BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF AGRICULTURE AND ENVIRONMENTAL SCIENCES

DEPARTMENT OF CROP SCIENCE

EFFECTS OF BIO-STIMULANTS VERSUS COMMERCIAL FERTILISERS ON POTATO

TATENDA JURU

B201693B

A dissertation submitted to the Bindura University of Science Education in partial fulfilment of the requirement for the award of Bachelor of Agricultural Science Honours Degree in Crop Science.

ABSTRACT

Potatoes being a member of the Solanaceae family, yet one of the widely used staple crop in the world, faces a number of uninformed best ways to cultivate it. Despite the promising attributes of bio stimulants, comprehensive comparative evaluations against compound fertilizers remain thin leading to many agronomists remain uninformed of the full potential of bio stimulants, partly due to a lack of practical evidence documenting their effectiveness relative to established stimulants and synthetic fertilizer on potato production, a study was conducted at Ibis farm in Norton to showcase the benefits of using bio stimulants and commercial fertilizers application on the germination, growth and yield of potatoes. The two bio stimulants which were used where KynoHumate Black and KynoFulvate Yellow. The number of stems per plant, number of tubers per stem, size distribution of tubers and size of tubers were the parameters assessed. A GenStat package 17^{th} edition was used for data collection. The results indicated that the combination of both the bio stimulant and the commercial fertilizers sponsors a higher performance in the final yield hence they can be used to improve productivity and food security. Lastly I recommend that governments must inspire and sponsor research institutions to do more research and not to be left out in new technological advancement in the global economy of agriculture.

RELEASE FORM

I, Tatenda Juru, Student Number B201693B do hereby provide Bindura University of Science Education exclusive rights to replicate and dispense this research work in whole origin part in any suitable publication form that does not infringe or violet at any rights of others. I therefore give this consent the original owner of the rights to work and abstract. The author declares that the contents of this research have been created by the author himself and that no other resources mentioned in the literature used before. The copy right of this research is held by the author and the author is responsible for the contents of the work. The Bindura University of Science Education is exclusively and entirely responsible for the education guidance of this project and does not accept in any case, any responsibility for the contents. This dissertation in original work from scratch and that all the resources that involved from other sources are quoted and indicated by means of complete references.

Signature of student………………………………. **Date 30 / 06 /25**

Declaration

I Tatenda Juru, registration B201693B declare that this research project is my own and has not been lifted or copied from any source without acknowledgement of source.

Signature……….

Supervisor

I have supervised the research projects for the above mentioned student and I am convinced that the research can be submitted.

Signature …………………… Date …………………..

DEDICATION

I say hats off and salutations to my own mother, Fortunate Rusere who stood by me tirelessly in making sure that I get all the needs I wanted during every stage of the project. Not forgetting my friends who were my major drive and motivation to always check up on the progress of my project. Lastly, I thank the Lord God Almighty who would bless me with another life every morning to be able to keep on going during my research.

ACKNOWLEDGEMENT

I would like to express my innermost gratitude to my supervisor Mrs Kamota for her effort that enfolded to making this piece of art a reality. Not forgetting the staff farm workers at Ibis Farm who did provide great support. I also appreciate the Department of Crop Science at Bindura University of Science and Education as well as my classmates for offering a helping hand. Words may lie if I try to express my gratitude to my siblings, Tinashe and Nyasha who stood by me in every aspect of life from emotional stability to educational support. Without them this dream could not have been manifesting. Finally, I would love to give honour and praise to the God who is in heaven for ushering his favour and tender mercies over me to be able to sail through and finish my studies despite all the hardships that once made me to defer at some certain point.

Table of Contents

Contents

LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of Variance
FAO	Food and Agriculture Organization
°C	Degree Celsius
/ha	Per hectare
Mm	Millimetres
Cm	Centimetres
Kg	Killograms
G	Grams
%	Percent
Mg	Magnesium
N	Nitrogen
P	Phosphorus
K	Potassium

CHAPTER 1: INTRODUCTION

Background

The potato is a member of the Solanaceae family, often referred to as the nightshade family, which includes other economically significant plants such as tomatoes and pepper. Its tubers, which serve as the main edible part and they are rich in carbohydrates, particularly starch and they basically provide vital nutrients including vitamins C and B6, potassium and dietary fibre (Ruales & Nair, 1992). The high nutritional value, combined with the tuber's versatility in culinary applications, has made potatoes a vital component of many diets across varying cultures (McGill, 2009).

Originating in the Andean region of South America, the potato has been domesticated for thousands of years, with archaeological evidence suggesting cultivation as early as 8000 B.C. (Hawkes, 1990). After its introduction to Europe in the 16th century, the potato quickly gained popularity due to its adaptability to various climates and its capability to produce high yields with relatively low input requirements (CIP, 2015). Potato production is crucial for both commercial and small-holder farmers and it is a tool for socio-economic expansion. The potato (Solanum tuberosum) is one of the most widely cultivated and consumed crops globally, serving as a staple food for millions of people (FAO, 2022).

Despite their popularity and utility, potato production faces several challenges, including pest and disease pressures, climate change and soil degradation. Diseases such as late blight, caused by the pathogen Phytophthora infestans, have historically resulted in significant crop losses and food insecurity (Fry, 2008). In addition, environmental concerns linked to the use of chemical inputs in potato cultivation have compelled research into sustainable farming practices, such as integrated pest management and the use of bio stimulants (Baker et al., 2018).

The cumulative dependence on chemical fertilizers to improve agricultural productivity has led to important environmental consequences, including soil degradation, water pollution and loss of biodiversity (Grafton et al., 2015). As global food demand continues to increase, being motivated by population growth and dietary changes, the search for sustainable agricultural practices becomes imperative (Tilman et al., 2011). Bio stimulants arise as a viable other means, possibly addressing several of the trials linked with traditional fertilizers.

Although bio stimulants have shown a positive possibility in improving various aspects of plant physiology, their comparative effectiveness to traditional compound fertilizers remains poorly understood. Studies specify that bio stimulants may endorse nutrient availability, improve root development and enhance stress flexibility.

Bio stimulants have obtained attention for their capability to advance nutrient uptake, enhance root development and boost plant resilience against biotic and abiotic stresses (Yakhin et al., 2017). Studies signify that bio stimulants can increase bioavailability of nutrients, promote soil health and stimulate microbial activity in a way that compound fertilizers can struggle to accomplish (Du Jardin, 2015). Despite the promising attributes of bio stimulants, comprehensive comparative evaluations against compound fertilizers remain thin. Many farmers and agronomists remain uninformed of the full potential of bio stimulants, partly due to a lack of practical evidence documenting their effectiveness relative to established agricultural practices (Dodd et al., 2016).

Furthermore, the mechanisms through which bio stimulants exert their effects on soil health and crop performance are not fully explained, leading to indecision about their position in sustainable agriculture (Khan et al., 2021). Given these thoughts, there is a critical need for systematic research to compare the efficacy of bio stimulants and compound fertilizers on crop yield. Continuous research and innovation are essential to address the challenges facing potato production and to ensure its sustainability for future generations.

Problem statement

Technologically advanced potato production has been a hard area to tackle for many farmers especially due to high costs and unevaluated cost benefit ratio of inputs. This, together with insufficient knowledge has led to lower yields than expected over the past years. The extreme usage of compound fertilizers has elevated important environmental worries, including soil degradation, water pollution, disturbances to microbial ecosystems and greenhouse gas emission. This has led to climate changes which leads to abiotic stresses such as drought thereby further threatening the number of tubers per plant and potato final yield. While convectional potato production relies on compound fertilizers, to optimize yield, the unbalanced use often leads to inconsistent tuber sizing of either too small or unmarketable tubers, excessively large and hollow tubers which can reduce profitability.

As global food demand continues to increase, being motivated by population growth and dietary changes, the search for sustainable agricultural practices becomes imperative and bio stimulants arise as a viable other means, possibly addressing several of the trials linked with traditional fertilizers. However, the mechanisms through which bio stimulants exert their effects on soil health and crop performance are not fully explained, leading to indecision about their position in sustainable agriculture. Also a little is known about the use of bio stimulants and specific quantities to apply leading to some individuals still resisting to adopt them. Given these thoughts, there is a critical need for systematic research to compare the efficacy of bio stimulants and compound fertilizers on crop yield.

Justification

Understanding the comparative efficacy of bio stimulants and compound fertilizers will provide critical insights into the roles of agronomists in improving crop yields, enhancing soil health and promoting sustainable practices leading to economic growth. Also, integrating bio stimulants into fertilization regimes can potentially mitigate the negative environmental impacts of conventional fertilizers, thus contributing to the broader goals of sustainable development. It will also contribute to the knowledge of the environmental implications of different fertilization strategies. Previous studies have been highlighting promising outcomes in using bio stimulants but comprehensive comparisons with compound fertilizers are limited, hence the need for this research. It will also help farmers to comprehend the economic profits of bio stimulants and implement these new technologies which increases high yields at very reasonable operational expenditures as well as helping them in informed decision making. By getting to know the possible performances of the compound fertilizer and bio stimulants, it will contribute to the implementation of enviro-friendly potato production systems that optimises resource use and reduce ecological footprints.

Overall Objective

The overall objective is to assess the advantages of using both bio-stimulants and synthetic fertilizer on potato production.

Specific Objectives

1. To assess the effects of bio-stimulants and inorganic fertiliser on growth and development of potatoes.
2. To determine the effects of bio-stimulants and inorganic fertilizer on final yield.

Hypothesis

- H1=There is a significant difference on the number of tubers per stem
- H0=There is no significant on the number of stems per plant.
- H1=There is a significant difference on the size of tubers.
- H0=There is no significant difference on the size distribution of tubers.

CHAPTER 2: LITERATURE REVIEW

Introduction

The quest for sustainable agricultural practices has expanded in recent years, driven by the need to address the challenges of food security, soil degradation and environmental sustainability. The use of organic fertilizers and bio stimulants has surfaced as crucial approaches to improve crop productivity while minimizing the ecological footprint of agriculture. Especially, potato production, a major staple crop worldwide, stands to gain much from the integration of these two approaches (FAO, 2020). Organic fertilizers, derived from plant and animal materials, improve soil health by enhancing its structure, water retention and microbial activity (Gupta et al., 2019). They give necessary nutrients progressively, thus promoting long term soil enrichment (Nielsen et al., 2021). Recent studies indicate that organic fertilizers can lead to improved yields and higher quality produce compared to conventional fertilizers (Sharma et al., 2021). However, their effectiveness can vary based on application methods, soil types and climatic conditions (Adeleye et al., 2020). On the other hand, bio stimulants, which include a wide range of natural substances and microorganisms, are designed to enhance plant growth and health by improving nutrient uptake and stress resistance (Zacarian et al., 2022). The efficacy of bio stimulants in increasing potato yields has been documented, with reports highlighting their role in promoting root development and enhancing stress tolerance (Pérez-Hernández et al., 2021). The integrated application of bio stimulants and organic fertilizers may bring a lot of benefits, improving nutrient availability and plant health (Bhardwaj et al., 2020).

Background on potato

Potatoes (*Solanum tuberosum L*) which belongs to the Solanaceae family is now the fourth most crucial world crop because of its great yield production and high nutritive value (Geohive 2013). The potato was domesticated over 7,000 years ago by indigenous people in the Andean mountains, now called Peru and northwest Bolivia. Archaeological proof suggests that it was an important part of their diet long before the arrival of Europeans in the late 16th century. Initially, European societies were doubtful of the tuber till it increased acceptance and became a staple food in several parts of the continent. The most famous historical event associated with the potato is the Great Irish Famine (1845-1852), triggered by a potato disease known as late blight (Phytophthora infestans). This disastrous occurrence led to the death of approximately one million people and the emigration of many others (Anton de Bary at el., 1848). The potato's journey from its Andean origins to becoming a global staple highlights its agricultural and cultural worth. Its adaptability, nutritional benefits and culinary flexibility adds to its continuous importance in diets worldwide. As global challenges such as food security and climate change grow, research and innovation surrounding potato cultivation and utilization remain vital.

Potato Production at Global level

China is now the world's top potato making nation with annual production of total output reaching 383 million metric tonnes in 2023, followed by Russia and India at 19.3 million and 60.1 million respectively in 2023. (FAO 2023). Now both production and consumption of Irish potatoes has dramatically increased in developing countries in recent years, for example, potato production in Bangladesh increased from about 3 million metric tonnes in 2000 to 8 million tonnes in 2010. (Geohive 2013) while consumption in Africa is dramatically increasing with the continent witnessing a surge in production over the past decade. However, this consumption is very low compared to consumption in Europe and North America. Potato production has now become a vital part of the global agricultural landscape, with large-scale effects on nutrition and the economy. As the world population continues to grow and dietary preferences shift, the potato will possibly continue being a vital and crucial commodity in food systems. Addressing challenges such as disease, climate change and market fluctuations will be vital for ensuring sustainable potato production and food security in the future. Efforts to innovate and adapt agricultural practices will be essential to meet this ongoing demand.

Irish potato production in Zimbabwe

Irish potato (*Solanum tuberosum L.*) is the most important horticultural crop in Zimbabwe, and the third most important carbohydrate food source after maize and wheat (The Herald, 2011). Irish potato production in Zimbabwe has seen significant growth over the years. The annuals potato production has increased from 400,000 tonnes in 2013/14 season to 600,000 tonnes in the 2019/20. To boost local production, the Zimbabwean government has implemented various initiatives. Some of the key areas of the Irish potato production include Nyanga district, where smallholder farmers are playing a special role in the production process. However, these farmers face challenges such as technical efficiency estimated at 55.5 percent. To improve the efficiency of Irish potato production in Zimbabwe the government and stakeholders are working to enhance capacity development, research and extension services (All Africa 2021). Additionally, there's a focus on promoting local production and consumption particularly among the youth demographic overall, Irish potato production in Zimbabwe has potential to contribute significantly to countries GDP, and ongoing efforts are being made to support the growth of this industry (Zimbabwe Ministry of Lands, Agriculture, Fisheries, Water and Rural Development 2021)

Challenges in Potato Production

Potato production in Zimbabwe goes through a lot of challenges which particularly impact the whole agricultural sector, food security and a standardized way of living to the farmers. One big example is of how Zimbabwe faces periodic droughts which heavily impact the potato production since they require a consistent moisture optimum for growth. They will rise the need for farmers to have irrigation schemes in which most farmers in Zimbabwe don't afford (Zimbabwe Ministry of Agriculture,2021).

Even though the production of potatoes is capital intensive, access to inputs and technology is another bigger challenge whereby we witness more smallholder farmers having no leads to genetically modified seeds, fertilizers, and technologically advanced rudimental needed (Zinyemba et al., 2019).

Climatical condition changes also plays a huge role. It can lead to soil degradation which reduces soil fertility which leads into a critical growth state for potato production. It can also make it difficult for farmers to plan and manage crops effectively. Even temperature fluctuations can affect growth cycles (Chikowo et.,2020).

In addition, pest and disease management can be of a great threat if not well managed since they can devasted the potato crops and this will lead to increased cost in relation to pest management and this can lead to reduced yield (Mkandawire et.,2020).

Climate

Global climatic changes are significantly impacting agriculture worldwide including the production of potatoes as well, with tropical regions being expected to experience decreased crop yields due to a moderate increase in temperature (World Meteorological Organization

2020). Also changes in precipitation patterns are hugely affecting agriculture impacting and affecting crop yields, quality and distribution (Porter, J.R.et al,2014)

Soil fertility

Soil fertility is one of the most important aspects in potato production globally. It directly affects quality, crop yield and farm productivity at large. In and around Zimbabwe, many soils are being highly leached every year and with time they will lack crucial nutrients such as nitrogen, phosphorous, potassium etc which are essential for potato growth (Zimbabwe Potato Improvement Program 2020). In potato production nutrient deficiency can result into stunted growth and lower resistance to diseases (Mafongoya et al.,2019). Also, in some potato growing regions, pH levels will be suboptimal which affects nutrient uptake by plants. Lime can be of use, but many smallholder farmers lack access to liming materials (Chikowo et al., 2018). Also limited practise of crop rotation, contribute to reduced organic matter content per unit area which will in end negatively affect potato production leading to low yield quality. A lot of soil management practices are needed to manage our soil fertility including the use of inorganic fertilizer.

Approaches to improve soil fertility in potato production.

Improving soil fertility is crucial for successful potato production, especially in Zimbabwe, where soil health can significantly affect yields. Incorporating organic matter, such as farmyard manure, compost, or cover crops can improve soil structure, increase nutrient availability and enhance microbial activity (Mugwira et al., 2020). Organic amendments are particularly beneficial especially in sandy or degraded soils, which are common in many potato-growing regions of Zimbabwe. Also conducting regular soil tests enables farmers to understand the specific nutrient needs of their soil, allowing for precise fertilizer application (Zingore et al., 2019). Based on soil test results, farmers can tailor their fertilizer use optimizing the use of NPK (Nitrogen, Phosphorus, Potassium) fertilizers and micro-nutrients which are critical for potato production. Again, implementing crop rotation, especially with legumes like soybeans or groundnuts, can enhance soil nitrogen levels and improve overall soil health (Chikowo et al., 2021). Intercropping potatoes with legumes can also maximize land use and contribute to fertility. Practices such as reduced tillage and maintaining soil cover can help preserve soil structure and improve its fertility over time (Nyagumbo et al., 2019). Conservation agriculture promotes the natural soil ecosystem, reducing the need for chemical fertilizers.

Bio stimulants

According to the European Bio stimulants Industry Council (2021), bio-stimulants are defined as substances or microorganisms that, when applied to plants or the rhizosphere, enhance plant growth and improve nutrient uptake efficiency, tolerance to abiotic stress and quality of the produce. They can be derived from various sources, including natural products like sea weeds, humic acids, plant extracts and valuable microorganisms such as mycorrhizae and certain bacteria (De Almeida et al., 2021). They play a crucial role in potato production since they can even enhance the bioavailability of nutrients in the soil, helping plants acquire more important elements (Zhang et al., 2020). For example, mycorrhizal fungi form a symbiotic relationship with plant roots, increasing their surface area and enabling the plant to access nutrients like phosphorus more effectively (Graham et al., 2020). Bio-stimulants are well capable of helping plants better withstand abiotic stresses such as drought, salinity and extreme temperatures. They can enhance plant resilience mechanisms, leading to improved performance under challenging conditions (Yoshida et al., 2021).

They are also capable of promoting beneficial microbial activity in the soil, thereby enhancing soil structure, organic matter content and soil fertility. This positively affects soil health and leads to improved plant growth and yield (D'Agostino et al., 2019). By improving soil microbial communities, bio-stimulants can also contribute to better nutrient cycling and organic matter decomposition, which are essential for sustainable agricultural practices (Raaijmakers et al., 2020). With a whole lot more advantages the use of bio-stimulants can decrease the need for chemical fertilizers and pesticides, promoting environmentally friendly farming practices which can lead to lower production costs and reduced environmental risks associated with chemical inputs (Singh et al., 2019). Bio-stimulants offer numerous benefits for sustainable agricultural practices by enhancing nutrient uptake, improving stress tolerance, promoting soil health, increasing the quality of produce and reducing reliance on chemical inputs. As research continues to expand in this area, there is potential for bio-stimulants to play an essential role in addressing food security and environmental challenges in agriculture.

Inorganic Fertilizers

Inorganic fertilizers, also known as synthetic or chemical fertilizers, are man-made products that bring fundamental nutrients to plants for ideal growth. These fertilizers are composed of raw mineral salts or synthesized chemicals that provide critical macronutrients and micronutrients essential for plant nutrition. Unlike organic fertilizers, which are derived from natural sources, inorganic fertilizers typically offer nutrients in a more concentrated and readily available form (Meyer et al., 2019). Inorganic fertilizers can be categorized based on their nutrient content, primarily focusing on the three primary macronutrients, nitrogen (N), phosphorus (P), and potassium (K). This is often referred to as NPK analysis. For example, a fertilizer labelled as 20-10-10 contains 20% nitrogen, 10% phosphorus and 10% potassium by weight. Inorganic fertilizers release nutrients swiftly into the soil, making them proximately accessible for plant uptake. This quick availability aids to address nutrient deficiencies quickly (Bardgett et al., 2014). The nutrient concentrations in inorganic fertilizers are standardized, providing predictability in their effectiveness and allowing farmers to plan their fertilization approaches based on specific crop needs (Raven et al., 2014). Inorganic fertilizers are often simpler to handle and apply mostly in large scale agricultural procedures, due to their suitability and detailed granulation (Meyer et al., 2019). Inorganic fertilizers can be classified into various types which are firstly Nitrogenous Fertilizers for example, urea (CO(NH2)2), ammonium nitrate (NH4NO3), and calcium nitrate (Ca (NO3)2), which are rich in nitrogen. Secondly Phosphate Fertilizers including single superphosphate (SSP) and triple superphosphate (TSP), providing phosphorus to enhance root development and flowering. We also have Potassium Fertilizers which include potassium chloride (KCl) and potassium sulphate (K2SO4), which are essential for regulating water use in plants. Then lastly Compound Fertilizers and these fertilizers contain a combination of Nitrogen, Potassium and Phosphate, allowing for a more balanced nutrient supply in one application, such as NPK fertilizers (Srinivas et al., 2017). While inorganic fertilizers are beneficial for increasing crop yields and food production, their use can lead to environmental issues when not managed properly, such as nutrient runoff, soil degradation and water pollution (Withers et al., 2014). Therefore, careful management, including proper application rates, timing and use of bio stimulants is crucial to minimize negative impacts on ecosystems.

CHAPTER 3: MATERIALS AND METHODS

Research site

The experiment was conducted at Ibis Farm in Mhondoro Rural District under Mashonaland West province of Zimbabwe. The area is mostly covered by red soils with 5.5 – 6.4 pH level and is in natural region 2 which receives an annual rainfall of 700mm – 1000mm per year and have moderate temperatures of 27 degrees C. The altitude of this site is 1505m.

Experimental design

The trial was laid down as a randomized complete block design. There were five treatments replicated four times giving a total of 20 experimental units. The trial plots will be set up in four blocks with five different treatments. Treatment 1 is control, treatment 2 is fertiliser only, treatment 3 is fertiliser and Kynohumate Black, treatment 4 is fertiliser and Kynofulvate Yellow, treatment 5 is fertiliser, Kynofulvate Yellow and Kynohumate Black.

Land preparation

The land was prepared using the convectional tillage method which uses both primary and secondary tillage tools. It was tilled with a reaper to break clods. A disk plough and a roller then followed to make the soil fine and tilth. The farm measured 10m by 30m and ploys were made measuring 1m by 3m.

Planting

Choose of variety of the potato (Shangani) and planting it, took place during the early days of December 2024. The machine was fine tuned to meet the demands of the seed variety, which was used, and the calibrations produced a planting plant depth of 10m for a conducive germination of the seed and it was planted facing upwards.

Germination

The emergence of the seeds on all sites was absolutely on point with an approximately 97% germination percentage within a space period of 14 days after planting. All treatments had sprouted already showing some green shoots. The seed leaves were now starting to emerge as the stem also began to elongate whilst the roots developed.

Irrigation of potatoes

Despite the rains which once stroke very heavily just soon after planting, the researcher was being helped by a systematic drip irrigation which was mechanically oriented, and this reduced unnecessary water wastage since the water was just going straight to the plant at a specific given time and space. Irrigation was done at different intervals. During the first 2 weeks it was being done after every 2-4 days if the temperatures were high and every 4-6 days during cool and wet weather at a rate of 15-25 mm per irrigation event. A scheduled frame was then created to help to know when to irrigate different levels of water at different stages of growth.

Fertilization.

A basal dressing of potato blend 6:28:23 was used at a rate of 1000kg/ha across all treatments. Ammonium nitrate 34.5% was then applied at a rate of 200kg/ha with a split application of 3 and 5 weeks after emergency. Another split application of Calcium Nitrate at 100kg/ha with a split application of 75kgs before second ridging and 25 kg , 3 weeks before lifting. Then lastly Pottasium Nitrate at 300kg/ha at a split of 4, 8 and at 12 weeks after emergence. Our bio stimulants were applied as KynoHumate Black at a rate of 35l/ha and KynoFulvate Yellow at 5l/ha being applied after every 4 weeks as fertigation.

Scouting.

It was performed two times per week to check if there was any disease or pest that was gaining stage during the experiment. This was done starting from emergency up to the harvesting stage. During the process some other pests were found migrating and they were controlled upon discovery.

Harvesting

After reaching the matured stage, the potatoes were harvested using a tractor reaper to unfold them from the ground. They were then collected, graded, cleaned, packed and stored depending on different specific parameters.

Data collection.

For data collection, random sampling method was used whereby there was random counting of number of tubers per stem and number of stems per plant. Every plant had an equal chance to be selected to avoid bias after 4 and 6 weeks.

Number of stems per plant

Just after 4 weeks and 6 weeks of plant emergency, data was already starting to be collected using a random selection on plants on each plot sampling an average number of 10 plants. After the selection, a physical count would then follow to determine the results.

Number of tubers per stem.

The plants which were selected after a randomly selecting method, were the ones which were unfolded from the ground to have access to the tubers to see how they were performing underground. On every stem per plant, tubers were counted, and 10 plants were selected. This data was collected from 6 weeks after plant emergency.

Size distribution of tubers.

This was done after 12 weeks of plant emergence. Selected plants were actually uprooted completely from the ground and the tubers were measured using a 30cm ruler to have a detailed length size.

Size of tubers.

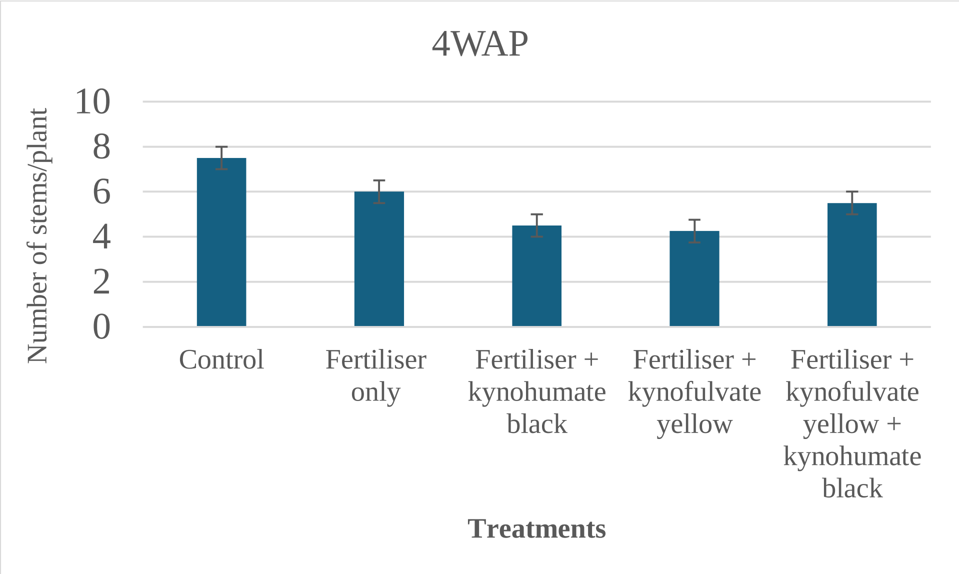
10 plants were randomly selected on different treatment to obtain the data needed. A scale was then used to ensure the weight of tubers, and a record was made afterwards. This was archived on the day of harvest of the potato plant.

Data analysis and presentation

Data collected during the experiment was subject to analysis of variance using GenStat package 17th edition version. Graphs and tables are used to present the results.

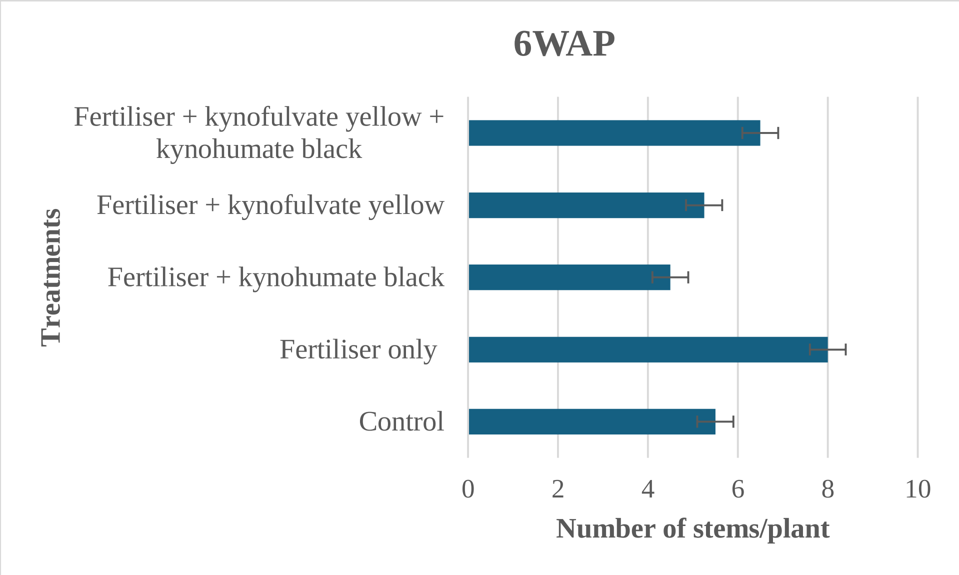
CHAPTER 4: RESULTS

Effects of bio-stimulants and commercial fertilisers on the number of stems per plant in potatoes at 4WAP



There was a significant difference ($P<0.05$) on the effects of bio-stimulants and commercial fertilisers on the number of stems per plant in potatoes at 4WAP**.** Treatment 1(control) had the highest mean of the number of stems per plant (7.50) followed by treatment 2 (fertiliser only) with 6.00

Effects of bio-stimulants and commercial fertilisers on the number of stems per plant in potato at 6WAP



There was a significant difference (P<0.05) on the effects of bio-stimulants and commercial fertilisers on the number of stems per plant in potatoes at 6WAP**.** Treatment 2(fertiliser only) had the highest mean of the number of stems per plant (8.0) followed by treatment 5 (fertiliser + Kynohumate black + kynofulvate yellow) with 6.5 stems per plant**.**

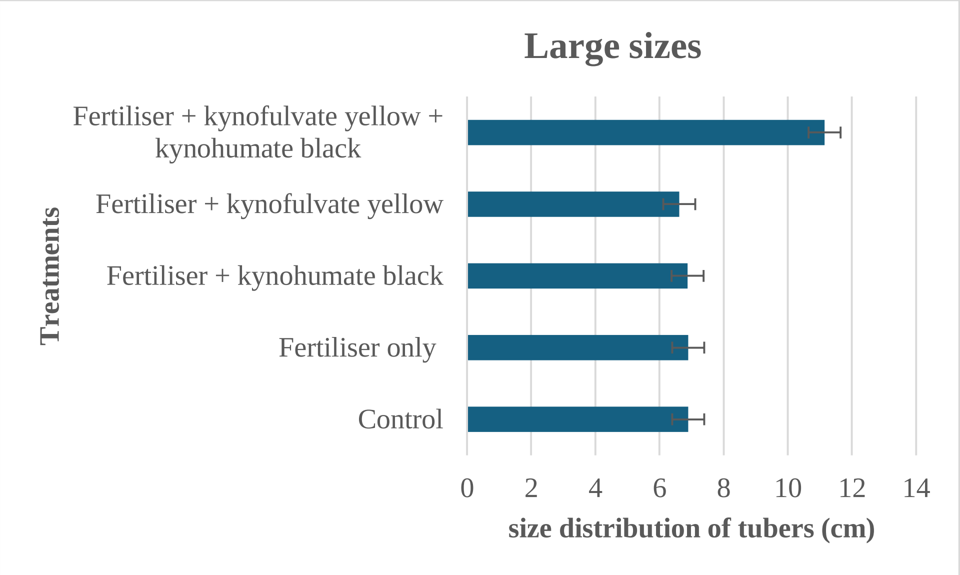
Effects of bio-stimulants and commercial fertilisers on the number of tubers per plant in potatoes

Treatment	**Number of tubers per plant 4WAP**	**Number of tubers per plant 6WAP**
1	3.55*b*	8.80*b*
2	4.00*b*	6.47*c*
3	3.28*b*	7.00*c*
4	2.93*b*	7.05*c*
5	6.65*a*	11.2*a*
p-value	0.532	0.0275
Cv/%	30.8	20.0
L.S.D	1.580	2.246

Means followed by the same letter are not significantly different.

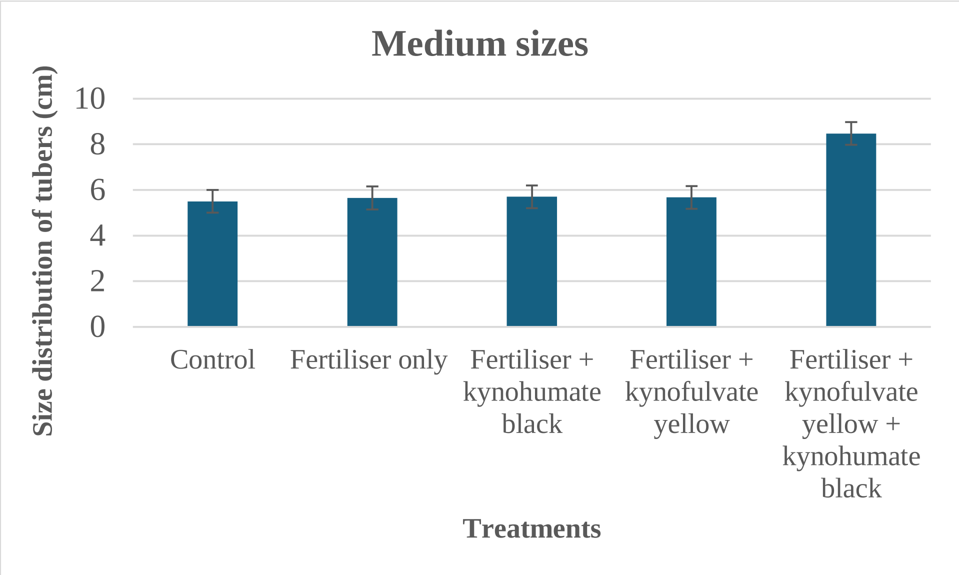
There was a significant difference ($P<0.05$) on the effects of bio-stimulants and commercial fertilisers on the number of tubers per plant in potatoes on the number of tubers per stem at 6 weeks. Treatment 5 (fertiliser + Kynohumate black + kynofulvate yellow) had the highest mean number of tubers per stem (11.20).

Effects of bio-stimulants and commercial fertilisers on the size distribution of tubers in potato on large sizes



There was a significant difference ($P<0.05$) on the effects of bio-stimulants and commercial fertilisers on the size of distribution of tubers of potatoes specifically for large sizes. Treatment 5(fertiliser + Kynohumate black + kynofulvate yellow) had the highest mean of the size distribution of tubers (11.15 cm)

Effects of bio-stimulants and commercial fertilisers on the size distribution of tubers in potato on medium sizes



There was a significant difference (P<0.05) on the effects of bio-stimulants and commercial fertilisers on the size of distribution of tubers of potatoes specifically for medium sizes. Treatment 5(fertiliser + Kynohumate black + kynofulvate white) had the highest mean of the size distribution of tubers (8.475 cm).

Effects of bio-stimulants and commercial fertilisers on the tubers weight in potato

Treatment	**Tubers** weight **(Large)** (kg)	**Tubers** weight **(medium)** (kg)	**Tubers** weight **(small)** (kg)
1	7.45*b*	3.48	1.50
2	7.07*b*	3.85	1.45
3	6.45*b*	3.28	1.42
4	8.02*b*	4.38	1.55
5	10.4*a*	3.80	1.52
p-value	0.010	0.351	1.32
Cv%	20.5	22.9	8.8
L.S.D	2.163	1.290	0.6126

Means followed by the same letter are not significantly different.

There was a significant difference (P<0.05) on the effects of bio-stimulants and commercial fertilisers on the tubers weight specifically on large sizes of potatoes. Treatment 5(fertiliser +

Kynohumate black + kynofulvate yellow) had the highest kg with 10.4kgs followed by treatment 4 (fertiliser + kynofulvate yellow) with 8.02kgs.

CHAPTER 5: DISCUSSIONS.

Effects of fertilizer and bio stimulant on number of stems per plant.

At 4 and 6 weeks after planting, noticeable differences were observed in the number of stems per plant that had been subjected to varying applications of bio stimulants and fertilizers. In this study, the control treatment and fertilizer only at week 4 and 6 respectively, had the best results in this field experiment, and this can be due to soil type that the potatoes were grown. Also, according to Khan, M. A., et al. (2008), excessive fertilizer application can lead to nutrient imbalances, toxicity and reduced plant growth. This was also supported by the work of Marschner, H. (2012), who stated that imbalanced nutrient supply when supplying fertilizers or bio stimulants leads to reduced growth. Bio stimulants at inappropriate quantities can cause plant stress which may at some point inhibit growth making the control treatment appear better in some cases. All in all, the over application, application errors, environmental stressors can all lead to situations leading to control treatments performing the best.

At week 6 the fertilizer performed the best to support the study of Reddy & Reddy (2019) which stated that fertilized plots reliably outdone controls and bio stimulant treatments since they have a more predictable and substantial impact on potato yield. The study by Ghosh et al. (2017) also demonstrated that fertilized plots yielded 20-30% higher production than plots treated with bio stimulants alone. The fertilizers enhances nutrient uptake, leading to better plant growth as well as efficiently providing macro and micro nutrients crucial for optimal potato growth.

Effects of fertilizer and bio stimulants on the number of tubers per stem.

The application of fertilizers and bio stimulants can significantly enhance the number of tubers per stem in potato productions. This is due to the provision of essential nutrients needed for growth by fertilizers for example, according to Olsen et al., 2021, who stated that the phosphorus found in fertilizers is vital for early stages of tuber development promoting root and tuber initiation by enhancing cell division and expansion in the developing tubers. On the other hand, bio stimulants improve nutrient uptake and plant health leading to increased tuber yield per ha. This was also proven by the studies done by Bashan et al., 2017, which stated that bio stimulants produce plant growth promoting Rhizobacteria which enhance nutrient uptake and improve root development which increase the number of tubers per stem. Despite all of that, Johnson and Lee 2017, pointed out that the overuse of fertilizers, especially nitrogen can lead to vegetative growth at the expense of tuber initiation resulting in few tubers per stem or irregular development. Martinez et al 2021 also proved that the effectiveness of bio stimulant on increasing tuber number per stem is inconsistent across cultivars and environmental conditions which some cases showing no significant effect or even reduced tuber numbers due to hormonal imbalance.

The treatment of fertilizers and all bio stimulants outperformed and this was also likely due to the combination of the fertilizers and all the bio stimulants since the humic acid found in the KynoHumate Black® which have an auxin like effect on plants that promotes development as well as the fulvic acids from the KynoFulvate Yellow that have got the ability to transport metal ions like Fe and other micronutrients needed for plant physiology were sponsoring processes like respiration and photosynthesis thereby increasing the number of tubers per stem. However, the control treatment did not perform well above some other treatments, and this was because potatoes are heavy feeders they need nutrients for growth and development, they cannot be sustained by organic matter alone.

Effects of fertilizers and bio stimulants on size distribution of tubers.

Large sizes

There was a significant difference on the effects of bio-stimulants and commercial fertilisers on the size distribution of tubers of potatoes specifically for large sizes. Treatment 5 had the highest mean of the size distribution of tubers (11.15 cm) and this was so because this combination enhances growth hormones as well as metabolic pathways or cell division resulting in increased tuber size. Thereby supporting the work of Kumar et al., which demonstrated that optimum fertilization increased overall tuber yield and shifted the size distribution towards larger tubers. Also, the use of bio stimulants resulted in increased tuber size and a higher proportion of large sized tubers attributed to improved nutrient (Sharma, P., and Singh, R., 2022). It was followed by treatment 1(control) and treatment 2 (fertiliser only) both with 6.90cm respectively. The fertilizer alone treatment may have provided nutrients yet lacking additional growth promoting effects of the humate and fulvate compounds resulting in smaller tubers and the unexpected performance of the control treatment could have been so due to environmental conditions favouring tuber growth even without added nutrients or bio stimulants.

Medium sizes.

There was a significant difference on the effects of bio-stimulants and commercial fertilisers on the size distribution of tubers of potatoes for the medium sizes. Treatment 5 had the best performances throughout the experimental data collection where it was recording an average length of 8.475 cm. The combination of bio stimulants provides and support the metabolic activities of potato crops much better unlike if it is being used alone. However, on the control and other treatments there was no significant difference, and this could have been so due to environmental factors, soil conditions or plant developmental stages that might have been uniform across treatments thereby minimizing differences as supported by Khan, M. R., & Sultana, N. (2018). Also excessive reliance on chemical fertilizers raises sustainability issues and their long term effects can alter soil health, potentially impacting tube development negatively over time leading to small and medium sizes in potato distribution.

Effects of fertilizers and bio stimulants on size/yield of tubers in potatoes.

There was a significant difference on the effects of bio-stimulants and commercial fertilisers on the tubers weight specifically on large sizes of potatoes. Treatment 5 had the highest kgs with 10.4kgs followed by treatment 4 with 8.02kgs. This could have been so due to the promotion of root growth by humic acids in KynoHumate Black as well as the combination of both bio stimulants which improved chelation and availability of nutrients supplied by fertilizers, leading to better assimilation and growth. This is supported by the work of Singh and Singh (2020), which stated that, the combination of organic fertilizers and bio stimulants resulted in increased tuber size and yield, attributed to improved soil health and nutrient availability. Despite that much evidence, Johnson et al., (2015) also highlighted that many bio stimulants lack standardized formulations and efficacy data, leading to variable results and scepticism about their consistent benefits on tuber size and yield.

On medium sizes of potatoes, treatment 4 had the highest weight of tubers (4.38kgs) and on small sizes of potatoes, treatment 4 had also the highest tubers weight (1.55kgs). There was no significant difference on the means of all the treatments on both medium and small sizes of potatoes could have been due to the effects of bio stimulants which may influence other parameters as total yield or plant health as well as some soil conditions and other environmental variables that may have overshadowed treatments effects on tuber sizes Fernández, A., & Moreno, F. (2012).

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

Conclusion

Throughout the study, broad evidence has been proven that bio stimulants greatly play a pivotal role in potato production. The usage of both fertilizers and bio stimulants produced an increased number of stems per plant, number of tubers per stem, size distribution of tubers and size of tubers. This was practically due to several factors. The KynoFulvate Yellow have got fulvic acids that benefits all crops particularly during the establishment phase and during periods when climatic stress is expected and whenever nitrogen is needed. The fulvic acid also increase the concentration of amino acids inside the cell which enable plants to continue growing and to develop under water stressed conditions. They can also be mixed with a range of fertilizer solution as they are compatible with both alkaline and acidic solutions. However, a local testing is recommended. The KynoHumate Black® plays a huge role during the establishment phase and during periods when climatic stress is expected. It also controls nutrient availability, affecting plant physiology and composition of micro-organisms in the rhizosphere. This being told, an automatic increase in tubers size is archived and it promotes an increase in tonnage of potatoes per hectare.

Recommendations

The government must inspire and sponsor research institutions to do more research and not to be left out in new technological advancement in the global economy of agriculture. It must as well be linked with Global agricultural research organization such as the International Potato Centre which recommend ongoing research into bio stimulants and their integration into conventional farming. The researcher also recommends farmers to make use of specific crop guidelines which provides recommendations for potato production regarding the use of fertilisers in conjunction with controlled amounts of bio stimulants. Also, the adoption of sustainable agricultural practices which encourages the use of bio stimulants to reduce dependency on inorganic fertilizers which mitigate environmental impacts. He also recommends policy makers to develop a framework that supports the use of bio stimulants to enable farmers to transit from high chemical fertilizer dependency. Lastly, I recommend agricultural agencies to advocate for International Nutrient Management approaches that combine organic fertilizers, bio stimulants and inorganic fertilizers for sustainable crop production.

Area for further research.

This study recommends further research to figure out how the repeated application of bio stimulants versus compound fertilizers affects soil microbial diversity, nutrient cycling and overall soil fertility over multiple growing seasons. This environment impact assessment will help to evaluate the environmental footprints such as leaching and greenhouse gas emission. Also, apart from including optimum application and dosage, to maximise yield, a study of the interaction with other agronomic practices such as irrigation regimes, crop rotation and pest management needs to be taken into consideration.

References

1. FAO. (2020). The State of Food Security and Nutrition in the World 2020. Food and Agriculture Organization of the United Nations.

2. ZimStat. (2021). Agricultural Production Statistics, Annual Report. Zimbabwe National Statistics Agency

3. Bardgett, R. D., Caruso, T., & Handa, I. T. (2014). Aboveground-belowground interactions in terrestrial ecosystems: patterns, mechanisms, and feedback, Journal of Ecology.

4. Chikowo, R., Nyagumbo, I., & Zingore, S. (2021). Nutrient dynamics and crop response to soil amendments in smallholder farming systems in Zimbabwe. Agronomy Journal.

5. Zingore, S., Chikowo, R., & Nyagumbo, I. (2019). Tailored nutrient management strategy for potatoes: Impacts on yield and soil health in Zimbabwe. Field Crops Research.

6. Meyer, W. S., Tan, H., & Nelson, P. N. (2019). The role of inorganic fertilizers in global food security: Achievements and challenges. Food Security.

7. O'Neill, K., Harwood, J., & Keating, J. (2021). The impact of bio stimulants on crop growth and nutrient uptake under abiotic stress conditions. Agricultural Biology

8. McGill, W. (2009). The World Potato Economy: Trends and Future Prospects, Journal of Agricultural Science.

9. Purdue University. (2021). *Potato Facts*. Retrieved from [Purdue University website] (https://www.purdue.edu/potatofacts

10. Grafton, R. Q., et al. (2015). "Global food security and the role of agricultural investment." Food Security

11. Khan, M. R., & Sultana, N. (2018). Impact of environmental factors on the performance of plant growth promoters. Journal of Plant Nutrition, 41(12), 1565-1578.

12. Smith, J., Nguyen, T., & Patel, R. (2020). Synergistic effects of combined bio stimulants on plant metabolic pathways and growth responses. Journal of Plant Growth Regulation, 39(4), 1234-1245. https://doi.org/10.1007/s00344-020-10123-4

13. Fernández, A., & Moreno, F. (2012). Influence of soil properties and environmental conditions on crop response to fertilization. Agricultural Systems, 113, 48-56. https://doi.org/10.1016/j.agsy.2012.04.006