BINDURA UNIVERSITY OF SCIENCE EDUCATION

DEPARTMENTOF CROP SCIENCE

EFFECTS OF COMPOUND D AND AMMONIUM NITRATE FERTILIZER APPLICATION RATE ON GROWTH AND YIELD OF SC513 MAIZE VARIETY

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TO FULFILL THE REQUIREMENTS FOR A BACHELOR OF AGRICULTURAL SCIENCE HONOURS DEGREE IN CROP SCIENCE, THIS DISSERTATION WAS SUBMITTED AS A PARTIAL FULFILLMENT OF THE NECESSARY CRITERIA

(July 2023)

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DECLARATION

I Mandipiwa Felix. K do hereby declare that this dissertation was the result of my own original efforts and investigations, and such work has not been presented elsewhere for any degree or any university program. All other supplementary sources of information have been acknowledged by means of references.

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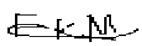
Signature: …….  ……….

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CERTIFICATION OF THE DISSERTATION

Bindura University of Science Education

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The undersigned certify that they have read and recommend to the Bindura University to accept a dissertation entitled:

EFFECTS OF COMPOUND D AND AMMONIUM NITRATE FERTILIZER APPLICATION RATE ON GROWTH AND YIELD OF SC513 MAIZE VARIETY

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In partial fulfilment of the requirements for the Bachelor of Science Honours Degree in Agriculture.

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DATE ....03/07/2023...

DEDICATION

This research study is dedicated to my mother, Emma Zimuto, my sister, Florence Mandipiwa and my brother in law Tendai Nyambuya.

ACKNOWLEDGEMENT

I am immeasurably grateful to the Almighty for providing me with protection and guidance throughout this course, from its beginning to its conclusion. Additionally, I wish to extend my gratitude to my supervisors, Dr. T Goche and Prof. R Mandumbu, for their invaluable assistance in the composition of this dissertation. Furthermore, I would like to convey my appreciation to my associates in Macheke for supporting me with project management in my absence. The support of the Mushandi Home Farm team was also instrumental in my success, and I am deeply grateful for their contribution. Lastly, my family's unwavering financial support has been a beacon of hope, and I am forever grateful for their generosity. God bless you abundantly.

ABSTRACT

The most essential crop to use as food, feed as well as income generation worldwide is maize. As a result, proper management should be practiced to boost production. This research was done at Mushandi Home Farm in Macheke. It was aimed at investigating the effects of compound D in combination with ammonium nitrate fertilizers application rates on growth and yield of maize variety SC513. A randomized complete block design with four treatments of compound D and ammonium nitrate and a control with no fertilizer was used. The fertilizer treatment rates were 0.0kg/ha, 200kg/ha, 350kg/ha, 400kg/ha for compound D and 0.0kg/ha, 200kg/ha, 300kg/ha, 400kg/ha for ammonium nitrate. These treatments were replicated three times to overcome variation due to differences in the soil characteristics and location on the slope. Maize stem height and leaf length were measured in week 2, 3 and 5 whilst cob length was measured in R1, R2 and R3 development stages and grain weight was weighted after harvest and drying. Data on mean plant height, cob length, leaf length, and yield were collected, recorded and analyzed using a one-way ANOVA. Results showed that fertilizer rates significantly increased the growth and yield of maize variety SC513. An application rate of 400kg/ha produced the highest stem height (32.1cm), leaf length (48.93 cm) in the 5^{th} week, cob length (25.17cm) in R3 development stage and grain weight (30.89kgs/9m^2). An application rate of 300kg/ha of fertilizer was recommended for SC513 in this study.

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LIST OF ACRONYMS

ANOVA	Analysis of Variance
AN	Ammonium nitrate
ATP	Adenosine triphosphate
DNA	Deoxyribonucleic acid
LSD	Least Significant difference
NADP	Nicotinamide adenine diphosphate
NPK	Nitrogen phosphorus and potassium
S. E. D	Standard Error of Differences of Means

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Maize (*Zea mays L.*) is one of the most important crops in the world (FAO, 2023). It sustains the food demands of the nations as a result of its high returns. An increment in population and continuous urbanization is cutting short the cultivation area increasing pressure on providing a better living for the people (Peng, 2022). This calls for innovation in the Agricultural sector to meet the demands of the rising population.

Maize provides a growing population with nutritious, safe, and affordable food (Tesfaye *et al*., 2015). In Zimbabwe, white maize is used as the staple food whilst the animal husbandry make use of yellow maize in feeding the livestock (Chikobvu *et al.*, 2010). The consumption rate of maize was estimated at about 110kg per annum for a single family. Therefore, the post approximations of Zimbabwe's yearly maize requirement for house hold feeding lies at around 2.2 million metric tons (Messages, 2022). Again, about 3 metric tons of maize is also required for livestock feed. Thus, the total national demand for corn in 2022 and 2023 is estimated at 1.9 million tons. Since Zimbabwe's has a sluggish financial progression and liquidity limitations, eating patterns are not likely to change rapidly meaning good farming practices should be done to boost production (Esterhuizen, 2018).

The Input Scheme initiated by the president is being utilized by the government of Zimbabwe to enhance maize production. In this initiative, over million small-scale and communal farmers are supported. Through this scheme, the Zimbabwean government distributes free inputs for maize production, including 10kg maize seed, 50kg basal fertilizer, and 50kg top dressing fertilizer. These agricultural inputs are also available on the open markets at the beginning of the seasons, but high prices and limited cash available to purchase the inputs affect most communal farmers. This research aims to promote the efficient use of the farmers' little to produce high yields (Pindiriri *et al.*, 2021).

On the other hand, the Land Reform Program which took place in 2000, Zimbabwe's farming sector underwent a fundamental transformation. The land in Zimbabwe is categorized into different types of ownership, which include communal land, old resettlement areas, A1-farmers' land, small-scale commercial plots, and A2 farmers' land (Chitsike, 2003). The communal farmers are estimated to produce approximately 32% of the maize yield, followed by A2 agrarians at 31% of the maize yield whilst A1 farmers contribute 26% of the maize yield (Chitsike, 2003). Small-scale commercial and previously resettled farmers produce the rest of the maize crop. Communal farmers are already producing in Zimbabwe which means if they are equipped with proper knowledge through this research there will be high maize production reducing grain shortages (Mugabe, 2016).

The land resettlement program, climate change, pests, and diseases have contributed also to the decline of maize productivity in Zimbabwe (Thomas, 2003). This has inversely affected the balance of trade. Zimbabwe is now more of a grain importer than an exporter. This has also resulted in the loss of foreign currency which is necessary for maize farming investment through inputs and farm machinery. However, this research will influence the farmers to adapt to these changes and try by all means necessary to produce more in these challenging times (Thomas, 2003).

Africa's biggest problem is ensuring food security in the region as many countries are facing hunger (Africa Agriculture Status Report, 2013). Numerous aspects are accountable as far as the grain shortages are concerned. Amongst those aspects, incorrect plant nourishment supervision, in addition to deprived topsoil richness in nutrients, remain the utmost significant influences accountable for low yields (Waleed *et al.*, 2009).

1.2 Problem Statement

In most communal areas, subsistence farming is practiced to support the family through food and surplus sales. Even though most families work very hard, it is very difficult to alleviate poverty in these communities. The government has tried to support the subsistence farmers with inputs such as fertilizers and seeds but to no avail. The main cause of these problems is a lack of knowledge on how to use inputs like fertilizers. Farmers tend to be unaware of the importance of the amount of fertilizer to supply their maize crops. On fertilizer application, some communal farmers try to save money by under-fertilizing their crops, some try to maximize the yields by applying too much than required.

1.4 Justification

These challenges have compelled the researcher to ask the question, "What are the effects of using different fertilizer rates on the SC513 maize variety production concerning the growth and yield?" This research will guide farmers on how fertilizer can affect production. Through continuous improvement of the per-unit harvest of maize, a stiff increase in the food consumption can be met, preventing global food shortages. Recommendations on good farming practices will be availed to farmers.

1.4 Main Objective

- To assess how the growth and yield of SC513 maize variety are impacted by compound D and ammonium nitrate fertilizers.

1.4.1 Specific Objectives

- To determine the effects of compound D and ammonium nitrate fertilizer application rate on the growth rate of SC513 maize variety(stem height, leaf length, and cob length)
- To determine the effects of compound D and ammonium nitrate nourishment application rate on the yield of SC513 maize variety(dry weight of shelled grain)

1.5 Hypothesis

- H_0 Compound D and ammonium nitrate fertilizer application rates have no significant effect on growth parameters of maize variety SC513

- H_1 Compound D and ammonium nitrate application amounts significantly affect the growth parameters of the SC513 maize variety.

- H_0 Compound D and ammonium nitrate fertilizer application rates have no significant effect on yield of maize variety SC513

- H_1 Compound D and ammonium nitrate application amounts significantly affect the yield of the SC513 maize variety

CHAPTER 2

LITERATURE REVIEW

2.1 Ecology and origin of Maize

Maize (*Zea mays)* is a domestication of a wild grass teosinte which was found in Mexico and Central America as its center of origin about 9000 years ago (Benson *et al.*, 2017). Since it is highly adaptable and productive, maize spread in Europe and everywhere else worldwide (McCann, 2005). The Portuguese were the first to introduce the maize crop in Africa through trade around the 16th century (Miracle, 1996). Historical records show that maize cultivation started around 1541 in Cape Verde, 1590 in Angola, and 1821 in Mozambique (McCann, 2005). The first maize imports to Southern Africa were the Caribbean and Brazilian flints, consisting of the yellow-to-orange or blue flint variety. In 1890, the White settlers started producing maize in Zimbabwe (Weinmann, 1972). Maize became the staple crop of Southern African people in the 20th century (Hassan *et al.*, 2001).

2.2 The Importance of Maize

Archaeological evidence from the central Andes of Peru shows that maize underwent a significant transformation between A.D. 500 and 1500, becoming a more complex and symbolic food that was processed into beer and had political significance. Maize is a nutrient-rich crop that can be processed into various products, providing employment opportunities (Ryan, *et al.*, 2013).

Maize is a critical crop in Zimbabwe, and the nation requires about 2.1 million metric tons of it to ensure food security(Chikobvu *et al.*, 2010). The majority of corn produced in Africa is meant for human consumption, unlike in developed nations where it is primarily intended to feed the livestock. Although the mean maize production in West and Central Africa is around 1 ton per hectare, it is higher in East Africa, Asia, and Latin America (Kling *et al.*, 1997).

The majority of Grain Marketing Board (GMB) maize sales in Zimbabwe are used for human consumption, with smaller percentages used for livestock and poultry feed and industrial purposes (Cain, 1981). During times of surplus production, Zimbabwe exports maize to earn foreign exchange. Domestic consumers prefer white maize, but in times of emergency, such as droughts, people may switch to yellow maize, which is mainly grown for livestock feed. The value of maize is highly displayed within Zimbabwe and other nations around Africa, as it is a significant basis for animal feedstuff, as well as a staple food crop for human consumption (Cain, 1981).

The current population of Zimbabwe depends heavily on maize production for food, it is the most important food crop in Zimbabwe and is grown by over 80% of the rural population (The Ministry of Lands, Agriculture, Fisheries, Water and Rural Resettlement, 2021). In 2020, the estimated population of Zimbabwe was 14.78 million people (World Bank, 2021).

In Africa, maize is a staple food comparable to rice or wheat in Asia, and it accounts for a significant portion of the calories and protein consumed within the regions of East and Southern Africa (Chikobvu *et al.*, 2010). Within Mesoamerica, maize consumption is particularly high, with some countries exceeding 80 kg per capita annually (CGIAR, 2016). This demand shows that necessary research on yield improvements should be carried out to promote food security worldwide.

2.3 Maize Crop Morphology

Maize is a warm-season grass that is grown annually and characterized by a tall, deep-rooted solitary stalk with long, smooth leaves attached at the stem nodes (Jean du Plessis 2016). The male flower is located at the stalk's end, while the female flowers are borne on the ears that arise at a leaf axle near the midpoint of the stem, with the flower organs and grain kernels enclosed in papery tissue layers known as husks, forming the cob (Jean du Plessis 2016).

The time requirements for maize to mature varies among varieties, with the SC513 maize variety taking approximately 135 days to mature (Seed Co, 2018). Maize kernels are available in various sizes, shapes, and types, with the kernel comprising an outer pericarp and an inner testa or true seed coat, while the endosperm makes up almost 0.66% of the total volume and is primarily composed of starch (Costa *et al.*, 2002).

In most types, the embryo, which contains most of the corn oil, is found near one side of the kernel (Kling *et al.*, 1997). Maize has a delicate root system that can spread laterally up to 1.5 meters and extend downward to approximately 2.0 meters or more, given optimal growth conditions (Jean du Plessis, 2016).

2.4 Fertilizer Requirements for Maize Crop

The key areas of research that are important for improving grain yield include management systems, soil fertility, and nutrient use efficiency (Akasairi *et al.*, 2022). It is also significant to study nitrogen, phosphorus, maize productivity, climate change, and food security. Currently, there is an increased emphasis on researching fertilizer use efficiency, cropping systems, and profitability, with a focus on balancing the use of fertilizers with environmental and economic considerations (Akasairi *et al.*, 2022).

The nutritional status of a soil sample, spacing, as well as the expected yield are the determinants of maize crop nutrient needs. Poorly nourished soils need additional fertilizer, the same as a higher expected maize produce (Benson *et al*., 2017). Maize efficiently produce higher yields in the presence of nitrogen and phosphorous. However, it also needs potassium as well as small traces of zinc in other soils. One the other hand, manure should be the first choice to supply maize nutrition. It is an outstanding source of nutrients as it comes with soil health benefits (Benson *et al*., 2017). Inorganic nutrients can be used as supplement to organic fertilizer. Using the spacing of 90cm by 30cm and fertilizer cup numbers 5, 8, and 12, the fertilizer application rate is 200, 350, and 400kg/ha respectively for basal dressing, and for top dressing, it is 200, 300, and 400kg per hectare (Seed Co, 2017).

2.5 Fertilizer Management for maize Production

To grow and yield high amounts of grain, maize requires fertile soil. However, most tropical soils have low fertility, which can hinder maize production as the crop can exhaust the soil (Amali *et al.*, 2015). The type of crop also affects when and how often fertilizer should be applied, as some crops have a greater need for certain nutrients than others. Maize, for example, is known to require high levels of nitrogenous fertilizer and should be fertilized in week four after crop establishing (Amali *et al*, 2015).

The effectiveness and efficiency of various fertilizer practices for maize depend on multiple aspects, which include soil nature, plant species, weather, as well as availability of irrigation water (Jackson, 1972). On the other hand, nutrient supplies for maize differ at varying developmental phases, and the specific chemical properties of the fertilizer used also play a role. These factors interact with each other, and the most effective way to apply nitrogen fertilizers depends on growth determinants such as soil temperature, soil fertility, and moisture conditions (Jackson, 1972).

Deep placement of nitrogen fertilizers is generally better than shallow or surface placement, and low rates of application of phosphorus fertilizers are most effective when banded near the seed at planting. In areas where larger amounts of phosphorus fertilizer are used, plough-down applications of phosphate are commonly practiced (Jackson, 1972). Leaching or volatilization of N losses can be highly influenced by moisture conditions (Mohammed *et al.*, 2022).

2.6 Literature on Compound D and Ammonium Nitrate

Chemical fertilizers can be grouped into three classes which consists primary fertilizers, secondary fertilizers, and micronutrient fertilizers. These provide the plants with diverse nutrients. Macronutrient fertilizers quantity the primary nutrients, which include nitrogen, phosphorus, and potassium. Macronutrients are exploited in the largest quantities by plants (Repository, 2008).

Compound D is a complex fertilizer that typically contains nitrogen, phosphorus, potassium (NPK), and other essential micronutrients. On the other hand, ammonium nitrate fertilizer is a nitrogen-based fertilizer with a high nitrogen concentration. Both fertilizers have been widely used in maize cultivation, and their effects on the crop have been extensively studied (Seed Co, 2017).

A study by Wang *et al*., (2019) found that the application of Compound D significantly increased the height, stem diameter, and leaf area of maize plants. Similarly, investigations by Ali *et al*., (2018) concluded that Compound D significantly increased the growth and yield of maize, with the highest yields observed at a rate of 180 kg/ha.

Phosphorous is present in nucleic acid, phospholipids, DNA, coenzyme such as NADP, and is predominantly found in ATP (Muhitamu, 2008). It triggers coenzymes for amino acid products used in protein synthesis, decomposes carbohydrates produce in photosynthesis, and is involved in many other metabolic processes required for normal growth, such as photosynthesis, glycolysis, respiration, and fatty acid synthesis (Muhitamu, 2008).

Phosphorus is considered a limiting factor in the Zimbabwean soils and its deficiency cause constraints on maize productivity (Chirinda *et al.,* 2014). Phosphorus deficiency in maize plants lead to reduced photosynthetic rates, chlorophyll content, and biomass production, these can be seen through stunted growth, and reddish-purple leaf tips and margin coloration (Mashingaidze *et al.,* 2017). Soil fertility management practices, such as the use of organic fertilizers and crop rotations, can improve phosphorus availability in Zimbabwean soils (Mafongoya *et al.,* 2007).

Another important nutrient for the process of photosynthesis is potassium. Potassium promote disease resistance, it opens and closes the stomata in response to different weather conditions, increase the quality or appearance of fruit crop and increase the oil content of the oil crop (Muhitamu, 2008). Potassium deficiency may display yellowing of leaf margin or tips beginning from the older leaves and progressing to tender leaves (Katsvanga *et al.,* 2020). The plant will eventually turns yellow in severe cases, leading falling of lower leaves as well as stunted growth (Muhitamu, 2008). Potassium deficiency is a common problem in Zimbabwean soils and can be addressed through the use of potassium containing fertilizers (Katsvanga *et al.*, 2020).

Ammonium nitrate is amongst the collective nitrogen containing nourishments which have half of their nitrogen in the ammonical formula and the remainder in the nitrate formation (Gowariker *et al.,* 2009). Ammonium nitrate is instantly accessible by plants whereas ammonical nitrogen needs nitration before uptake by plants. Maize, like other plants, takes up nitrogen mainly in the form of nitrates, making ammonium nitrate more suitable for top-dressing maize (Gowariker *et al.,* 2009). Since nitrogen is a building block of amino acids which manufacture proteins and other associated complexes, it participates in nearly every metabolic processes taking place in plants. Nitrogen is also an essential part of chlorophyll production through the process of photosynthesis. Indications of nitrogen shortages are initially seen on the lowest leaves. The tips on lower leaves then turn brown, and then disintegrated before dropping off. (Gowariker *et al.,* 2009).

Ammonium nitrate top dressing has also been revealed to significantly influence maize growth and production. An investigation by Sillanpää *et al.,* (2018) reported that using ammonium nitrate fertilizer meaningfully increases maize yield, with the maximum yield observed at a rate of 150 kg/ha. Similarly, a study by Lu *et al*., (2017) proved that using of ammonium nitrate fertilizer significantly increased the height, stem diameter, and leaf area of maize plants.

A limited amount of nitrogen can decrease light interception by reducing the leaf area index leading to reduced yields (Basso *et al.,* 2005). However, too much of nitrogen and reduced soil moisture content was found greatly disturbing yields.

Belay and Adare, (2020) also conducted a field experiment for two successive years to assess the reaction of growth, yield components, and yield of hybrid maize diversities to recently introduced blends of nitrogen, phosphorus, sulfur and nitrogen1fertilizer rates. This research focused on new rates of fertilizer but not those in current use and how they are being used by farmers. In another research, Kovar, (2021) assessed the response of maize to Sulphur using, different rates. However, this research could not compare the increased rate of Sulphur to a standard or recommended rate to which the farmers can easily see how the rates they use can impact their productivity.

Bakhtiari *et al.*, (2014) also assessed the effects of nitrogen fertilizers concerning economics, which is the cost of production and the returns or profit per increase rate. Again, this research focused on one nutrient rate but maize also requires phosphorus, and potassium which can affect maize production when their rates are altered, that will be considered in this research considers that.

Excessive use of ammonium nitrate and other fertilizers can lead to environmental pollution, such as the contamination of water bodies with nitrates. Therefore, it is essential to use fertilizers in appropriate amounts to avoid negative environmental impacts. In conclusion, the use of enrichers for instance Compound D and ammonium7nitrate significantly aid the increment on growth rate and yield of maize but, it is important to use fertilizers in appropriate amounts to avoid negative environmental impacts. Further studies are needed to define the best application rates of these fertilizers for each maize variety cultivated under different soil and climatic conditions.

2.7 The Level of Maize Production in Zimbabwe

African food production has not competed with population increase, and efforts to increase per capita production levels have been a primary focus of food security strategies (Rohrbach *et al*., 1989). National policies have prioritized food self-sufficiency goals, while issues of household-level food access have received less attention. However, even with high levels of per capita food supply, many households and individuals still lack reliable access to nutritionally adequate food, particularly in rural areas and among the urban poor (Rohrbach *et al*., 1989).

Maize production efficiency in Zimbabwe has received little attention. Maize serves as primary plant. It is used as household food and employment generation. However, its production has been declining, and Zimbabwe has transitioned from exporter to importer of grain since 2001 (Tawonezvi *et al.*, 2004). Currently, there is a decline in food sustainability which is generally as a result of poor food access, resulting from high food costs and reduced wages and salaries due to the skyrocketing inflation (FAO, 2023). Again, a decline in cereal production in 2022 has worsened the situation. This has left about 3.8m people in need of food help in Zimbabwe (FAO, 2023). The decline in agricultural output is also attributed to the lack of skills and inefficiency in smallholder farming as compared to large-scale commercial farming. It has been worsened by low soil fertility caused by continuous cropping without replenishing nutrients in communal farming (Ncube *et al.*, 2007).

The main obstacles to increasing maize production in small-scale farming of sub-Saharan Africa is the depletion of soil nutrients as result continued farming without replenishing the nutrients that have been used up (Rusinamhodzi *et al.*, 2011). This is a widely recognized issue and has been discussed in various studies, including those by Breman *et al.*, (2003), and (Sanchez, 2015). Although there are different estimates of the current use of nutrients, they are all relatively low. In fact, in most countries, the combined application of nitrogenous, phosphorus, and potassium (NPK) nutrients in form of organic as well as inorganic fertilizers is less than 10 kg per hectare (ten Berge *et al.*, 2019).

The quality of the season significantly impacts maize produce in Zimbabwe (MoLAWCRR, 2020). The rainfall in the 2020-2021 season began in early November for most provinces, but some experienced a false start in October, which caused farmers to plant again, because of failure of maize as a result of a prolonged dry weather conditions due to abruptly ending of the rainy season in late February to early March throughout the country (MoLAWCRR, 2020). Overall, there was a good distribution of rainfall in terms of time and location, with more wet spells in Southern as well as central provinces. However, dry weather conditions took place in certain regions. Unfortunately, the experienced rainfall caused nutrient shortages, particularly nitrogen, and induced logging resulting in reduced yields. Additionally, the nitrogen insufficiency worsened as a result high price of nitrogenous4fertilizers. Complete failure of crop was experienced in a number regions (MoLAWCRR, 2020).

Due to unfavorable macroeconomic conditions and recurrent drought, Zimbabwe struggles to meet its maize production targets and often has to buy maize from surrounding nations (Chikobvu *et al.*, 2010). Grain produce of Zimbabwe mainly come from high precipitating zones. However, low grain yield are obtained in drought-prone dry regions. This regions have insufficient rainfall which results in poor harvests and hunger. Farmers in this tend to liquidate their assets to meet household food requirements, leading to underutilization of available land for cultivation (Chikobvu *et al.*, 2010).

On the other hand, high prices of fertilizers is discouraging their use by local farmers. This is resulting in average to low national yield levels (FAO, 2023). It is therefore of great importance to find ways to boost maize yields of Zimbabwe through good agronomic practices.

CHAPTER 3

METHODOLOGY

3.1 Experimental Area

This experiment was carried out at Mushandi Home Farm which is located in Macheke. Mushandi Home Farm is 6 km off the main arterial road in the Valley of Macheke River. The coordinates of the field are (S181^0 18``52' E314$^0$ 97``58`). Macheke is in the Mashonaland East province which is in the ecological region 2a. This farm has an elevation of 1500m above sea level and obtains 750 to 1000mm rainfall annually. Field soils are characterized by loamy sand soils with 72% sand content, 16% clay content, and 12% silt content.

3.2 Experimental Design

A randomized complete block design (RCBD) with three replicates was used. The treatments included different application rates of Compound D and ammonium nitrate fertilizer, as well as a control treatment with no fertilizer. The factor in consideration was different compound D and Ammonium nitrate (AN) application rates. The treatments for compound D were, 400 kg/ha, 100% (11g per station), 350 kg/ha, 87.5% (10g per station), 200 kg/ha, 50% (10g per station), and 0.0 kg/ha (0.0 per station). The treatments for ammonium nitrate, 400 kg/ha 100% (11g per station), 300 kg/ha 75% (8g per station), 200 kg/ha 50% (5g per station), and 0.0 kg/ha (0.0 per station) as control, were used. The rates were named as T1 to T4 where T1 is the control and T4 had highest fertilizer rate. The split application method was used on ammonium nitrate and it was hill placed next to the plants.

3.3 General Management

Land preparation was done using a disc harrow and disc plow to achieve a depth of 3cm. A hole was used to make raised beds of 3m×1m in size, and 12 beds were made. Each bed represented a plot for a treatment. Planting stations were made using a spacing of 90cm inter raw and 30cm in row to provide a total of 37 000 maize plants in a hectare, in this case, a total of 240 plants were planted on 12 plots. Compound D was applied at planting and ammonium nitrate after germination. Weed management and pest control were also practiced during this experiment.

3.4 Data Collection

To assess the growth and yield effects due to varying application amounts of compound D together with Ammonium nitrate, results were collected on various growing as well as yield components, including stem height, leaf1length, cob length, and grain weight. The data was collected at regular intervals throughout the growth cycle of maize. A random sampling method was used and 4 plants were measured for each plot. Plant height and leaf length were measured in week seek 2, 3, and 5 after germination whilst cob length was measured 3 times a week after the set to the hard dough stage, that is at R1, R2, and R3 stage and grain weight was recorded after harvesting and shelling.

3.4.1 Stem Height

Stem height was measured using a tape measure and 5 plants were measured on each bed. The plants were measured starting immediately above ground to the uppermost point of the arch of the topmost leaf with its tip facing down.

3.4.2 Leaf Length

A tape measure was also used to measure the leaf length. The tape measure was stretched along the leaf blade from the node to the leaf tip. Leaves of the same level were chosen from four randomly chosen plants on each plot.

3.4.3 Cob Length

Cob length was measured a week after the cob was set to the hard dough stage using a 30cm rule. Again, four plants were selected at random per plot, calculating their average which were recorded for each treatment.

3.4.5 Yield

The yield was weighed using a scale. Five cobs were harvested at random per plot, shelled and sun dried before being weighted. An average grain weight for each treatment was calculated and recorded in the data collection sheet.

3.5 Statistical Data Analysis

The observed results were subjected to a one-way analysis of variance (ANOVA) by means of statistical software GenStat 18th edition. Means differentiation was carried out via the least significant difference (LSD) test at 0.05 significant level.

CHAPTER 4

RESULTS

4.1 Effects of fertilizer rate on maize stem height in week 2

There was a significant difference in the maize stem height ($p<0.001$). Treatment 4 with 400kg of compound D and ammonium nitrate had the highest stem height. The control treatment produced the lowest maize stem height as shown in (Figure 4.1)

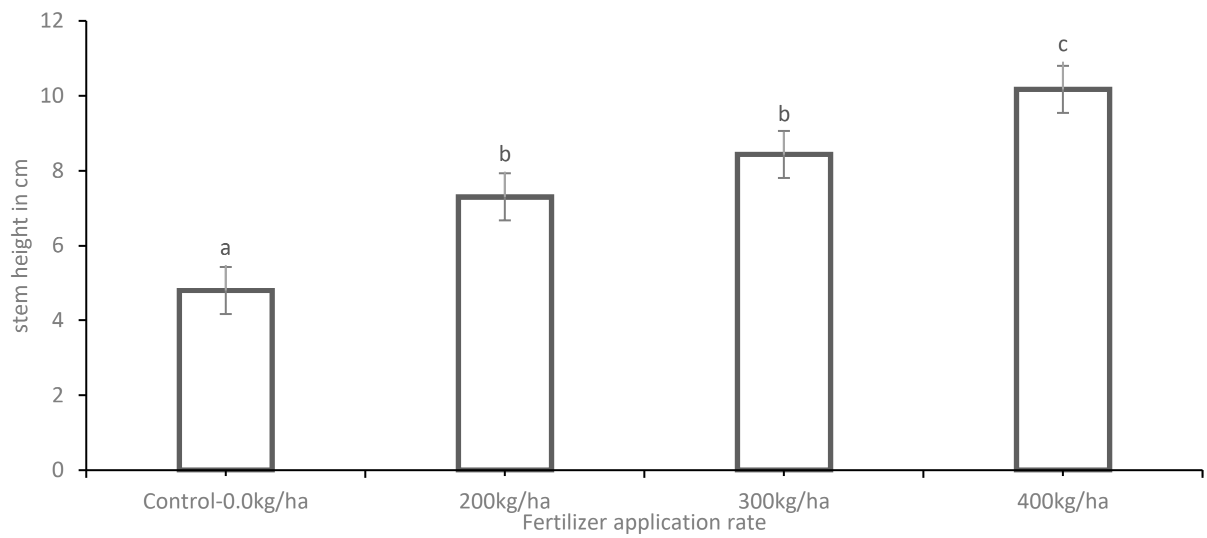

Figure 4.1 The effects of fertilizer application rates on stem height in week 2. Bars represent the mean stem of SC513 maize variety at week 2, calculated from 3 replicates for each treatment. The error bars represent the mean +/_ standard error of difference of means (s.e.d) (n=15). Statistical analysis was done using one-way ANOVA on GenStat 18th edition.

4.2 Effects of fertilizer rate on stem height in week 3

Fertilizer application rates caused a significant difference on the mean stem height of SC513 maize variety in the third week after germination ($p<0.011$). As the fertilizer rates increased, the stem height also increased. The control with no fertilizer obtained the lowest stem height as shown in (Table 4.1)

Table 4.1 Effects of different fertilizer rates stem height in week 3

Treatment	mean height(cm)
Control (0.0)	13.3[a]
200 Compound D, 200 AN (Kgs)	21.1[b]
350 Compound D, 300 AN (Kgs)	25.4[b]
400 Compound D, 400 AN (Kgs)	28.1[b]
$p<0.011$	
LSD 7.26	

4.3 Effects of fertilizer rates on maize stem height week 5

There is also a significant difference between the mean stem heights of SC513 maize variety in week 5 ($p=0.002$). Highest mean stem height was recorded in treatment 4 whilst the lowest stem height was recorded in the control (Table 4.2). There was no significant difference between treatment 2, 3 and 4.

Table 4.2 Effects of different fertilizer rates on stem height in week 5

Treatment	mean height(cm)
Control (0.0)	13.67[a]
200 Compound D, 200 AN (kgs)	21.67[b]
350 Compound D, 300 AN (kgs)	26.33[b]
400 Compound D, 400 AN (kgs)	32.10[b]
P=0.002	
LSD 6.288	

4.4 The Effects of Fertilizer Rate on Leaf Length Week 2

There is a significant difference in the leaf length (P<0.002) among the different treatments of compound D and ammonium nitrate. 400 Kgs of Compound D and Ammonium nitrate produced the longest leaves of SC513 maize variety in week 2. As the fertilizer rate increased the leaf length also increased significantly (Figure 4.2).

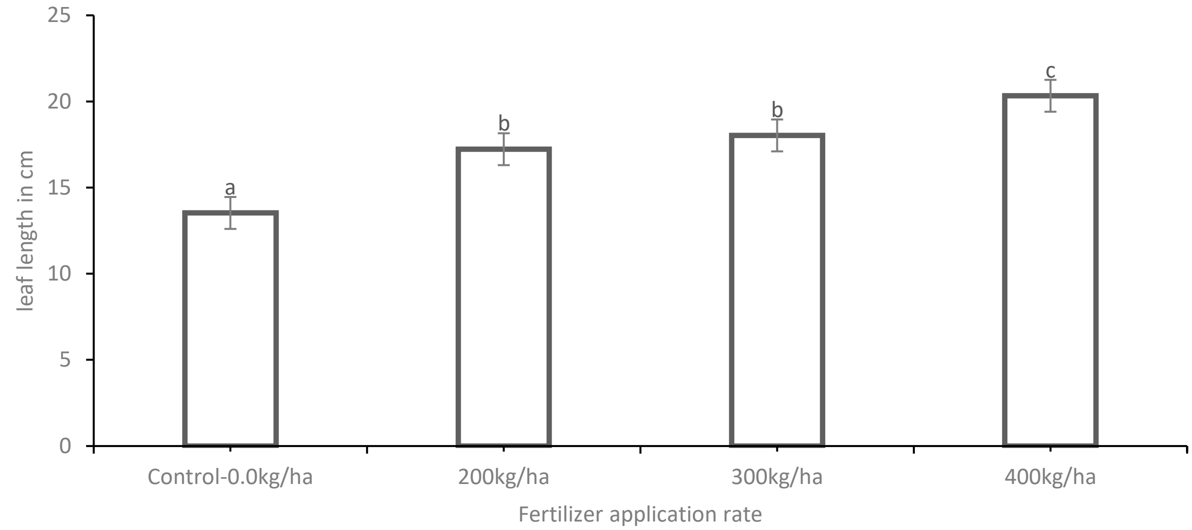

Figure 4.2 The effects of fertilizer application rates on leaf length in week 2 after planting. Bars represent the mean leaf length of SC513 maize variety at week 2, calculated from 3 replicates for each treatment. The error bars represent the mean +/_ standard error of difference of means (s.e.d) (n=15). Statistical analysis was done using one-way ANOVA on GenStat 18th edition.

4.5 The Effects of Fertilizer Application Rate on Leaf Length Week 3

There was a significant difference in the maize leaf length in week 3 ($p<0.001$). An increase in the rate of Compound D and ammonium fertilizer was inversely proportional to leaf length. The highest rate obtained the longest leaf length as compared to the control with short leaf length. However, there was no significant differences on the length of leaf in treatment 2 and 3 (figure4.3).

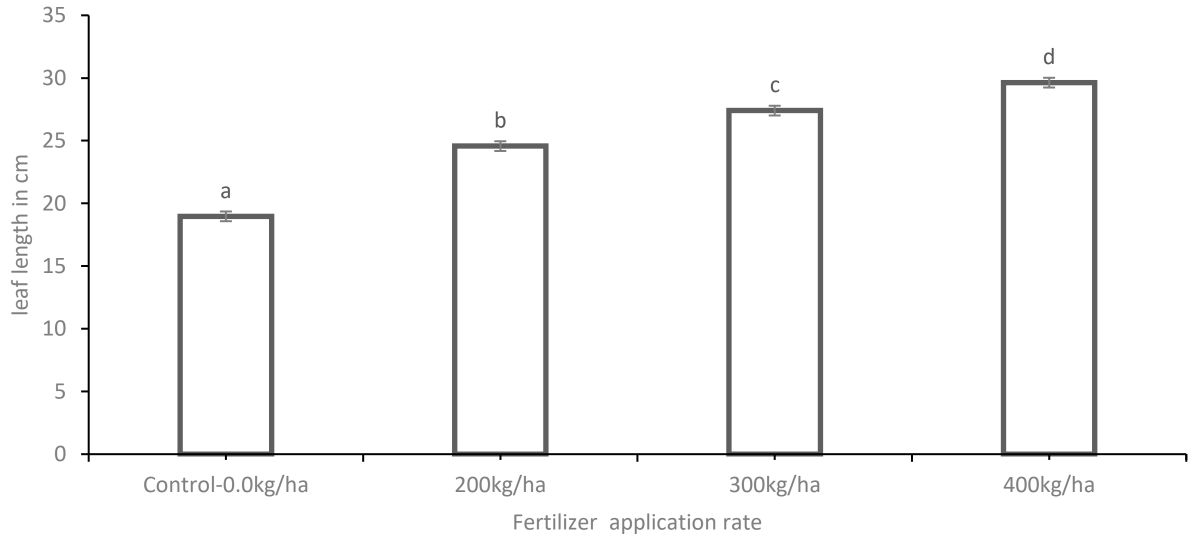

Figure 4.3 The effects of fertilizer application rates on leaf length in week 3 after planting. Bars represent the mean leaf length of SC513 maize variety calculated from 3 replicates for each treatment, at week 3. The error bars represent the mean +/_ standard error of difference of means (s.e.d) (n=15). Statistical analysis was done using one-way ANOVA on GenStat 18th edition.

4.6 The Effects of Fertilizer Application Rate on Leaf Length Week 5

There was a significant difference among the different fertilizer application rate on leaf length of SC513 maize variety ($p<0.001$) at 5% significant level. Lowest leaf length was recorded in the control treatment and it increased as the rate increase in treatments 2, 3 and 4 (Table 4.3).

Table 4.3 Effects of different fertilizer rate on leaf length in week 5

Treatment	mean length(cm)
Control (0.0)	24.467^{a}
200 Compound D, 200 AN (kgs)	39.000^{b}
350 Compound D, 300 AN (kgs)	45.100^{c}
400 Compound D, 400 AN (kgs)	48.933^{d}
P<0.001	
LSD 0.65197	

4.7 The Effects of Fertilizer Application Rate on Cob Length at R1 stage

There was a significant difference on the cob length of SC513 maize variety (P<0.001) at R1 developmental stage. Treatment 4 achieved the highest cob length followed by treatment 3 and 2. Treatment 1 had the lowest cob length. Cob length increased as fertilizer rate increased (Table 4.4).

Table 4.4 Effects of different fertilizer rates on cob length at R1 development stage

Treatment	mean length(cm)
Control (0.0)	13.50[a]
200 Compound D, 200 AN (kgs)	16.23[b]
350 Compound D, 300 AN (kgs)	17.27[c]
400 Compound D, 400 AN (kgs)	19.43[d]
P<0.001	
LSD 0.911	

4.8 The Effects of Fertilizer Application Rate on Cob Length in R2 stage

A significant difference was also obtained on the cob length of SC513 maize variety (p<0.001) at 5% significant level in R2 development stage. The cob length was inversely proportional to the rate of fertilizer applied. The control treatment gave the smallest cobs in R2 whilst treatment 4 gave highest cob length (Figure 4.4).

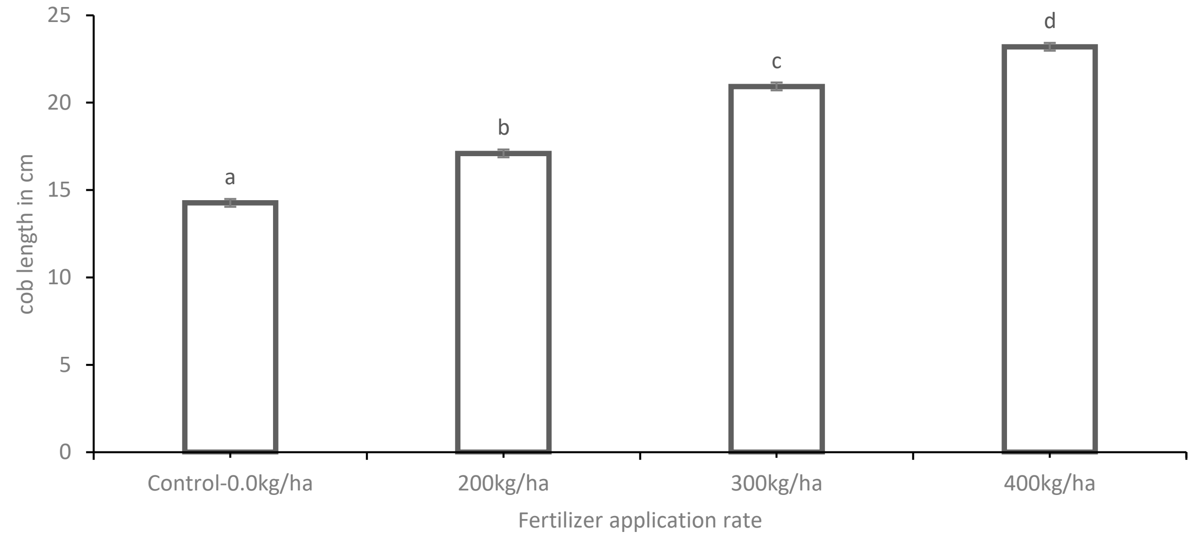

Figure 4.4 The effects of fertilizer application rates on cob length at R2 development stage. Bars represent the mean cob length of SC513 maize variety calculated from 3 replicates on each treatment at R2 development stage. The error bars represent the mean +/_ standard error of difference of means (s.e.d) (n=15). Statistical analysis was done using one-way ANOVA on GenStat 18th edition.

4.9 The Effects of Fertilizer Application Rate on Cob Length in R3 stage

Table 4.8 shows a significant difference of ($p<0.001$) at 5% significant level in the R3 developmental stage of SC513 maize variety on cob length. Treatment 4 with 400kgs had the biggest cobs followed by treatment 3 with 300kgs and then treatment 2 with 200kgs of fertilizer. The lowest cob length was recorded in the control treatment with no fertilizers (Table 4.5).

Table 4.5 Effects of different fertilizer rates on cob length at R3 development stage

Treatment	mean length(cm)
Control (0.0)	15.100[a]
200 Compound D, 200 AN (kgs)	19.667[b]
350 Compound D, 300 AN (kgs)	23.967[c]
400 Compound D, 400 AN (kgs)	25.167[d]
P<0.001	
LSD 0.4578	

4.9.1 The Effects of Fertilizer Application Rate on Yield

There was a significant difference on the yield of maize variety SC513 ($p<0.005$) at 5% significant level after harvest. Treatment 4 with 400kgs per hectare of compound D and ammonium nitrate gave the highest yield followed by an average yield between treatment 3 and 2 and the inferior yield in the control as shown by (Figure 4.5).

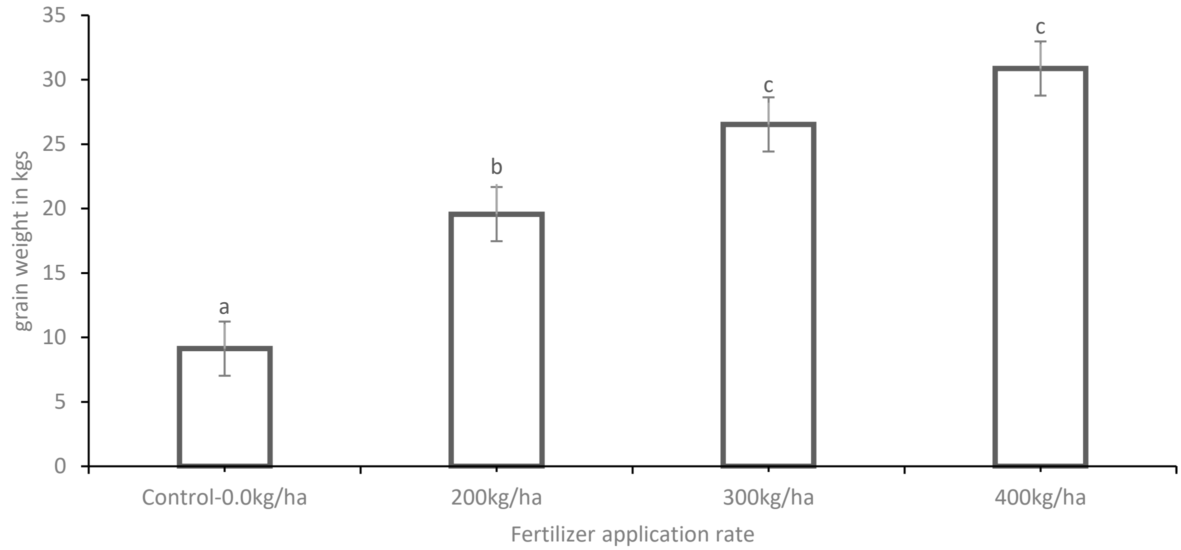

Figure 4.5 The effects of fertilizer application rate on grain weight post-harvest. Bars represent the mean grain weight of SC513 maize variety calculated from 3 replicates for each treatment after harvest. The error bars represent the mean +/_s standard error of difference of means (s.e.d) (n=3). Statistical analysis was done using one-way ANOVA on GenStat 18th edition.

CHAPTER 5

DISCUSSION

5.1 Effects of Compound D and Ammonium Nitrate Rate on Stem Height

This research showed that the fertilizer application rate has a significant effect on the stem height of SC513 maize variety (Figure 4.1). The highest stem height was recorded in the treatment one and two which had 400kg/ha and 350kg/ha of compound D and 300kg/ha ammonium nitrate (Figure 4.1). As the fertilizer rate decreased in treatment 2 and 3 the stem height also decreased significantly. However, there was no significant difference between stem height in 400kg/ha, 300kg/ha, 200 kg/ha application rate (Figure 4.2). The rate 300kg/ha achieved a more economical stem height compared 600kg/ha (Fabunmi, 2010).

Compound D contains 7.14.7 of nitrogen, phosphorus and potassium respectively. This gives total 24.5.49.24.5kg of NPK at 350kg/ha. With high a rate of phosphorus, well-developed root system and large surface area for absorption of water and mineral ions was increased leading to high growth rate of maize plants. It also resulted in high photosynthesis rate due to high yield of ATP and NADPH (Elsworth *et al.,* 2009). Stunted roots have low density and a reduced surface area for absorption of nutrient and water needed for the process of photosynthesis. With reduced photosynthesis reactance, there is reduced growth and development.

5.2 Effects of Compound D and Ammonium Nitrate Rate on Leaf Length

The results showed that the lowest leaf length was recorded in the control treatment with 0.00kg/ha (Table 4.5). This is consistent with the general understanding that plants require nutrients to grow and development (Chikowo *et al*, 2014).

As the application rate of fertilizers increased from 200kg/ha to 400kg/ha, an increase in leaf length was observed (Table 4.5). This could be attributed to the increased availability of nutrients such as nitrogen, phosphorus, and potassium that are essential for plant growth (Mapfumo *et al.,* 2015). Nitrogen, in particular, is important for leaf growth and chlorophyll synthesis, which are essential for photosynthesis and plant growth (Giller *et al.,* 2011).

The highest leaf length was observed at 400kg/ha, which suggests that beyond this point, the effect of fertilizers on leaf growth may remain constant (Table 4.4), excessive fertilizer application can lead to nutrient imbalances and toxicity, which can negatively impact plant growth and yield (Tavirimirwa *et al.,* 2018). These observations also agrees with those obtained by Ganya *et al.,* (2018) where rape achieved higher leaf length at 400kgs/ha of ammonium nitrate.

5.3 Effects of Compound D and Ammonium Nitrate Rate on Cob Length

The results of this study showed lowest cob length recorded in the control treatment with 0.00kg/ha (Figure 4.5). This is consistent with previous research that has shown that the application of fertilizers is critical for enhancing maize growth and yield (Mashingaidze *et al.,* 2016). In the absence of fertilizers, the plant may not have sufficient nutrients to support its growth, resulting in reduced cob length.

As the rate of fertilizer application increased from 200kg/ha to 400kg/ha, cob length also increased (Table 4.5). This is consistent with previous studies that have shown that increasing fertilizer application rates can enhance maize growth and yield (Mashingaidze *et al.,* 2016; Nyamangara *et al.,* 2007). The increase in cob length with increasing fertilizer rates is attributed to the fact that fertilizers provide essential nutrients such as nitrogen, phosphorus, and potassium, which are critical for plant growth and development. This resulted in the efficient light and dark reactions producing large amounts of ATP for respiration which promotes cellular growth and cob development.

The highest cob length was observed at 400kg/ha, which is consistent with previous research that has shown that excessive fertilizer application can have a positive effect on maize growth and yield (Nyamangara *et al.,* 2007). However, it is important to note that excessive fertilizer application can also have negative effects such as soil degradation, pollution, and reduced yield in the following growing seasons (Mashingaidze *et al.,* 2016).

5.4 Effects of Compound D and Ammonium Nitrate Rate on Grain Weight

In maize production, the product of interest is yield. Highest mean grain weight was recorded in treatment number 4 with 400kg/ha application rate of compound D and ammonium nitrate (Usman *et al.*, 2015). There was no significant difference between grain weight produced by 400kg/ha and 300kg/ha (Figure 4.5). This makes 300kg/ha more economical than 400kgs/ha which may increase costs and induce luxurious growth rather than yield component (Nkomo *et al.*, 2019). Maize yield parameters benefited more from 300kg/ha of NPK that any rate higher than this (State, 2019). This was because well-developed root system due to sufficient and balanced phosphorus concentration in the soil caused high nutrient and water uptake, ammonium nitrate caused high leaf growth rate and surface area for the process of photosynthesis. High photosynthesis rate caused high rate of carbohydrates production through the Calvin cycle and these were translocated in the grains during grain filling promoting a higher yield.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

Conclusion

Based on the observed results of this study, there was a significant difference on the effects of compound D and ammonium nitrate fertilizer application rate on the stem height, leaf length, cob length, and yield of SC513 maize variety. The growth rate increased as fertilizer application increased from 0.0kg/ha to 400kg/ha. However, there was no significant difference between the yield produced by 400kg/ha and 300kg/ha. The control had the lowest stem height, leaf length, cob length and yield. As a result, the null Hypothesis was rejected since fertilizer application rate had a significance influence on the growth rate and yield of maize.

Recommendations

Basing on the location and the results of this study, farmers are encouraged to use 300kg/ha of comound D and ammonium nitrate fertilizers. It will be uneconomical and wasteful to use the rate of 400kg/ha as it will only result in luxurious growth with poor yield components. An aapplication rate of 300kg/ha resulted in high growth rate and yield of SC513 maize variety. Communal farmers are also encouraged to use even the lowest rate in case of shortage of money to buy sufficient fertilizers for their maize production rather than not using fertilizer at all. By doing this, maize production is boosted, increasing food security, creating employment and alleviating poverty in Zimbabwe. This was made certain by a higher yield obtained in treatment 3 (Figure 4.5). The farmers will be able to feed their families hence no food shortage. The surplus can sold and the money can used to educate their families, buy inputs for the next season and for hiring labour.

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APPENDIX

Appendix 1: Analysis Of Variance on Stem Height in Week 2

Variate: Stem_Height_in_week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.7350	0.3675	0.62	
Blocks.*Units* stratum					
Treatment	3	45.5692	15.1897	25.61	<.001
Residual	6	3.5583	0.5931		
Total	11	49.8625			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Blocks 1 *units* 3	1.12	s.e.	0.54

Tables of means

Variate: Stem_Height_in_week_2

Grand mean 7.67

Treatment	T1	T2	T3	T4
	4.80	7.30	8.43	10.17

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.445

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.629

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	1.539

Stratum standard errors and coefficients of variation

Variate: Stem_Height_in_week_2

Stratum	d.f.	s.e.	cv%
Blocks	2	0.303	3.9
Blocks.*Units*	6	0.770	10.0

Appendix 2: Analysis Of Variance on Stem Height in Week 3

Variate: Stem_height_in_week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	4.03	2.01	0.15	
Blocks.*Units* stratum					
Treatment	3	374.58	124.86	9.46	0.011
Residual	6	79.18	13.20		
Total	11	457.79			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Stem_height_in_week_3

Grand mean 22.0

Treatment	T1	T2	T3	T4
	13.3	21.1	25.4	28.1

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	2.10

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.97

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	7.26

Stratum standard errors and coefficients of variation

Variate: Stem_height_in_week_3

Stratum	d.f.	s.e.	cv%
Blocks	2	0.71	3.2
Blocks.*Units*	6	3.63	16.5

Appendix 3: Analysis Of Variance on Stem height in Week 5

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	32.002	16.001	1.62	
Blocks.*Units* stratum					
Treatment	3	575.977	191.992	19.38	0.002
Residual	6	59.438	9.906		
Total	11	667.417			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Blocks 3 *units* 4	4.69	s.e.	2.23

Tables of means

Variate: Stem_height_in_week_5

Grand mean 23.32

Treatment	T1	T2	T3	T4
	13.17	21.67	26.33	32.10

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.817

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.570

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	6.288

Stratum standard errors and coefficients of variation

Variate: Stem_height_in_week_5

Stratum	d.f.	s.e.	cv%
Blocks	2	2.000	8.6
Blocks.*Units*	6	3.147	13.5

Appendix 4: Analysis Of Variance on Leaf Length in Week 2

Variate: Leaf_length_week_2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	2.102	1.051	0.82	
Blocks.*Units* stratum					
Treatment	3	71.790	23.930	18.59	0.002
Residual	6	7.725	1.288		
Total	11	81.617			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Blocks 3 *units* 1 1.85 s.e. 0.80

Tables of means

Variate: Leaf_length_week_2

Grand mean 17.28

Treatment	T1	T2	T3	T4
	13.53	17.23	18.03	20.33

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.655

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.926

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	2.267

Stratum standard errors and coefficients of variation

Variate: Leaf_length_week_2

Stratum	d.f.	s.e.	cv%
Blocks	2	0.513	3.0
Blocks.*Units*	6	1.135	6.6

Appendix 5: Analysis Of Variance on Leaf Length in Week 3

Variate: Leaf_length_week_3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.6467	0.3233	1.43	
Blocks.*Units* stratum					
Treatment	3	191.2092	63.7364	282.58	<.001
Residual	6	1.3533	0.2256		
Total	11	193.2092			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_length_week_3

Grand mean 25.14

Treatment	T1	T2	T3	T4
	18.97	24.57	27.40	29.63

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.274

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.388

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	0.949

Stratum standard errors and coefficients of variation

Variate: Leaf_length_week_3

Stratum	d.f.	s.e.	cv%
Blocks	2	0.284	1.1
Blocks.*Units*	6	0.475	1.9

Appendix 6: Analysis Of Variance on Leaf Length in Week 5

Variate: Leaf_length_week_5

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.1550	0.0775	0.73	
Blocks.*Units* stratum					
Treatment	3	1039.6092	346.5364	3257.26	<.001
Residual	6	0.6383	0.1064		
Total	11	1040.4025			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Leaf_length_week_5

Grand mean 39.375

Treatment	T1	T2	T3	T4
	24.467	39.000	45.100	48.933

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.1883

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.2663

Least significant differences of means (5% level)

Table	Treatment
rep.	3

d.f.	6
l.s.d.	0.6517

Stratum standard errors and coefficients of variation

Variate: Leaf_length_week_5

Stratum	d.f.	s.e.	cv%
Blocks	2	0.1392	0.4
Blocks.*Units*	6	0.3262	0.8

Appendix 7: Analysis Of Variance on Cob length at R1 development stage

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.2317	0.1158	0.56	
Blocks.*Units* stratum					
Treatment	3	54.6492	18.2164	87.56	<.001
Residual	6	1.2483	0.2081		
Total	11	56.1292			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Cob_length_R1

Grand mean 16.61

Treatment	T1	T2	T3	T4
	13.50	16.23	17.27	19.43

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.263

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.372

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6

l.s.d.	0.911

Stratum standard errors and coefficients of variation

Variate: Cob_length_R1

Stratum	d.f.	s.e.	cv%
Blocks	2	0.170	1.0
Blocks.*Units*	6	0.456	2.7

Appendix 8: Analysis Of Variance on Cob Length at R2 development stage

Variate: Cob_length_R2

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.10500	0.05250	0.70	
Blocks.*Units* stratum					
Treatment	3	141.98917	47.32972	633.41	<.001
Residual	6	0.44833	0.07472		
Total	11	142.54250			

Information summary

All terms orthogonal, none aliased.

Tables of means

Variate: Cob_length_R2

Grand mean 18.875

Treatment	T1	T2	T3	T4
	14.267	17.100	20.933	23.200

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.1578

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.2232

Least significant differences of means (5% level)

Table	Treatment
rep.	3

d.f.	6
l.s.d.	0.5461

Stratum standard errors and coefficients of variation

Variate: Cob_length_R2

Stratum	d.f.	s.e.	cv%
Blocks	2	0.1146	0.6
Blocks.*Units*	6	0.2734	1.4

Appendix 9: Analysis Of Variance on Cob Length at R3 development stage

Variate: Cob_length_R3

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	0.24500	0.12250	2.33	
Blocks.*Units* stratum					
Treatment	3	188.24250	62.74750	1195.19	<.001
Residual	6	0.31500	0.05250		
Total	11	188.80250			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Blocks 1 *units* 1 -0.325 s.e. 0.162

Tables of means

Variate: Cob_length_R3

Grand mean 20.975

Treatment	T1	T2	T3	T4
	15.100	19.667	23.967	25.167

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	0.1323

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	0.1871

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	0.4578

Stratum standard errors and coefficients of variation

Variate: Cob_length_R3

Stratum	d.f.	s.e.	cv%
Blocks	2	0.1750	0.8
Blocks.*Units*	6	0.2291	1.1

Appendix 10: Analysis Of Variance on Yield after Harvest

Variate: Grain_weight

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Blocks stratum	2	26.460	13.230	1.99	
Blocks.*Units* stratum					
Treatment	3	809.216	269.739	40.66	<.001
Residual	6	39.807	6.634		
Total	11	875.482			

Information summary

All terms orthogonal, none aliased.

Message: the following units have large residuals.

Blocks 2 *units* 3 -3.83 s.e. 1.82

Tables of means

Variate: Grain_weight

Grand mean 21.53

Treatment	T1	T2	T3	T4
	9.13	19.57	26.53	30.87

Standard errors of means

Table	Treatment
rep.	3
d.f.	6
e.s.e.	1.487

Standard errors of differences of means

Table	Treatment
rep.	3
d.f.	6
s.e.d.	2.103

Least significant differences of means (5% level)

Table	Treatment
rep.	3
d.f.	6
l.s.d.	5.146

Stratum standard errors and coefficients of variation

Variate: Grain_weight

Stratum	d.f.	s.e.	cv%
Blocks	2	1.819	8.4
Blocks.*Units*	6	2.576	12.0

Appendix 11: Experimental Design

Blocks	**B1**	**B2**	**B3**
Plot			
P1	T3	T4	T2
P2	T1	T2	T3
P3	T4	T3	T1
P4	T2	T1	T4

B is Block

T1 to T4 are treatments, Fertilizer application rate assigned randomly in the blocks