dark conditions being the best. There was a significant loss of tubers to rotting under diffuse light conditions averaging 20% per treatment in four week period.

6.2 Recommendations

Due to the increasing demand on the market for more eco-friendly products in agriculture, aloe vera was observed to be effective and can be adopted and used as a sprouting agent. It is cheap, reliable, convenient and easily accessible. However, further studies for treatment rates specific to irish potatoes need to be conducted to assess the influence of different rates in sprouting of potatoes instead of 60ml per liter wich was prepared for dragon fruit cuttings. Also, the effect of natural diffuse day light environment in combination with sprouting agents still need further investigation since the effectiveness of light radiation varies with wavelength, place and its strength. Farmers with adequate financial capacity can still use gibberellic acid as a sprouting agent since its a highly effective and reliable synthetic plant regulator on the market. However, farmers need to take precautional and safe disposal measures since its a threat to human beings using it and to aquatic living organisms like fish as indicated on the product instruction label even though it has a green label. Calcium carbide is outdated and was banned hence, it's prudent

for farmers not to use it except for research studies under expert supervision. All the three plant growth regulators do well in a darkness environment.

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APPENDICES

Appendix 1 Chemical constituents of Aloe vera leaves.

Chemical constituents of Aloe vera leaves.

Chemical Constituents	Quantity	Unit
Nitrogen	80.65	mg/100 g
Phosphorus	6.95	mg/100 g
Potassium	60.14	mg/100 g
Iron	0.229	mg/100 g
Zinc	0.028	mg/100 g
Manganese	0.0266	mg/100 g
Calcium	40.00	mg/100 g
Copper	0.0042	mg/100 g
Magnesium	14.44	mg/100 g
Sodium	51.12	mg/100 g
GA3	**16**	**mg/100 g**
IAA	**0.63**	**mg/100 g**
ABA	3.06	mg/100 g
Total carbohydrate	10.1	%
Glucose	3.2	g/100 g
Protein	1.0	mg/g
Sterol	18.73	mg/g

Source: MDPI Journal, (2022)

Appendix 2. Effects of sprouting agents and environment on sprout length of the potato seed tubers.

Analysis of variance

Variate: Length

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	53.839	53.839	11.57	0.009
Sprouting_agent	3	85.262	28.421	6.11	0.018
Environment.Sprouting_agent					
	3	25.940	8.647	1.86	0.215
Residual	8	37.214	4.652		
Total 15 202.255					

Appendix 3. Effects of sprouting agents and environment on the number of sprouts per tuber.

Analysis of variance

Variate: Number_of_Sprouts_per_Tuber

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	6.4707	6.4707	8.59	0.019
Sprouting_agent	3	11.4139	3.8046	5.05	0.030
Environment.Sprouting_agent					
	3	2.4600	0.8200	1.09	0.408
Residual	8	6.0294	0.7537		
Total 15 26.3739					

Appendix 4. ***Effects of sprouting agents and environment on the diameter of sprouts.***

Analysis of variance

Variate: Diameter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	21.425	21.425	12.88	0.007
Sprouting_agent	3	21.988	7.329	4.41	0.042
Environment.Sprouting_agent	3	8.129	2.710	1.63	0.258
Residual	8	13.310	1.664		
Total 15 64.852					

Appendix 5. Effects of sprouting agents and environment on sprouting percentage.

Analysis of variance

Variate: Sprouting_%ge

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Environment	1	0.50766	0.50766	38.22	<.001
Sprouting_agent	3	0.59422	0.19807	14.91	0.001
Environment.Sprouting_agent	3	0.19797	0.06599	4.97	0.031
Residual	8	0.10625	0.01328		
Total 15 1.40609					

Appendix 6. Fisher's protected least significant difference test

Environment.Sprouting_Agent

	Mean	
1 2	0.9000	|
1 1	0.6500	| |
1 3	0.4500	| |
2 1	0.2500	| |
2 2	0.2500	| |
2 3	0.1000	|
1 4	0.0750	|
2 4	0.0500	|

	Mean	
1 2	0.9000	a
1 1	0.6500	ab
1 3	0.4500	bc
2 1	0.2500	cd
2 2	0.2500	cd
2 3	0.1000	d
1 4	0.0750	d
2 4	0.0500	d