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DEDICATION

This thesis is dedicated to my parents, late Father (Sanna Sanneh), Nyomo Gassama, Binta Sanneh and Yafatou Ndure. Special dedication goes to my beloved wife Sarjo Sanneh, my son Adama Sanneh and daughters Sereh Sanneh, Binta Sanneh, Hawa Sanneh and Isha Sanneh.

I am also extending dedications to Late Dr. Musa Bojang, Dr. Babou Ousman Jobe and Mr. Ansumana A.K. Jarju former Director Generals of National Agriculture Research Institute (NARI) The Gambia. I wish to dedicate it to Dr. Jallow Director General and Dr. Dibba Director of Research, National Agricultural Research Institute. Special dedication goes to Dr. Trawally Deputy Director General of National Agricultural Research Institute who introduced me to this scholarship.

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List of Abbreviations

AFOLU- Agriculture, Forest Options and Land Use

ANR- Agriculture and Natural Resources

BMBF- Bunderministerium fur Bildung und Fosrchung

CEC- Cation Exchange Capacity

CIS- Climate Information Services

CO2- Carbon dioxide

DSSAT- Decision Support System for Agrotechnology Transfer

EC- Electrical Conductivity

FAO- Food and Agricultural Organization.

FGD- Focus Group Discussions

GBOS- Gambia Bureau of Statistic

GDP- Gross Domestic Product

GHE- Gambia Horticulture Enterprice

GHG- Green House Gases

GNIAP- Gambia National Investment Plan

K- Potassium

LL- Leucaena Leaves

MOFA- Ministry of Food and Agriculture

NARI- National Agricultural Research Institute

NSS- National Seed Secretariat

N- Nitrogen

P- Phosphorus

PB- Poultry Bedding

SSA- Sub Saharan Africa

TYLCVD- Tomato Yellow Leaf Curl Virus and Disease

UNFCCC- United Nations Framework Convention on Climate Change

WASCAL- West African Science Service Center for Climate Change and Land Use

USTTB- Université des Sciences, des Techniques et des Technologies de Bamako

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Abstract

Tomato production in The Gambia is ranked second after onion in terms of production acreage and highly consumed. An agronomic trial was conducted in 2021 and 2022 at Horticulture unit in Yundum. The main objective was to enhance tomato production in The Gambia through determination of effects of organic and inorganic fertilizers as well as model climate impact on the performance of Mongal F1 and Thorgal F1 tomato varieties. The design of the experiment was split-plot design with three replications and four treatments such as Leucaena leaves, Poultry bedding, Nitrogen fertilizer and Leucaena leaves + Poultry bedding. Constant increase in temperature, wind and decrease in rainfall, an unpredictable rainfall pattern and prolonged drought are effects causing severe dropping of flowers and rotting of tomato fruits. Use of synthetic pesticide, planting of trees and fertilizers are use as adaptation strategies. Mongal F1 tomato variety had performed better than Thorgal F1. Poultry bedding and leucaena leaves has increased soil fertility than leucaena leaves + poultry bedding and Nitrogen. Response to growth and yield, Leucaena leaves and poultry bedding performed better than Nitrogen and Leucaena leaves +poultry bedding. The results from DSSAT (CROPGRO) model shows the existance of climate change such as unpredictable and erratic rainfall, higher temperatures etc. The model indicated that, highest amount of rainfall was recorded in September, and the lowest was in July, contrary both temperature's solar radiations were very high in July and declined in September. In addition, days after start of simulations for tomato growth, and yield, treatments did not impacted well due to their longterm effects.

Keywords: Tomato, Climate Change, Modelling, Organic and Inorganic Fertilizers, Farmers.

Résumé

La production de tomates en Gambie est classée deuxième après l'oignon en termes de superficie de production et très consommée. Un essai agronomique a été mené en 2021 et 2022 à l'unité d'horticulture de Yundum. L'objectif principal était d'améliorer la production de tomates en Gambie en déterminant les effets des engrais organiques et inorganiques ainsi qu'en modélisant l'impact du climat sur les performances des variétés de tomates Mongal F1 et Thorgal F1. La conception de l'expérience était une conception en parcelles divisées avec trois répétitions et quatre traitements tels que les feuilles de Leucaena, la litière de volaille, l'engrais azoté et les feuilles de Leucaena + la litière de volaille. L'augmentation constante de la température, le vent et la diminution des précipitations, un régime pluviométrique imprévisible et une sécheresse prolongée sont des effets qui provoquent une chute importante des fleurs et la pourriture des fruits de la tomate. L'utilisation de pesticides synthétiques, la plantation d'arbres et d'engrais sont utilisés comme stratégies d'adaptation. La variété de tomate Mongal F1 s'est mieux comportée que Thorgal F1. La litière de volaille et les feuilles de leucaena ont augmenté la fertilité du sol que les feuilles de leucaena + la litière de volaille et l'azote. En réponse à la croissance et au rendement, les feuilles de Leucaena et la litière pour volaille ont obtenu de meilleurs résultats que l'azote et les feuilles de Leucaena + la litière pour volaille. Les résultats du modèle DSSAT (CROPGRO) montrent l'existence de changements climatiques tels que des précipitations imprévisibles et irrégulières, des températures plus élevées, etc. les radiations étaient très élevées en juillet et ont diminué en septembre. De plus, quelques jours après le début des simulations de croissance et de rendement des tomates, les traitements n'ont pas eu un bon impact en raison de leurs effets à long terme.

Mots clés : Tomate, Changement Climatique, Modélisation, Engrais Organiques et Inorganiques, Agriculteurs

CHAPTER ONE

1.0: INTRODUCTION

1.1: Problem or Justification

According to African Development Bank (2018) indicated that the main economic activity in The Gambia is agriculture, which accounts for 25% of the country's GDP and provides employment for 70% of its workforce, 32% of whom are actively engaged in main agricultural output. For around 72% of the extremely poor rural households, the sector is their primary source of income. Small-scale, rain-fed subsistence crop agriculture (primarily the production of groundnuts, coarse grains, rice, and cassava), traditional livestock raising, semi-commercial horticulture and groundnut production, as well as a sizable artisanal fishing sub-sector, are characteristics of the region (FAO, 2018). It has long been recognized that the cultivation of horticulture crops can help the Gambia diversify its economic basis, increase the producers' level of independence, and, most critically, enhance the nation's food security. The urban areas of The Gambia, a small but highly populated country, are concentrated in and around Banjul. The urban region has been regarded as the primary location for the production of horticultural crops, with a large number of community gardens devoted mostly to the growth of cool-season vegetables. Although some of the older gardens are also producing fruit crops like mangoes, paw-paws, and citrus, the main vegetable cultivars planted are tomatoes, onions, peppers, and cabbage. Women's organizations manage the communal gardens' production (TCARC, 2019).

The tomato is thought to be a member of the Solanaceae family. It is regarded as the second-most significant vegetable crop after potato and one of the most important fresh and processed fruits in the world. According to the description, the cultivar is an annual crop that is primarily grown in temperate settings, however under low nonfreezing temperatures of below 12°C, the crop suffers physiological damage (Heuvelink, 2018). The most recent evaluation report in The Gambia said that among vegetables, tomato production ranks second only to onion in terms of production acreage. (D., 2000). In addition, (Jaiteh Malanding, 2010)also stated that Lycopene continues to be primarily obtained from tomatoes, and processed tomato products include significant levels of dietary carotenoids. It is recognized as an antioxidant that can fend off conditions like cancer, heart disease and premature aging. The crop was discovered to have high levels of vitamins AB and C as well as adequate levels of phosphate, potassium, and iron. The harvest is in fresh tomatoes, and canned varieties like paste, concentrate, and puree are becoming more popular in West Africa and in dem, where they are a staple of the cuisine.

One of the most difficult and challenging issues facing the world today is the changing and variable environment. The risk factors for climate change and its variations have been shown to be quite high in much of Sub-Saharan Africa (SSA), and it is predicted that these risks would only increase as development barriers to protecting livelihood security and eradicating poverty increase. Environmental and sociocultural disruptions are the result of the intensification of climate change, which has also affected natural systems that support life and livelihoods (Bank, 2018). With annual rainfall ranging from 800 to 1200 mm, the climate of The Gambia is classified as tropical sub-humid. Two seasons—a wet season (between June and October) and a dry season (November to April), which is six to seven months without rain, define the climate. There is a lot of regional and temporal variance in the yearly average rainfall. The southwest of the country experiences more rainfall, with an estimated 1200 mm annually. The North-Northeast region of the country experiences the least amount of annual precipitation. The capital city of Banjul experiences an average of 54 rainy days whereas Basse Santo Su experiences 31 days on average. The Gambia's normal temperatures range from 18 to 28 degrees Celsius in January to 23 to 36 degrees Celsius in June (Jaiteh Malanding, 2010)

Agriculture and Natural Resources, The Gambia (2009) reported that the soils of the Gambia are typically highly deficient in organic matter and chemical fertility, necessitating significant inputs of manure and fertilizer to improve agricultural yields and quality. The bulk of producers, small-holder farmers, do not have adequate access to inputs like fertilizers in sufficient amounts to improve the quality of the resource situation. Land that may be used for farming is becoming less and less available as river banks and coastal mangrove regions deteriorate more quickly. The source is mwntioned abive (ANR, 2009). Organic fertilizer is eco-friendly, it renders lower yield in comparison to inorganic fertilizers. In this regard, by applying the combination of organic and inorganic fertilizer, it can increase tomato production as well as improve soil health. In addition, this combined application also maximizes the use of available organic resources and minimizes the use of expensive inorganic fertilizers (Jaiteh Malanding, 2010). Application of animal dung, which is thought to be the repository for plant nutrients, will aid in refilling and sustaining the soil.

For the tomato crop to obtain the necessary nutrients, such as macro and micronutrients, through improved biological processes, increase nutrient solubility, alter soil salinity, sodicity, and pH, and is done by the stimulation of the activity of microorganisms, organic manures improve the soil structure, aeration, and water holding capacity. The carbonaceous matter that the organic manures add to the soil, which decomposes to provide minerals, plays a significant part in the soil's fertility (Myint *et al.*, 2010). (Khaitov *et al.*, 2019) reveals that application of organic manure enhances the availability of organic components in soil, boosting the nutrient usage efficiency (NUE) of crops and reducing the negative effects of climate change on crop productivity. Cheryl A. Palm *et al.*, (2001), explained that in any agricultural system, plant remains constitute a significant source of nutrients and carbon for the growth of crops. With their immediate impacts on nutrient delivery and longer-term contributions to the development of soil organic matter, organic materials play a highly important role in the maintenance of soil fertility in the tropics. Furthermore, (El-Naqm *et al.*, 2019) reported that green manures have received renewed attention with a focus on the long-term sustainability of the agricultural system because they can be used as a source of soil nutrients and an alternative to maintaining soil fertility.

However, tomato production in this region is not commonly using the product as a source of soil fertility. Herbaceous legumes (Lablab purpureus) were found to be inexpensive, and they provide a chance to preserve soil fertility by supplying nutrients throughout decomposition with a delayed release of nutrients that may be better timed with plant absorption while minimizing nutrients losses. To maintain productivity while promoting growth and output, tomato plants will need to get an adequate amount of fertilizer. There is a shortage of study data on the usage of NPK fertilizer, improved tomato cultivars, and short-term green manure. According to FAO, (2015) indicated that, Climate change and variability are the fundamental risks to agriculture and food security today. Sub-Saharan Africa is the most susceptible region in terms of food security due to its recurrent vulnerability to catastrophic climatic events, heavy reliance on rainfed agriculture for both economic growth and basic food security, and entrenched poverty. Rather than resulting from changes in mean climatic conditions, climate change impacts on agriculture are currently and over the next few decades more likely to be caused by increased climate variability and increased frequency and intensity of extreme events. All around the world, high temperatures and inconsistent rainfall distribution reduce crop productivity. The food security of the poor world, where these climate and weather changes are most likely to have an impact. Against this background information, the research aimed to improve the soil fertility by enhanced the growth and yield of tomatoes through the application of organic and inorganic fertilizers and as well as crop modelling.

1.2: State of the Knowledge

The production and utilization of tomato has increased over the years in The Gambia. However, demand for the crop exceeds supply owing to its economic importance and increasing popularity as a result of economic gains and consumption. Tomato production in The Gambia is ranked second after onion in terms of production acreage among vegetables. The crop is high in vitamin AB and C and also contain good amount of potassium, iron and phosphorus. Fresh tomatoes and and canned types such as concentrates puree and paste are increasingly in demand in West Africa where they form an essential part of the diet (Costa, 2018). Soil fertility in the Gambia today is generally regarded as low, which is the unfortunate result of rapid population growth and poor agricultural management practices. Plant nutrient depletion rate is considered moderate and the loss of soil through erosion is estimated at 12.5 tons per hectare per year and these has affected tomato production in the Gambia as not meeting the demand. Green manures such as application of Leucaena leaves are specifically practice for building and maintaining soil fertility and structure, though they may also have other functions. Leucaena leaves are normally incorporated back into the soil, either directly, or after removal and composting. The leaves have generally been little used in the Gambia (nonorganic) producers, but have been enthusiastically adopted by organic producers. According to Tanzi b.n., *et al* (2013) reveals the impact of tree leaf biomass on soil fertility and tomato yield, organic farming is a viable alternative to conventional methods of fertilizer cost reduction and soil improvement. A significant organic source for increasing soil fertility is leaf biomass. The amount of N that is available for plant absorption is influenced by how quickly leaf litter decomposes. Although meeting the actual quantity is a struggle for many farmers in Africa, leaf litter contributes the carbon, nitrogen, phosphorous, potassium, and other nutrients in soil that are further viewed as vital markers of soil productivity and the health of the ecosystem. Even though the application of organic materials is crucial because they provide a variety of plant nutrients, including micronutrients, enhance the physical and chemical characteristics of the soil, increasing its capacity to hold and buffer nutrients, and ultimately enhancing microbial activity (Myint *et al.,* 2011). In addition, tomato will requires adequate fertilizer for growth and yield (Pandey and Chandra, 2013). Poultry manure is an excellent organic fertilizer, as it contains high Nitrogen, Phosphorus, Potassium and other essential nutrient (Oyewole *et al.,* 2012). In contrast to chemical fertilizer, it adds organic matter to soil which improves soil structures, nutrient retention, aeration, soil moisture holding capacity and water infiltration (Deksissa *et al;* 2008). Dauda *et al* (2008) reported that poultry manure promoted root development and vegetative growth, while Emuch (2010) reported that poultry manure significantly increased growth parameters and yield in tomato. (Akande & Adediran, 2004) found that poultry manure applied at 5t/ha significantly increased yield and dry matter content of tomato.

Furthermore, Nitrogen fertilizer is often regarded as the primary macronutrients because of the large quantities they are taken up by plants from the soil relative to other essential nutrients (Marschner, 1995). Tomato plants produce stunted growth, small leaves, and poor fruit yield if the plants are not properly nourished by N fertilizers at different growth stages (vegetative, flowering, and fruiting). Application of N promotes vegetative growth and fruit yield of tomato, and later application in the growing stages favors fruit development, thus nitrogen has a dramatic effect on tomato growth and development in soils with limited N supplies such as sandy soils (Hokam *et al.,* 2011). In the past decade, emphasis has been placed on using crop models to assess how climate change would affect crop productivity. Cropping system models have been used primarily to analyze the effects of climate change on agriculture and to evaluate mitigation and adaptation options at various regional scales and levels of complexity (Stöckle et al., 2014). One of the most significant horticultural crops in the world is the tomato. There have been numerous tomato growth models created in the past (Heuvelink, 1995); with different levels of complexity and for different purposes. Decision support systems like the well-known DSSAT, a global leader in decision support, have integrated tomato crop growth models (Jones *et al.,* 2003) as well as many others (Massa *et al.,* 2013; Jizhang *et al.,* 2006). Additionally, the development of 3D models of tomato plants has been done for things like adjusting LED lighting to boost light absorption and crop growth (de Visser *et al.,* 2014). According to (Tanzi *et al.,* 2013) study on the impact of tree leaf biomass on soil fertility and tomato yield, organic farming is a viable alternative to conventional methods of fertilizer cost reduction and soil improvement. A significant organic source for increasing soil fertility is leaf biomass. The amount of N that is available for plant absorption is influenced by how quickly leaf litter decomposes. Although meeting the actual quantity is a struggle for many farmers in Africa, leaf litter contributes the carbon, nitrogen, phosphorous, potassium, and other nutrients in soil that are further viewed as vital markers of soil productivity and the health of the ecosystem. Even though the application of organic materials is crucial because they provide a variety of plant nutrients, including micronutrients, enhance the physical and chemical characteristics of the soil, increasing its capacity to hold and buffer nutrients, and ultimately enhancing microbial activity, it does not immediately benefit the plants during the first growing season. Additionally, as plants require N, organic stuff continuously releases it ((Myint *et al.*, 2010)

In the past decade, emphasis has been placed on using crop models to assess how climate change would affect crop productivity. Cropping system models have been used primarily to analyze the effects of climate change on agriculture and to evaluate mitigation and adaptation options at various regional scales and levels of complexity (Stöckle et al., 2014). One of the most significant horticultural crops in the world is the tomato. There have been numerous tomato growth models created in the past (HEUVELINK, 1999) with different levels of complexity and for different purposes. Decision support systems like the well-known DSSAT, a global leader in decision support, have integrated tomato crop growth models (Jones *et al.*, 2003) as well as many others (Massa *et al.*, 2013; Jizhang *et al.*, 2006). Additionally, the development of 3D models of tomato plants has been done for things like adjusting LED lighting to boost light absorption and crop growth (Massa *et al.*, 2006)

1.3: Research Hypothesis

Significant differences will not be shown among the treatments and modelling on the soil and tomato cultivars whereas significant effects will be resulted from the application of fertilizers and modelling for soil and tomato cultivars.

1.4: OBJECTIVES

1.4.1: Overall Objective

To enhance tomato production in The Gambia through determination of effects of inorganic and organic fertilizers as well as modelling climate impact on the performance of Mongal F1 and Thorgal F1 tomato cultivars.

1.4.2: Specific Objectives

1. To assess farmers perception about climate change, impact and adaptation strategies use for tomato production in The Gambia.

2. To evaluate the growth and yield performance of tomato varieties on the application of inorganic and organic fertilizers.

3. To determine the effects of treatments on soil fertility.

4. To predict tomato yields through calibration, validation and application of DSSAT tool.

CHAPTER TWO

2. 0: LITERATURE REVIEW

2.1: Origin and Distribution of Tomatoes

According to Hermann Cyr Toni, (2020) depicted that the Solanaceae plant family includes theannual crop tomato (Lycopersicum esculentum Mill). It is thought that, the crop originated in Peru and Mexico in Southern and Central America before being exported to other parts of the world. Ministry of Environment, Forest and Climate Change (2019) also stated that tomatoes are originally from North America, but they were introduced to Europe in the 15th century, 2019). Tomatoes are originally from North America, but they were introduced to Europe in the 15th century, from there, they acquired popularity and eventually expanded to the rest of the world. Peralta and Spooner (2007) revealed that, the Andean regions of Western and Southern America are thought to be where the tomato first appeared. However, other hypotheses claimed that Mexico, not America, was the country from where the crop variety was designated. (Bai & Lindhout, 2007) Peru is cited as the most likely center of diversity of tomato wild relatives while Mexico is the initial center of domestication, although reports that the early history of tomato domestication is disputed. (Larry and Joanne, 2007). It was discovered by the Spanish in the American hemisphere discovered is as an edible herbaceous plant called "tomatl," which was translated into Spanish, and ultimately became tomato. (Lillo-Saavedra *et al.,* 2022).

In addition, Jenkins J. A., (1998) also stated that the Peruvian and Ecuadorian regions were the only places where the cultivated tomato's ancestral form could be found. When it first arrived in Mexico, it was been observed as a weed that had spread to the north during the pre-Columbian era. The cultivation techniques had spread around the world from Mexico. According to (FAOSTAT, 2017) depicted that it was once thought that wild species tomatoes were indigenous to Western South America. (FAOSTAT, 2017) revealed that the wild tomatoes that come from Peru, Ecuador, and other regions of South America, such the Galapagos Islands, are connected to the cultivated tomato. Mexico serves as the primary hub for its domestication and diversification.

2.2: General Description and Taxonomy of Tomatoes

According to FAOSTAT (2011) reveals that tomato plants often have a weak stem that typically sprawls over the ground and can grow to a height of 1 to 3 meters. Although it may also be cultivated outside as an annual crop in temperate areas, it is categorized as a perennial crop in its natural habitat. Some of the cultivars have red fruits, but many of them are also found in various places of the world with fruit that is yellow, orange, pink, purple, green, black, or white. Fruits with stripes and multiple colors are also quite eye-catching. Contrary, (Lichtfouse, 2010) initially acknowledges the tomato (Lycopersicum esculentum Mill) as an annual plant that is a member of the Solanaceae family. Although they are herbaceous, wild tomatoes are also capable of secondary growth. Wild tomatoes most likely act as annuals in their natural environments since cold or drought destroy the plants after the first growing season. All species have initially upright shoots, but as the weight of the branches increases, the plants turn prostrate and have the ability to root at the nodes (Ho Dinh Hai, 2015). The Solanum icopersicum tomato species S. habrochaites, S. chilense, and several races of S. peruvianum are strong and may keep the upright habit for a longer period of time until they reach heights of 80–100 cm.. All tomato species of (S. peruvianum, S. pimpinellifolium and S. Iycopersicum) can produce long branches that can grow up to more than 4m long. Pubescence has been regarded as a crucial taxonomic characteristic, specifically identifying S. habrochaites and S. pennellii. (Adebisi-Adelani & Oyesola, 2014).

Additionally, there are taxonomically significant changes in the leaf, inflorescence, flower, and fruit of wild tomato species. Imparipinnate leaves have 2–6 pairs of sessile or petiolate, opposite or subopposite leaflets. S. peruvianum's leaves vary greatly between species and within species, from pinnate to bipinnate with primary, secondary, and tertiary leaflets as well as interposed leaflets. Another important taxonomic characteristic is the number of leaves per sympodium, which can be 2 or 3 (Spooner & Peralta, 2000). A cyme with various types of branching, such as monochasial, dichotomous, and polychotomous, makes up the fundamental inflorescence. Another crucial taxonomic characteristic is the development of inflorescence bracts. (Rick *et al.*, 1995). As with other Solanaceae, the flowers are generally yellow and gamopetalous at the base. The stigma is frequently integrated or flush with the anther, and the self-compatible species typically have smaller stellate blooms. The blooms and stigmas of the self-incompatible 7 species are bigger and more exerted. The distinctive stamen morphology of tomatoes has an extended sterile tip at the apex apex and anthers that connive laterally to form a flask-shaped cone (except in S. pennellii).

The buzz pollinates flowers. Size, color, and pubescence are all highly changeable characteristics of the fruit that can be used to classify it. (Isack & Lyimo, 2015) the size, color, and radial walls of the seed coat cells, whereas (Peralta & Spooner, 2000)

2.3: Brief Description of Horticulture Sector of The Gambia

According to Agriculture and Natural Resources, (2015) reveals that horticulture is one of the main sectors of the Gambian economy that is growing and changing quickly. Currently, the industry employs more than 65% of the agricultural labor force and contributes an average of 4% to the GDP. Currently, it is acknowledged that the production in this sector is an important source of rural income, employment, and food that significantly contributes to food security and the reduction of poverty. The following are typical horticultural crops grown in The Gambia: (tomatoes, onions, cabbage, eggplant, okra, green herbs, peppers, lettuce, , carrots, beans, citrus fruits, mangoes, cassava, potatoes, papaya, banana, cucumber,) etc. (The Gambia, 2010) reveal that horticulture is one of the most promising sectors of the Gambian economy in terms of food, nutrition, and income security as well as export potential. According to its value chain analysis, public sector initiatives have constructed and equipped 250 ha (or 25%) of a planned 1,000 ha with boreholes, overhead tanks, and water reticulation systems. With the assistance of the private sector, a number of horticultural development models utilizing out-grower schemes and sponsored by the Gambia Competition Project (GCP) were put into practice. (GHE and Radville).

2.4: Level of Tomato Production and Consumption in Sub-Saharan Africa and World

One of the veggies that is grown the most on the continent is the tomato. African production climbed from 1,968,812 tons in 1961 to 14,918,554 tons in 2007, with the continent's total production area growing from 159,593 ha to 660,215 ha. (Linda Dari, *et al.*, 2016). According to FAO estimates, northern Africa, which includes Egypt, Morocco, and Algeria, has the largest area and the highest production, whereas southern and central Africa have the smallest areas and the lowest production. (FAO, 2009). The southern part of Africa has higher production due primarily to South Africa, with average yields ranging from 6 t/ha in central Africa to 34 t/ha (FAO, 2009). Over the past 50 years, acreage and production have increased in each country, but at varying rates; productivity has mostly stayed low. For instance, in Tanzania, the area grew from 1,400 ha in 1961 to 19,000 ha in 2007, while the output stayed the same at 7.1 to 7.6 t/ha. (FAO, 2009). FAO (2012) According to FAO estimates, 178.5 million Nigerians need fresh tomato fruit at a rate of 1,785 tons per day, or 651,525 tons annually. (World Population Review, 2014). Nigeria produces 1.701 million tonnes of tomatoes annually at an average of 25–30 tonnes per hectare, ranking second in Africa and thirty-first globally. (FAO, 2012). (TO & KO, 2018) stated that despite a reported 1,701,000 tons of tomato output in Nigeria across 265,000 ha, the yield production in the country's humid forest zone is very low when compared to the average data currently available, which is 14t/ha-1 from the global record. However, China, Turkey and India, were the world's top three tomato producers in 2019. Twenty-one (21) countries produced more than one million metric tons of tomatoes in 2019, while China alone produced more than 62 million metric tons of tomatoes. (François-Xavier & Branthôme, 2019) In 2002, 108 million tonnes of tomatoes were produced, with the crop being farmed on 9.9 million acres throughout more than 160 nations. Over the past ten years, the global production has climbed by more than 35%. China with 25 million tonnes, as the largest producer, followed by the US with 12.2 million tonnes. Other significant growers include Turkey, India, Italy, and Egypt, with yields exceeding 5 million tonnes. (Gibba, 2022). The current global average production is 27 t/ha, although European glasshouses provide the largest yields, sometimes reaching 700 t/ha in a single season. Fresh tomato crops cultivated in high yielding fields with furrow irrigation often yield 50 to 70 t/ha. Today, the world's production is cultivated for the processing industry to the tune of about 25%. This is almost twice the level in the middle of the 1980s. The average annual consumption of processed goods per person is 5.6 kg, ranging from 37.4 kg in the USA to 0.1 kilogram in India.

2.5: Significance of Tomato Production

The tomato has retained its position as the most significant vegetable in the world thanks to its rising nutritional and commercial value, extensive production, and use as a model plant in scientific studies. It can be consumed as a fresh crop or transformed into other products like paste, puree, and liquids. The fruit contains a lot of water, few calories but high in lycopene, beta-carotene, iron, phosphorus, and vitamins A and C. (D. Melomey *et al.,* 2019). Different tomato cultivars have a significant role in Ghanaian households' meals. Every year, almost 440,000 tons of tomatoes are consumed, accounting for 40% of family vegetable spending. (Ministry of Food and Agriculture (MoFA, 2020).

The tomato fruit is a significant economic crop in sub-Saharan Africa (SSA). (Ochilo *et al.*, 2019) The fruit is a key component of human nutrition and can be consumed raw in salads, cooked in stews, fried, or baked, as well as used to make juice or soup. It can also be used as the primary component in a variety of meals. Specifically, tomatoes are a good source of iron, phosphate, and vitamins A, B, and C. The fruit includes nutrients that are crucial to a healthy diet, including vitamins B complex, thiamin, niacin, and riboflavin. (Singh *et al.*, 2005)). Additionally, it includes a large quantity of flavonoids, lycopene, ascorbic acid, phenolic acids, and beta-carotene (a pro-vitamin A carotenoid), all of which are phytonutrients that support greater health. ((Fufa *et al.*, 2011)). Similarly Kumar (2014) also stated that lycopene, an essential component of tomatoes, can prevent and treat chronic illnesses. Tomato antioxidants operate as preventive agents by neutralizing reactive oxygen species, thereby considerably postponing and avoiding oxidative damage.

2.6: SOIL TYPES IN THE GAMBIA

JATTA, (2013) stated that Alluvial soil and continental terminal soils are the two major kinds into which the soils of The Gambia can be separated.

2.6.1: Alluvial Soils

These soils are made up of alluvial materials that were dumped by the River Gambia and its tributaries, and they are frequently subject to intermittent or ongoing wet conditions. About 30% of the area in the Gambia was covered by this type of soil, although the corresponding extension declines moved steadily eastward from the west. Most alluvial soils are hydromorphic, fine-textured, and typically contain clay and more than 80% silt. On the high lying levees in the east of the Gambia, less hydromorphic and somewhat coarser textured soils are present, and sandy layers have been discovered in the majority of recent river sediments. The alluvial soils can be roughly split into two groups: those that are or have been inundated by salt water, and those east of around 150 W that don't exhibit any signs of salinity. Mangrove vegetation covers the saline-affected soils, while bare flats result when accretion has elevated the soil level above the tidal flooding threshold.

2.6.2 Continental Terminal Soil

These are situated on uplands created by the underlying Continental Terminal acid complex's weathering products. These well-drained, low chemical fertility soils, which were produced on the Continental Terminal, have a Cation Exchange Capacity (CEC) of clay that is roughly 6 meq/100g. The surface horizon typically contains no more than 0.3-0.4% organic carbon. The range of the soils' CEC is 1.5 to 5.5 meq/100g. Base saturation is typically rather high, frequently between 40 and 100%, and calcium typically predominates. However, in some subsoil strata, the amount of magnesium on exchange complex may be higher than that of calcium. Phosphorus that is readily available is typically only 3-6 ppm. Poorly constructed and having a hard to very hard consistency when dry, the soils on the continental Terminal are. The bulk density of the majority of soil strata is high, ranging from 1.65 to 1.85 g/cm, which is a level typically linked to severely constrained root growth. All profiles, with the exception of the shallowest soils, exhibit a textural gradient from coarser to finer surface layers within 2 meters of depth. Sand and loamy sands are typically found in surface horizons; sandy loams are less prevalent; and sandy clays are most frequently found in subterranean horizons, however a range from loamy sands to clays may occur. The soils of the plateau are different from the colluvial and interfluves soils in two ways. First, plateau soils typically have finer surface horizons than colluvial soils, or coarser surface horizons on top of finer texture, depending on the locality. The soils on the uplands are mostly used for the cultivation of coarse grains and groundnuts. The use of highland soil is significantly impacted by the severe effects of climate change. Short-lived rainfall, combined with inadequate water retention and low intrinsic fertility, have significantly decreased these soils' productivity.

2.7: Climate and Soil Requirement for Tomatoes

William, T. Kelley, & George, (2017) indicated that, to avoid becoming spindly and producing small, unripe fruit, tomatoes prefer a pleasant, warm location with full sun exposure for eight hours each day. In warm climates, tomatoes will thrive at temperatures between 21 and 24°C (69.8–75.2°F). (FAOSTAT, 2017) depicted that Tomatoes can be grown all year round, but the best yields come from well-drained soils and temperatures between 20 and 27 degrees Celsius. Similarly, (James Arim, 2019) stated that Tomatoes can be grown up to 2,000 meters above sea level, and they do well in regions with more than 600 millimeters of annual rainfall. Throughout the growing season, it need to be evenly dispersed. Tomatoes perform best in warm climates when it comes to temperature. The ideal temperature range is 20 to 25 0C during the day and 15 to 17 0C at night.

In addition, (William, T. Kelley, & George, 2017) also reported that 70 to 85 degrees Fahrenheit during the day and 65 to 70 degrees Fahrenheit at night are optimum for tomato development. Temperatures that are much higher or lower might have a negative impact on fruit set and quality. The crops require a pH range of 5.5 to 6.8 on a deep, loamy, well-draining soil. Tomatoes can be planted in a raised bed if soil drainage is an issue. Because unequal water absorption can result in a variety of issues with tomatoes, including flower drop, fruit splitting, and blossom-end rot, the plant needs soil that will hold water as uniformly as possible. Clay loam or well-drained sandy loam are the best soil types for tomatoes. The pH range for soil is 6.0 to 7.5. Tomatoes have performed well when grown in heavy clay loams free of hardpan and well-managed sandy loams, but the best results are obtained in deep, well-drained loams. The soil should have a pH between 6 and 7 and be rich in organic matter and plant nutrients. (Anon, 2021). For best results, tomatoes need full exposure to sunshine. Extreme heat or cold have little effect on tomato growth. Temperatures for an extended period below 14°C or above 30°C will prevent fruit from setting. Tomatoes will yield well on a variety of fertile, well-drained soils with pH levels between 5.5 and 7.5. (Anon, 2022).

In addition, Department of Agriculture, Forestry and Fisheries (2010) also stated that tomato is a frost-sensitive warm-season crop. The ideal range for daily average temperatures for growth, yield, and fruit quality is 20 to 24 °C. Temperatures between 12 °C and 35 °C have poor effects on fruit set and quality. While persistent moist, rainy weather leads to the occurrence and spread of foliar diseases, hot, dry winds produce excessive flower drop. Therefore, it is advised that tomatoes be cultivated in arid climates with irrigation. Tomatoes have performed well when grown in heavy clay loams free of hardpan and well-managed sandy loams, but the best results are obtained in deep, well-drained loams. The pH of the soil should be between 6 and 7, with an abundance of organic matter and plant nutrients.

2.8: Current Situation of Climate Change in The Gambia

The Gambia is listed among the top 100 countries most vulnerable to climate change (IPCC, 2020), and is also one of the 10 nations in the world most vulnerable to coastline erosion and sea level rise. (Gomez, Adelagun, *et al.,* 2020). Drought, flooding, coastal erosion, windstorms, high temperatures, and heavy and irregular rainfalls have all become more frequent and intense in the nation in recent years. The country's efforts to eradicate poverty and develop sustainably are greatly hampered by these extreme weather phenomena, especially the drought. There are two distinct seasons in The Gambia's tropical Savannah climate: a dry season (November to May) and a rainy season (June to October). During the dry season, temperatures typically vary from 18°C to 30°C, whereas during the wet season, they range from 23°C to 33°C as an average. Temperatures typically run colder than normal during La Nia years. The country's average annual rainfall ranges from 700 millimeters in the far north to 1,000 millimeters in the South and Southeast. (World Bank, 2021). Since 1960, mean annual temperatures have risen by 1.0°C, or 0.21°C on average every decade. At 0.32°C per decade, the rate of growth has been at its fastest in the months of October, November, and December. Routine observation showed that nationwide minimum temperatures have been progressively rising since the 1950s at a pace of 0.4 to 0.67°C every decade. (World Bank, 2021). The number of "hot" days and nights as well as prolonged heat waves would increase by the end of the twenty-first century. Between 1960 and 2006, The Gambia's wet season rainfall (July, August, and September) dropped at an average rate of 8.8 mm per month every decade, according to linear trends. As inter-annual rainfall variability has increased, so too has the length of the rainy season. (World Bank, 2021). The duration of the growth season for the primarily rain-fed crops is reduced as a result of this unpredictable rainfall pattern, and the additional mid-season dry spell might result in drought conditions for farming even during periods of average rainfall.

(FAOSTAT, 2022) reported that with rising air and soil temperatures, climate change and variability in The Gambia have brought about seven-month dry seasons from November through May. This is even worse by the average rainfall decreasing from 860 mm in 2000 to 800 mm in 2020 nearly a third of the nation is 10 meters above sea level and is subjected to yearly flooding. The country has a typical sudan-sahelian climate, with a long dry season from October to June and a brief rainy season from mid-June to early October. During the dry season, the northward harmattan wind frequently has an impact on the nation. During the dry season, the average temperature ranges from 180°C to 300°C, whereas during the wet season, it ranges from 230°C to 330°C. During the dry season, relative humidity is roughly 68% along the coast and 41% inland, while it is above 77% across the entire nation during the rainy season. The average annual rainfall is around 1000 mm, however depending on the agro-ecological zone, it can range from 850 mm to 1500 mm. Rainfall is a major factor in agricultural productivity, but during the past 30 years, its distribution has been inconsistent and insufficient. JATTA F. (2013).

2.9: Causes of Agriculture, Forestry and Land Use Sector Green House Gas Emissions (GHG) and Projections in The Gambia

AFOLU (agriculture, forestry, and land use) scenario GHG emissions were also estimated. The emissions are documented under livestock, aggregate sources, and forestry. In 2020, cattle generated 434 GgCO2e in greenhouse gas emissions, and by 2050, these emissions are expected to reach 1,085 GgCO2e. For the growth of GHG emissions from forestry and aggregate sources, a similar pattern is seen. Estimated emissions from all sources are expected to total 270 GgCO2e in 2020 and 674 GgCO2e in 2050. Estimates for forestry put the amount of carbon dioxide produced at 232 GgCO2e in 2020 and 578 GgCO2e in 2050 (Locatelli, 2011)

According to historical statistics, enteric fermentation emissions were 452 GgCO2e in 2011 and rose to 362 GgCO2e in 2020. This indicates a 20% reduction in emissions. Future emissions, however, are projected to rise given that cattle is often imported from Senegal, a neighboring country, to meet demand. The estimated amount of emissions in 2050 is 903 GgCO2. Similar trends can be seen in the estimates of emissions from manure management. The emissions in 2020 were 73 GgCO2e, and by 2050, they are expected to increase to 182 GgCO2e. The primary source of methane emissions in livestock is enteric fermentation. Ruminant animals including cattle, sheep, and goats are the main source of methane emissions in the livestock subsector. Figure 6 is shown below. With 45% of all ruminant animals, goats make up the majority. Cattle come insecond with 34%, and sheep come in last with 21%. GHG emissions from soils are estimated for the aggregate source, lime application, and rice agriculture categories. In 2020, flooded rice cultivation practices are forecast to produce 126 GgCO2e, and by 2050, they are expected to yield 308 GgCO2e. In The Gambia, smallholder farmers primarily grow rice. Both the uplands and the lowlands are used by these farmers to grow rice. The production of lowland rice is more prevalent, though. Lowland rice ecologies produce rice while it is submerged in water. Rice fields are not adequately drained during harvest. The majority of farmers employ manual harvesting techniques and dump rice straws into still waters, where they decompose and release methane into the sky. In

2020, the direct and indirect emissions of N20 totaled 170 GgCO2, and by 2050, they are expected to reach 363 GgCO2e. (Ministry of Finance and Economic Affairs, 2018). Charcoal and firewood GHG emissions were also recorded. In urban and peri-urban regions, charcoal is primarily utilized for cooking, whereas firewood is the primary energy source in rural areas. According to estimates, firewood emissions were 128 GgCO2e in 2011 and 172 GgCO2e in 2020. According to an emission projection, there will be 428 GgCO2e in 2050. The emissions from the manufacturing of charcoal, on the other hand, were 38 GgCO2e in 2011, 50 GgCO2e in 2020, and later anticipated to be 150 GgCO2e in 2050. This demonstrates that firewood accounts for more than 60% of the emissions in this subsector, placing a significant burden on the forest and accelerating deforestation. The country's declining forest cover is being hastened by the rising reliance on firewood and charcoal. Given that the nation's forests are meant to act as a carbon sink, the present rate of deforestation will result in an increase in our GHG emissions. Solid waste disposal is responsible for the majority of emissions from the waste industry. With a predicted value of 1,065 GgCO2e in 2050, the emission from this activity was assessed to be 426 GgCO2e in 2020. Less greenhouse gas emissions were produced when garbage was burned outside. Emissions from rubbish burning in the open were anticipated to be 0.9 GgCO2e in 2020, and are expected to rise to 2.1 GgCO2e in 2050. These projections demonstrate that the emissions from the waste sector are nearly exclusively caused by the disposal of solid waste, which results in significant methane production. (Ministry of Environment, Climate Change and Natural Resources, 2017).

According to the Third National Communication of The Gambia submitted to the UNFCCC in July 2020:

• Emissions of direct GHG, that is, CO2, CH4 and N2O, add up to 3,332GgCO2, or 83% of the 2010 inventory total.

• CO2 emissions (1,090 GgCO2 eq) account for 26% of national emissions, and 32% of emissions excluding GHGs controlled under the Montreal Protocol. Energy and Agriculture, Forestry, and Other Land Use (AFOLU) source categories, including the transport and electricity sectors of the Gambian economy, as well as CO2 fluxes from agricultural soils in particular, are the main sources of CO2 emissions. The Gambia's Long-Term Climate-Neutral Development Strategy 2050 18

• CH4 emissions (1,914GgCO2 eq) in 2010 represent 47% of national emissions, and 57% of emissions excluding GHGs controlled under the Montreal Protocol. The AFOLU sector, accounting for (1,584GgCO2 eq), or 83% of national emissions, is by far the single largest source of CH4.

• The 2010 GHGI of the Gambia puts N2O emissions (338GgCO2 eq) representing 8% of national total emissions, which increases to 10% if GHGs controlled under the Montreal Protocol are excluded from the inventory total

• HFC emissions (705GgCO2 eq) in 2010 represent 17% of the national total. HFCs are generated almost exclusively from substitutes for ozone depleting substances (ODSs) used in refrigeration, air conditioning (311GgCO2 eq), and in aerosols (308GgCO2 eq).

• SF6 emissions (1.1GgCO2 eq) in 2010 represent 0.03% the national total.

• Energy industries were responsible for 70% (1.2 Gg) of SO2 emissions, whilst road transport accounted for 34% of NO2 emissions (1.11Gg).

2.10: EFFECTS OF ORGANIC AND INORGANIC FERTILIZER APPLICATIONS ON TOMATO PRODUCTION

2.10.1: Importance of Nitrogen Fertilizer Application on Tomato Production

The findings from (De Pascale *et al.,* 2006) stated that for the growth and development of tomatoes, nitrogen is a critical component of the enzymes, vitamins, chlorophyll, and other cell components. As a result, it is among the most crucial nutrients needed for producing significant yields of tomatoes. In many situations, especially in low organic soils, nitrogen fertilizer is the yield-limiting element for plant growth since it is one of the most crucial nutrients for plant nutrition and growth. N fertilizers can pollute groundwater and soil because they are frequently mobile in soil. As a result, N fertilizer management, including rate, kind, and application timing, is crucial. Akanbi *et al.* (2003) reported that N fertilizer has an impact on tomato crops' leaf number per plant, plant height, fruit number and weight per fruit, as well as the overall output per plant. (Department of Agriculture, 2010) studied t omato cultivars were examined, and it was discovered that cultivars significantly affect yield, with Bufalo and Nancy cultivars having the least and most yields, respectively. Similarly report from (Hokam *et al.*, 2011) depicted that in soils with low N supplies, such as sandy soils, nitrogen has a dramatic impact on tomato growth and development. Nitrogen fertilizer encourages tomato vegetative growth and fruit yield, while later application in the growing stages favors fruit development. (Alam *et al.*, 2017) reported that, when applied in the right amount, nitrogen is crucial for the formation of protoplasm and protein, which stimulates cell division and beginning meristematic activity. It also encourages tomato vegetative development, flowering, and fruit setting. It has the biggest impact on tomato productivity and quality. Vegetable production requires nitrogen (N) fertilization to provide adequate yields and top-notch quality. (Ministry of Food and Agriculture (MoFA), 2020). (Yousaf et al., 2021) reports indicated that use of N only Ca, Mg, and S levels in the soil are being depleted more. Higher use of N, P, and K fertilizers results in increased secondary and micronutrient deficiencies in soil. (Y.R *et al.,* 2009)

Furthermore, N is regarded as one of the most important macronutrients among all the mineral elements for the metabolism, resource allocation, growth, and development of all living tissues of plants, including tomatoes (Crawford, 1995, Stitt and Krapp, 1999). Application of nitrogen supports overall vegetable growth, yield, and quality (Khatri *et al.,* 2019). However, N fertilizer used at high rates resulted in decreased crop yields as well as poor tomato quality (Chengxiao *et al.,* 1992, Chen *et al.,* 2004). Environmental issues are undoubtedly brought on by frequent and ineffective agronomic methods, particularly nitrate (NO3) loss in the environment (Ji *et al.,* 2006). Application of fertilizers is crucial for improved tomato output and is highly significant. Particularly phosphorus is required after transplanting the tomato plant, and both nitrogen and potassium, which are important for plant growth and development, should be applied during thegrowing stage of the crop (Arya *et al.,* 1999). Compared to other elements, nitrogen is one element that plants need more of. Lack of nitrogen causes the tomato plant to develop stuntedly, which causes early flowering and a short growth cycle. This nutrient encourages the growth of plant organs and produces a lot of chlorophyll, with the exception of the roots, which grow quite slowly. (Lincoln and Edvardo, 2006). One of the primary nutrients, nitrogen is important for the physiological and developmental processes of plants. It is essential to feed nitrogen in accordance with crop demand if you want to achieve improved nitrogen management. The application of fertilizers at the right time and from the right source are also essential for better nitrogen management. Depending on the species of plant, nitrogen is absorbed from various sources in a variety of ways, but is typically absorbed as nitrate and ammonium (Aman & Rab, 2013). (Zakari et al., 2017) depicted that one of the essential nutrients for plant growth and development, nitrogen (N), plays a crucial part in plant nutrition. Therefore, it is one of the elements that limits tomato plant growth's ability to produce fruit in many crops, especially in soils with low levels of organic matter. Inadequate fertilizer application, denitrification by soil bacteria, or leaching loss as a result of heavy rainfall are the three main causes of nitrogen deficit. (Abdalla, 2021) reported that when given in the right amount, nitrogen causes a favorable reaction and is crucial for the development of protoplasm and protein, both of which promote cell division and the onset of meristematic activity. The tomato crop's quality and output are most influenced by nitrogen. Additionally, it encourages tomato blossom and fruit production. It dramatically boosts tomato growth and output. When it comes to tomato growth and development, nitrogen plays a significant role. It influences the distinctive deep green hue of the leaves and encourages both vegetative and reproductive growth. The addition of nitrogen boosted the fodder maize's plant height, leaf area, number of leaves, and stem diameter. It also increased the yield of both fresh and dry feed. Nitrogen was also shown to increase the leaf to stem ratio, and it is likely that this is because nitrogen treatments enhance leaf area and leaf number, which results in the production of heavier and more numerous leaves (Gasim, 2001). High tomato fruit yield and improved fruit quality result from the application of N fertilizer to the soil, however excessive application causes the plant's vegetative portions to proliferate luxuriantly at the expense of its reproductive growth.

2.10.2: Effects of Calcium Application on Tomato Production

Calcium is a crucial plant nutrient that serves a variety of purposes in the fruit cell (Hocking *et al.*, 2016). Both the plasma membrane and the components of the cell wall made of pectin can be stabilized by it. One of the most crucial mineral requirements for tomato production in greenhouses and open fields is calcium. When it is lacking in tomatoes, the size of the leaves decreases, and in severe situations, young leaves become necrotic and the yield is lost. Tomato fruit cracking and blossom-end rot increase when calcium levels in the fruit are low. Fruit that has received an excessive amount of calcium develops gold specks or spots, which are crystal-filled cells made of calcium oxalate, which alters the fruit's look and shortens its shelf life (Ilyas, M 2014). Calcium has a protective impact against tomato blossom-end rot and can also slow down the development of other physiological problems with fruit, like chill injury and internal browning (Nicholas FReitz *et al* 2021).

Additionally, calcium promotes the germination of pollen, controls some enzyme systems, and affects the development and wellbeing of cells and conductive tissues. It particularly has a significant impact on the quality of tomato fruits. End Blossom Rot (Anon, 2022). Calcium is essential for maintaining the integrity of plant cells, cell walls, and membranes (Hirschi, 2004). Calcium deficiency in edible plant tissues has a negative effect on overall production. Plant tissues with low calcium levels are more vulnerable to some parasite infections during storage than are tissues with normal calcium levels. (Park *et al.,* 2005) Because calcium (Ca) is a macronutrient and is very stationary in plants, drought circumstances have a negative impact on its uptake in roots. (Naeem *et al.,* 2017). Due to its crucial function in maintaining the balance of membrane structures, boosting food uptake, and activating metabolic activities, calcium is essential for plants' regular growth and development. (Birgin *et al.,* 2021) In addition the Ca is essential for several processes, including as pollination, senescence, fruit ripening, chlorophyll production, signal transduction, early auxin-responsive gene activation, disease resistance, stress tolerance, and fruit yield, to name a few. A vital nutrient, calcium is essential for the growth of fruit, the formation of cell walls and membranes, and the tethering of cells. Calcium controls the metabolism of antioxidants to lessen the negative effects of stress. Walid Zorrig, (2012) reported that numerous processes relating to tomato plant growth and development, as well as overall fruit quality, are regulated by calcium. It increases resistance to viral and bacterial illnesses. Although some Ca is translocated from the soil through the leaves to the fruit, this is a very little amount. As a result, plants like the tomato will require a steady supply of calcium for healthy leaf, canopy, and root development (Ilyas *et al.*, 2014)

2.10.3: Effects of Magnesium Appl ication on Tomato Production

(Cantu, 2022) mentioned that numerous research indicated that magnesium played a significant part in the quality of tomato crop. The output of black tomatoes increased when it was used as a therapy, especially when the concentration was 48 ppm. In comparison to the magnesium-free plot, the total soluble sugar and anthocyanin content were higher in the magnesium-treated plots. Numerous functions, such as the transfer of energy and the production of proteins, require magnesium. Magnesium is crucial for the formation of chlorophyll because it makes up 20–25% of a plant's total magnesium content. (Jin *et al.,* 2022) (Kasinath *et al.,* 2015) depicted that the earliest signs of a magnesium deficit in tomatoes are inter-venal chlorosis and older, excessively thin leaves. When a deficiency is severe, the leaves turn purplish-red and brittle, with a propensity to curl upward. A high enough magnesium concentration increases tomato crop productivity by improving fruit rigidity, leaf size, and root development.

Magnesium, however, also supports accelerated enzyme activity and is crucial for energy transfer activities. Leaf chlorosis occurs when the magnesium concentration is below the ideal level, which reduces fruit yield. (Jin *et al.*, 2022) stated that numerous research have demonstrated that applying magnesium fertilizers can enhance tomatoes' ability to absorb magnesium, as seen by the rise of tomato output and the content increase of chlorophyll and magnesium in tomato leaves. Bo Yan & Hou, (2018) stated Mg contributes to the production of chlorophyll and is a crucial component of tomato chloroplasts' natural structure. About 2.7% of the molecular weight of chlorophyll is made up of it. Recent studies point to the main cause of the decline in chlorophyll content and the loss of leaf greening and yellowing as being the harm caused by reactive oxygen species under the stress of magnesium.

2.10.4: Effects of Phosphorus Application on Tomato Production

Masao Higo *et al* (2020) concluded that a vital macronutrient that is essential for tomato development and metabolism is phosphorus. Plant growth is typically restricted by soil phosphorus because of its low mobility. To achieve high crop output, phosphorus deficit must currently be eliminated, and soil phosphorus availability must be increased. This underlines the necessity of using a lot of inorganic phosphorus fertilizers in agricultural ecosystems. Soil maintaining proper levels of P in the soil is crucial for optimum tomato growth and development because phosphorus is a well-known critical nutrient for the production of tomatoes and other crops like maize and soybean. Because of their quick development and lengthy growing season, tomatoes are regarded as "heavy feeders," making the crop extremely reliant on the fertility of the soil. According to the soil, the plant requires an average of 2.5–3 kg N and 0.2–0.3 kilogram Pho sphorus to produce one ton of fresh tomato fruits. (Gebremedhin & Gebremicheal, 2020)

In addition, Given that phosphorus deficiency results in a number of nutritional issues, it is clear that phosphorus nutrition has a big impact on how plants grow and develop. It is likely that some of the developmental and physiological responses attributed to phosphorus deficit may really reflect phosphorus deprivation driven deficiencies in other critical elements because phosphorus nutrition is connected to the uptake and assimilation of other mineral nutrients. The tomato needs phosphorus in particular after transplanting (Glomus mosseae and Glomus intraradices, 2014).

2.10.5: Effects of Potassium Application on Tomato Production

Potassium is crucial for the growth and development of plants. Potash should ideally be applied when the tomato crop is growing. Chemical fertilizers are applied between 40 and 120 kg/ha of nitrogen, 30 to 90 kg/ha of phosphate, and 30 to 90 kg/ha of potash in the tropics. (Iqbal *et al.*, 2011) An investigation from (Ehsan Akhtar *et al.,* 2010) depicted that when compared to grains, tomatoes are a much heavier provider of nutrients, particularly potash. On average, 280 kg N, 55 kg P2O5, and 540 kg K2O would be needed for a tomato crop to produce 30 t ha-1. High levels of K are absorbed by tomato fruits from the soil. Nutrient intake throughout the fruit growth period increases quickly with optimal diet. K is currently the most important nutrient. Numerous plant activities, including photosynthesis, osmoregulation, phloem transport, and determining the final yield, depend on an adequate K supply. Without adding K fertilizer, it is impossible to grow tomatoes with large yields in poor K soil. (Fontes *et al.,* 2000) Findings from Frederike Sonntag (2020) indicated that a macronutrient called potassium (K) is necessary for a number of physiological processes in plants, including tomatoes. These processes include enzyme activation, assimilate translocation, turgescence maintenance, and stomata modulation.

2.10.6: Effects of Sodium Application on Tomato Production

Various writers claim that little research has been done on the effects of applying sodium to tomatoes. Despite this, plants, including the tomato (Lycopersicon lycopersicum), absorb rather large doses of sodium. The higher tomato crop output in Nigeria is attributable to better plant water management when potassium and sodium were administered. On the other hand, more recent research found that the use of minor nutrients and low levels of sodium to achieve the necessary electrical conductivity increased tomato performance and yield in the nutrient culture and decreased production costs. Recent research on sodium application at a Na:K ratio of 1:32 to 1:8 boosted tomato plant growth and yield ((Idowu & Aduayi, 2007)).

2.10.7: Effects of Poultry Manure Application on Tomato Production

One of the most significant sources of organic fertilizer is poultry manure (PM). One acceptable organic fertilizer is organic material like chicken dung. It has a crucial role in preserving the fertility of the soil. As a result, it is less expensive, more widely accessible, and more environmentally friendly. The nutrients in organic manures are released more gradually and remain in the soil for a longer period of time, ensuring a lasting residual effect. However, among all animal manures, poultry excrement is the most useful when treated correctly. It has been documented that tomato yield, growth, and soil fertility can all benefit from using chicken manure. (A.O.Adekiya and T.M.Agbede, 2017). Ilodibia CV and chukwuma M.U (2015) stated that application of organic fertilizer, such as chicken manure, is an effective way to maintain soil fertility and is also good for the environment, which benefits the soil and tomatoes. Poultry manure contributes to the establishment of soil microbes that may help protect tomato plants from infections like nematodes and soil-borne insects as well as give growth hormones like auxins. It is an inexpensive and readilyavailable source of nutrients for the cultivation of crops. (Agbede and Ojeniyi, 2009).

Similarly, (Aliyu, 2000) reported that an increase in sweet pepper seed and fruit production as a result of using poultry manure. (Abdulmaliq et al., 2016) indicated that Cow dung, goat manure, and poultry manure are excellent sources of plant nutrients for soil amendments. When composted, organic manure, such as poultry manure, can give tomatoes vital nutrients and improve the soil. (Anon 2022). The macro- and micronutrient content of the soil and leaves, as well as the development and yield of the tomato plant, were all improved when poultry manure was added to the soil where it had been planted. By greatly raising the N, P, and exchangeable bases in the soil planted with spinach after the addition of chicken manure, soil fertility was improved. *(Azmi et al.,* 2019)

2.10.8: Effects of Leucaena Litters on Tomato Production

According to (Rusdy *et al.,* 2020) observed that Leucaena is a tropical tree legume plant that has been utilized all over the world to reduce soil erosion and keep or improve soil fertility. Its wide, dense roots and depth of penetration, which might provide both surface-level and deep-seated soil erosion control, are credited with its ability to prevent land deterioration. One of the best options to enhance soil health and provide for nutrient needs is green manuring. (Pandey & Kumar, 2013) In order to replace the lost humus, which is vital for maintaining the soil's health by boosting the nitrogen supply and encouraging the growth of microorganisms, it is required to apply organic matter like leucaena on a regular basis. With a multitude of agronomic and environmental benefits, leucaena litters are the most suitable for this use. Undecomposed green plant tissue is turned into the soil through the use of green manuring (Leucaena litters), which aims to increase the fertility and productivity of the soil. It enhances soil structure, water holding ability, and microbial population of soil by adding humus or organic matter. It also promotes soil fertility by directly adding nitrogen. According to the soils and climate's appropriateness, green manuring is used (Kaur R. 2015).

Additionally, it can enhance the physical, chemical, and biological characteristics of the soil, which will increase tomato yields. Other potential advantages of using Leucaena for green manuring include less nitrate (NO3) leaching risk and reduced fertilizer N requirements for tomato crops. However, its impact may differ depending on the type of green manure crop utilized, the soil, the crop, environmental factors, and its management. Green manuring's beneficial impacts on crop production shouldn't be assessed in isolation; rather, they should be considered in conjunction with chemical fertilizers (Wick *et al.,* 2017)

2.11: Production Constraints with Tomatoes in Sub-Saharan Africa and World

Tomatoes can be grown all year long, but the best yields come from well-drained soils and temperatures between 20 and 27 degrees Celsius. The biggest production restrictions change depending on the environment. The production of tomatoes during the rainy season is sometimes affected in highland regions of eastern and southern Africa by fungi that produce late blight (Phytophthora infestans), early blight (Alternaria solani), and fruit rot (Phytophthora parasitica). Farmers who cultivate tomatoes during the wet season might have higher production expenses because they need to use more fungal sprays, but they might be able to sell tomato fruit at better prices (Fakade Dinssa 2009). Tomato production during the dry season in the Sahelian regions may be constrained by irrigation water scarcity or exorbitant prices. For instance, in Katibugu village in Mali, frequent irrigation is needed during the dry season, which increases the time needed for irrigation and the expense of running generators to pump water from the river by roughly three times (pers. commun. with farmers, March 2008). Farmers' heavy use of groundwater in Funya village in the same nation may eventually deplete the aquifer (Fufa *et al* 2011). Major production barriers in arid and semi-arid agroecologies, as well as during the dry seasons of other agroecologies, include tomato yellow leaf curl virus disease (TYLCVD), heat, and sunscald. Bacterial wilt brought on by Ralstonia solanacearum can be a catastrophic disease that results in reduced yields in hot, wet agricultural areas and seasons like those in Mali and the Congo. The root knot nematode is a concern in numerous places, including Tanzania's coastline region. Red spider mites (Tetranychus sp.), whiteflies (Bemisia tabaci), fruit worms (Helicoverpa armigera), and thrips are significant tomatopests. In Africa, old open-pollinated cultivars including "Roma VF," "Rio Grande," "Marglobe," and "Moneymaker" are commonly grown (Ellis-Jones *et al.,* 2008), and the majority of seed sold on the market is imported from China, Europe, and India. For instance, Rio Grande, Roma, and Rossol dominate the market among the 57% of cultivars that are planted in Cameroon that are open-pollinated (Ellis-Jones *et al.,* 2008). Due of their susceptibility to serious illnesses, it is challenging to grow these cultivars without frequently applying chemical sprays. Some of these cultivars also don't have fruit firmness and shelf life that are strong enough to tolerate long distances and hard handling.

Due to a lack of supply, prices in Mali are higher from April to September than they are from October to March (high supply) (IER/ECOFIL, 2005). Among the factors limiting tomato production in sub-Saharan Africa, particularly Madagascar, are low soil pH and low soil fertility. Particularly given the rise in fertilizer prices, farmers use little or no fertilizer. Other physiological issues, such as blossom-end rot, can occur in soil with a pH below 6.0. Blossom-end rot is brought on by a lack of calcium and poor water management (Ho *et al.,* 1993; Saure, 2001; Taylor and Locascio, 2004). Fruit cracking brought on by erratic water supply is one of the other physiological issues (Peet, 1992; Peet and Willits, 1995), and cat-facing brought on by changes in temperature during bloom development (Rylski *et al.,* 1994). When the fruits of cultivars with inadequate leaf cover are exposed to direct sunshine, sunscald is a major problem.

Additionally, a variety of biotic and abiotic restrictions have complicated tomato production. Abiotic stressors are essentially interconnected; whether used singly or in combination, they alter the morphology, physiology, biochemistry, and molecular structure of plants, impairing their ability to grow and produce, and ultimately reducing their yield. The primary abiotic stresses that cause severe cellular damage in wild and domesticated tomato species include rising temperatures (heat), drought, cold, and salinity. These conditions are thought to be caused by climate change. (Bita and Gerats, 2013). Climate-related factors such as temperature, precipitation, CO2, CH4, nitrous oxide (N2O), O3, long-term water scarcity, unsuitable soil conditions, drought and desertification, and disease and insect outbreaks on crops and livestock are anticipated to have a substantial impact on crop development. According to predictions, climate change will directly affect the frequency and severity of diseases in crops, especially tomatoes, which will have a negative influence on our ability to get healthy food (Biratu, 2018) (Wakuma Biratu, 2013; Kurukulasuriya and Rosenthal, 2013; Ali *et al.,* 2017).

Perez K. *et al.,* (2017) reported that West African tomato farmers must contend with a variety of insect and disease issues. There are several diseases that affect plants that are soil-borne, including bacterial wilt brought on by Ralstonia solanacearum and fusarium wilt brought on by Fusarium oxysporum f. sp. lycopersici. Foliar diseases include bacteria spot brought on by Xanthomonas species, late blight brought on by Phytophthora infestans, and septoria blight brought on by Septori Worms like the cotton bollworm (Helicoverpa armigera), nematodes, mining insects, thrips, several species of aphids, and mites like spider mites are examples of pests (Tetranychus urticae). Recent outbreaks of the tomato leaf miner (Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) have resulted in significant damage to tomato crops in, according to (Karlsson *et al.,* 2018). A complex of whitefly (Bemisia tabaci)-vectored begomoviruses and betasatellites, however, have recently prompted tomato growers throughout West Africa to deal with a new viral illness known generically as tomato leaf curl disease (Zhou *et al.,* 2021). In several West African countries over the past ten years, begomoviruses (genus Begomovirus), which belong to the family Geminiviridae and are distinguished by a circular single-stranded DNA genome encapsidated within twinned isometric virions, have become the most significant barrier to tomato production, in some cases leading to up to 100% yield losses (Kirthi et al., 2004) There have been such severe losses in West Africa that many farmers have completely stopped growing tomatoes (Perez *et al.,* 2017).

2.12: Overview of Climate Change

Climate change is defined by the Intergovernmental Panel on Climate Change as a change in the climate's state that can be determined (using statistical tests) by changes in the mean and/or variability of its attributes, and that lasts for a significant amount of time, usually decades or longer. It describes any climatic change over time, whether it is brought on by natural variability or human activities. This definition of climate change is different from that used in the United Nations Framework Convention on Climate Change (UNFCCC), which uses the term to describe a change in the climate that is directly or indirectly related to human activity that modifies the composition of the earth's atmosphere in addition to natural climate variability seen over comparable time periods (UNFCCC, 2011). Globally significant climate change will have an influence on agriculture and, in turn, the availability of food. In and of itself, climate change is not inherently detrimental, but unpredictable events are what cause the difficulties. The tropics' crop output is subsequently decreased by records of erratic rainfall patterns and unpredictably high temperature periods. Land degradation, extreme geophysical occurrences, decreased water availability, the rise in sea level, and salinization are examples of latitudinal and altitudinal changes in ecological and agro-economic zones (TO & KO, 2018).

In addition, (Guodaar, 2021) reported that since the middle of the twenty-first century, the phenomena of global climatic shifts has been labeled as "unprecedented" and "unequivocal" by scientists. Many experts argue that the primary factor contributing to global climate variability is anthropogenic driving forces. As a result of its reliance on rain-fed agriculture, which is extremely sensitive to weather and climate variables like temperature, precipitation, and extreme events, as well as its limited capacity for adaptation, Sub-Saharan Africa is disputed as the region most vulnerable to being affected by the world's changing climate. Because of the greenhouse gas emissions in the atmosphere, such as carbon dioxide, methane, water vapor, and ozone, it is expected that crops and forage plants will experience rising temperatures and altered precipitation patterns, which together will have the effect of slowing plant growth and development.

Furthermore, (Urama K & Ozor N, 2011) depicted that One of the biggest threats to sustainable development is climate change, which is quickly becoming a key global development issue that affects many global industries. Globally, enormous growth in greenhouse gas emissions has increased the effects of climate change. Since agricultural operations rank third in terms of increasing greenhouse emissions, behind the use of energy and the manufacturing of chlorofluorocarbons, it has been established that they significantly contribute to climate change. In fact, it's estimated that about 15% of today's human greenhouse gas emissions come from agricultural sources. Another 8% or so of the total comes from changes in land use, which are frequently done for agricultural purposes.

2.13.: Specific Climate Elements Affecting Crop/Tomato Production in Africa

2.13.1: Temperature Effects

Since the turn of the century, the average global temperature has been rising, primarily as a result of the buildup of greenhouse gases caused by anthropogenic activity. The primary causes include increased agricultural production, deforestation, and the combustion of fossil fuels (coal, oil, and gas) to meet the rising energy demand (National Human Development Report 2008). Everywhere throughout the world, people notice that the climate is always changing, along with the temperature. Globally, the temperature of the surface air increased, and it is higher at higher latitudes. Regional climate changes, particularly temperature rises, have an impact on the evidence of changes in natural ecosystems. By the end of this century, the annual average temperature is predicted to increase by 0.6 to 4.1°C (Solomon et al., 2007). (Guodaar, 2021) studied Maximum temperature had a statistically significant inverse relationship with tomato yield, according to research on the impact of temperature on tomato productivity in Ghana's north district of the Ashanti area. Thisindicates that, when other confounding factors like soil type, application of agro-chemicals, irrigation, tomato variety, and regular weeding were held constant, a rise in temperature led to a noticeably lower tomato production (De la Peña & Hughes, 2007). (Vincent et al., 2018) concluded that, In Asia and Sub-Saharan Africa, high temperatures were shown to cause tomato failure to produce fruit, bud drop, abnormal flower development, poor pollen generation and dehiscence, ovule abortion and poor viability, reduced carbohydrate availability, and other reproductive abnormalities.

Additionally, as temperatures rise above their ideal level, photosynthesis is significantly inhibited, which results in a drastic loss of potential yield (Bita & Gerats, 2013) Due to heat damage and physiological issues with photosynthesis in vegetable crops, high atmospheric temperatures brought on by high CO2 concentrations would have a negative impact on farmers' livelihoods by lowering crop production. High temperatures are more harmful to vegetative than reproductive development, and even within a species, heat sensitivity varies amongst cultivars (Johkan *et al.*, 2011) Tomatoes need ideal conditions for normal germination, growth, and development. As a result, unfavorable temperatures cause irregular growth rates or prevent or restrict germination, growth, and development. Growth and timely development are restricted by temperatures that are below and over the minimum and maximum requirements, which vary among crops and with different growth phases in the same cultivars. Temperature in particular has a significant impact on crops during the reproductive phase, from pollen production to fertilization (Johkan *et al.*, 2011). Tomato seedlings generally grow more quickly and flower differentiation and development are encouraged in high temperature conditions. However, fruit set rates and proportions are declining. In tomato plants, floral abscission, deformed flowers, poor flowering, poor fruit quality, color disorder, and pollen sterility are caused by flowering temperatures that are too high (Johkan *et al.*, 2011). The best temperatures for tomato seed germination, seedling growth, fruit set, and red color development are between 16 and 29 degrees Celsius, while high temperatures have a negative impact on pollen viability and release, which results in poor fruit set (Naika *et al.*, 2005). Zakari, S. A., (2017) observed that Fruit set is frequently low during the rainy season (June-September), perhaps as a result of the warm nighttime temperatures. Tomato shortages during the off-season are primarily caused by a lack of water, particularly rain for farmers with littleresources. However, tomatoes cease growing and stop bearing fruit at high temperatures and high humidity.

2.13.2: Rainfall Effect

Tomato production is impacted by global trends and rainfall variability (Geography, 2020). The IPCC predicted that the shifting patterns of rainfall will have a significant influence on agricultural production and negatively damage human health and income (Dokken, n.d.)In a tradition that dates back to the 19th century, shifting rainfall patterns allow for the cultivation of a range of crops in accordance to regional weather circumstances. (Geography, 2020). Guodaar (2015) also found that the relationship between rainfall and tomato yield was negatively statistically significant. The upshot is that even though tomatoes need water, excessive rainfall is completely harmful to tomatoes and may result in a decrease in tomato yield. By 2050, it is predicted that East Africa will see warmer temperatures, a 5–20 percent increase in rainfall from December to February, and a 5–10 percent decrease in rainfall from June to August due to changing rainfall variability (Case, 2006)

However, due to periodic droughts, floods of varying intensity, and marketing systems, which have an impact on crop output with the exception of tomatoes, changing rainfall trends have an impact on the rural population. The intake of agricultural inputs is restricted or rendered ineffective by changes in rainfall patterns, which have a direct or indirect impact on tomato output (e.g. fertilizer, manures, pesticides and herbicides) (Kassie *et al.*, 2014). More unpredictable rainfall periods result in lower quantity and quality (Kumar *et al.*, 2012). Reduced precipitation results in lower water availability for irrigation in reservoirs and higher evapo-transpiration rates, which create water-stress conditions in the juicy tomato fruit, which contains more than 90% water (Adedapo, 2017)

2.13.3: Drought Effects

Drought is a dry spell that harms crops; it has more to do with changes in the soil and weather than it does with the hydration of plants and their tissues. When the relative humidity of the air and soil are low and the surrounding temperature is high, drought stress results ((Lipiec et al., 2013). Ample fresh water is essential for crops like tomatoes, which account for 70% of all water use globally. The biggest issue for wet season tomato production will be the water shortage brought on by global warming. Arid regions will increasingly desertify as temperatures rise due to increased evaporation from water sources and decreased precipitation. Drought will reduce the cultivable land, especially in semiarid areas, which could lead to hunger and mass displacement.

2.13.4: Wind Effects

(D.Dewbre *et al.,* 2014) reported that Wind has an impact on plant growth both directly and indirectly. Numerous vegetable crops, particularly tomatoes, can be badly harmed by wind alone or wind combined with sand. Plants can lose their leaves in strong winds, and in extreme cases, plants might be uprooted or have their stems shattered. Plant shape and agricultural yield can alter simply as a result of wind movement. Plant growth is constrained, development is inhibited, and the shape of the plant changes as wind speeds rise. Smaller plants under wind stress have stronger stems, shorter internodes, and smaller leaf surfaces. Flower parts become less appealing to pollination insects and less receptive to pollen as a result of wind desiccation. Lower rates of fertilization and a consequent decrease in fruit are the results.

2.14: Gambia's Climate Change Mitigation Actions to Achieving a Net-Zero Scenario

(D.Dewbre *et al.,* 2014) reported that, The Gambia's specified mitigation measures are founded on the long-term vision's defined preferred GHG reduction choices, which are built on ongoing initiatives to implement the Paris Agreement and UNFCCC. To attain a net-zero scenario by 2050, the LTV outlined a number of mitigation measures that are grouped under three sub-subsectors that must decarbonize. The three sub-sectors are waste, AFOLU, and energy.

2.14.1: Agriculture, Forestry and Land Use Sector Mitigation Options to Curb Green House Gas emissions

The long-term vision has put up multiple GHG mitigation action plans for the AFOLU sector, which can help the nation achieve a net-zero or net sink mitigation scenario by 2050. These sectors have a variety of GHG mitigation options. This will be accomplished by putting agroecology into practice, encouraging social protection against climate-related impacts, protecting forests, monitoring forests, reforestation, conservation agriculture, etc (Ministry of Environment, Climate Change and Natural Resources 2017). The vision also aims to keep 30% of the nation's total land area covered by forests. In 2030, it is expected that these climate change mitigation measures will result in a decrease of 330 GgCO2e. The objective is to achieve robust and sustainable land conversion processes and promote environmentally friendly agricultural output. In a broader perspective, the following mitigation actions will be pursued to achieve a net sink GHG mitigation scenario within the AFOLU sector (The Gambia National Climate Change Policy 2016):

MA13: Agro-ecological farming
MA14: System of Rice Intensification
MA15: Upland Rice Production
MA16: Controlled timber harvesting
MA17: Improved Manure Management
MA18: Genetic improvement of livestock species
MA19: Improved nitrogen-reduced animal feed
MA20: Mangrove rehabilitation
MA21: Afforestation and Reforestation Enteric fermentation from ruminant livestock (cattle, sheep, goats, etc.) is one of the leading causes of GHG emissions from the livestock sub-sector. The sort of animal feed consumed exacerbates the condition. Animals that eat feeds high in nitrogen are more prone to create large amounts of methane. As a result, feeding the animals decreased nitrogen feeds will cut down on the amount of methane their excrement emits (Qi, J. & Terton, A, 2022).

2.15: GENERAL ADAPTATION STRATEGIES TO CLIMATE CHANGE IMPACTS ON AGRICULTURAL CROPS

2.15.1: Planting of Drought Resistant Crop Cultivars

In drought-prone areas, putting more of an emphasis on drought-resistant crops may assist to lessen vulnerability to climate change. For instance, compared to rice grown during the dry season, wheat uses substantially less irrigation water. Smallholder farmers in Nigeria, Senegal, Burkina Faso, and Ghana have experimented with the use of drought-resistant crop varieties as strategies of coping with climate change (FAO, 2006). Additionally, nomadic pastoralists living on Kenya's desert fringes adopted drought-fighting tactics (Oluwole Matthew Akinnagbe and Ifeoma Quinette Anugwa, 2015). Agriculture's adaptation strategies include managing irrigation, altering cropping patterns, shifting planting dates, and using drought-tolerant varieties (De Pinto *et al.*, 2012)

2.15.2: Crop Diversification

In the medium to long term, diversification toward high value crops is viable. Both in irrigated and non-irrigated locations, crop diversification is a top priority adaptation strategy. For instance, land use is influenced in Southern Africa, resulting in land use conversion, such as the switch from cattle farming to game farming (Ziervogel *et al.*, 2008). Food crops have replaced cash crops in the western Sudanese states of Kordofan and Drafur, and more hardy crop varieties have been developed (DFID, 2004). Tanzanian farmers diversify their crop varieties to spread farm risks. Crop diversity can protect you from unpredictable rainfall.

2.15.3: Change in Cropping Pattern and Calendar of Planting

Crop production is negatively impacted by climate change through long-term variations in rainfall that alter cropping patterns and operational schedules. According to (Urama K & Ozor N, 2011) in the past five years, farmers in Central Africa (Cameroon, Equatorial Guinea, and the Central African Republic) have observed a general increase in the trend of uncertainty in extreme weather occurrences. In Tanzania, staggered plating is quite widespread among farmers, where crops are planted on uncultivated ground before rain begins (dry land) in order to prevent agricultural production risks caused by rainfall variability and drought. Some plots were planted right away after it rained, while others were planted a few days later. On the third week after the start of rain, fields that were planted before cultivation begin to be tilled. This allows for the destruction of early-geminating weeds and lowers weeding. These were done on purpose to spread risk by ensuring that the crop planted in the dry field made the most of any rain that did fall (Liwenga, 2003) In Egypt, Kenya, and Senegal, different planting dates are also regarded as a significant adaptation.

2.15.4: Mixed Cropping

Growing two or more crops close to one another in the same field is known as mixed cropping. In Tanzania, where cereals (maize, sorghum), legumes (beans), and nuts (groundnuts) are all cultivated together, the method is widely used. Mixing crops with different characteristics has advantages in terms of maturation length (for example, maize and beans), drought tolerance (for example, maize and sorghum), input requirements (for example, cereals and legumes), and product consumers (e.g. maize as food and sunflower for cash). The planting of various varieties of the same crop is thought to be one of the most significant adaptations in all countries, with the exception of Cameroon and South Africa, according to a study by (De Stefani et al., 2000)on examining adaptations achieved in Africa.

2.15.5: Improved Irrigation Efficiency

In locations that are prone to drought, the success of climate change adaptation depends on the availability of fresh water. It should be stressed that the majority of adaptation strategies, including increased irrigation effectiveness, are beneficial even in the most conservative climate change scenarios. Increased irrigation efficiency will be a crucial tool for adaptation as water becomes scarce, especially during the dry season because irrigation practices for arid areas require a lot of water. As a result of increased evapo-transpiration brought on by climate change, the ongoing introduction of high-yielding varieties, and intensive agriculture, it is anticipated that there would be less fresh water available (both surface and groundwater) and less soil moisture during the dry season (FAO, 2006) Significant numbers of farmers have adapted in Egypt, Kenya, and South Africa by using irrigation more frequently. Farmers use adaptation techniques such irrigation water transfer, water harvesting, and water storage in the Gambia, South Africa, and Sudan to mitigate the consequences of rainfall unpredictability (Akinnagbe & Irohibe, 2015) (TO & KO, 2018) and (Boko *et al.,* 2007). Farmers typically irrigate more often as the temperature rises. Undoubtedly, irrigation is a warming-related adaptive method. They tend to use natural rainfall more frequently and irrigation less frequently as precipitation increases. When the temperature rises, farms in the desert reduce irrigation. Similar to this, farmers near deserts increase irrigation when it rains more.

2.15.6: Adopting Soil Conservation Measures that Conserve Soil Moisture

Techniques for soil conservation are being used more frequently in Burkina Faso, Kenya, Senegal, and Niger. A study carried out by (M. & A., 2009) in Manyoni District of Tanzania revealed that farmers in Kamenyanga and Kintinku make sure that various farming activities are done at the right time, including burying crop residues to restore soil fertility, burning crop residues to speed up the release of nutrients, and letting livestock graze on farmlands after harvesting crops to increase soil organic matter. Farmers employed contour ridges in Tanzania as a technique to reduce soil erosion, promote greater root penetration, and improve moisture conservation. (M. & A., 2009) Local farmers in Senegal and Burkina Faso have increased their ability to adapt by doubling tree densities in semi-arid areas through the use of traditional pruning and fertilizing methods. These aid in stabilizing soils and halting desertification. (Boko et al., 2007) noted that Local farmers in the Sahel utilize mulching and other soil management strategies, such as zero till farming, to preserve carbon in the soils. Natural mulches regulate the extremes and temperatures of the soil, prevent illness and dangerous pests, and maintain the soil's hydration. Prior to the invention of artificial fertilizers, a substantial portion of local farmers relied on organic farming, which can help lower GHG emissions.

2.15.7: Planting of Trees (Afforestation) and Agroforestry

The act of transplanting tree seedlings is known as "tree planting," and it is typically done for forestry, land reclamation, or landscaping purposes. It is distinct from arboriculture's transplantation of larger trees and from the less expensive, slower, and less dependable dispersal of tree seeds. Depending on whether the area being planted has recently been forested or not, the silvicultural practice is referred to as either reforestation or afforestation. On a plot of ground where a forest has been cleared or damaged by fire, disease, or insects, seedlings are planted. In order to adapt to the effects of climate change, rural farmers in the majority of the African nations have been planting trees. Agroforestry is a methodical approach to land use planning that seeks to strike a balance between the growth of forests and food crops (Adesina et al., 1999) This method of growing shade-tolerant crops, like cocoyam and Dioscorea species, has been recorded in a region of south-western Nigeria where the land is essentially covered by a permanent forest (Akinnagbe

& Irohibe, 2014) Agroforestry techniques can be improved to better adapt to the new circumstances that are anticipated under drier conditions and a higher population density. They also enhance the quantity of organic matter in the soil, enhancing agricultural productivity and lowering strain on forests. Local farmers typically plant baobab (Adansonia digitata) and acacia (Acacia) trees in the drier regions of the Sahel because they recognize them as valuable trees, particularly during the hot and dry seasons (Akinnagbe & Irohibe, 2015)

Moreover (UNFCCC, 2011) reported that by ensuring that farming communities are better prepared to adapt to climate change and unpredictability, minimizing possible damages, and assisting them in coping with negative effects, farmers may significantly reduce vulnerability to climate change. Changes in crop management practices (e.g., choice of fields, planting dates, planting densities, crop varieties), land use and land management (e.g., fallowing, tree planting or protection, irrigation and water harvesting techniques, soil and water conservation measures, tillage practices, soil fertility management) are just a few examples of possible responses to climate change. Similar statement was also reported by (Fosu-Mensah et al., 2012) indicated that Changes in tomato variety, planting of early-maturing varieties, shifting of planting dates, and diversification are theprimary adaptation tactics of farmers in Ghana's Sekyedumase District. Furthermore(Boko *et al.,* 2007) noted that strategies for adaptation that have already been seen in Africa include selling labor, adjusting farming practices, and diversifying one's source of income. African Technology Policy Studies, (2013) depicted that Water harvesting technology, conservation tillage, the use of keyhole and trench gardens, agro-forestry, and the use of cultural approaches to control pests and diseases are a few of the farmers' adaption tactics in Lesotho. To boost resistance to climate shocks, Chinese farmers have established their own adaptation measures, such as modifying cropping patterns, increasing investment in irrigation infrastructure, utilizing water-saving technologies, and growing improved tomato varieties (Deng *et al.*, 2017)

Additionally, farmers in Cameroun are growing improved tomato varieties as adaptation techniques, which has been a significant reaction to pest and drought. In an era of climate variability, irrigation is one of the key adaptation measures that could increase tomato yields. (Malyse, 2021) Tomatoes are not drought-resistant. After the brief water shortage phase, yields drastically decline. Watering the plants frequently is crucial when they are producing flowers and fruit. The kind of soils determines how much water is required. One of the adaptive strategies employed by farmers in Santa during times of drought and low rainfall is irrigation. Farmers in Santa use a variety of irrigation techniques, including the use of water pipes and watering canes to draw water from wells to irrigate their farms. To reduce the danger of crop failure and production decline, tomato growers in Santa are transitioning from monoculture to mixed cropping, crop rotation, and intercropping. Tshiala and Olwoch (2010) reveal that the use of fertilizers and agrochemicals increases soil fertility and gets rid of pests, illnesses, and other issues that damage tomatoes. Additionally, using agrochemicals, particularly fertilizer, is an excellent adaptation tactic that increases tomato yields. The majority of farmers in this region use NPK 20:10:10 fertilizer to boost the fertility of their soils, particularly soils that have become fertile as a result of heavy rainfall or fluctuating rainfall.

2.16: Introduction to Crop Modeling (DSSAT)

Computer systems known as "crop simulation models" simulate crop growth by numerically integrating constituent processes using (FAO, 2006; Matthews *et la*, 2002). More specifically, it is a computer program that depicts the dynamics of a crop's growth in relation to its environment (such as rice, wheat, maize, groundnut, tea, etc.), operating on a time-step that is an order of magnitude shorter than the length of the growing season, and having the ability to output variables that describe the state of the crop at various points in time (e.g. biomass per unit area, stage of development, yield, canopy nitrogen content, etc.) (Matthews & Stephens, 2002) These crop models simulate crop growth and development for a certain set of inputs, such as information on the soil, the weather, and model parameters that are specific to the crop (Kephe et al., 2021). Crop simulation models are typically employed in agricultural production systems to evaluate the effects of anticipated climate change. It has been demonstrated by numerous scientists that crop simulation models have shown to be a useful and broad tool for researching plant and climatic relationships or studying the effects of climate change (Matthews and Stephens, 2002, Jones *et al.*, 2003; Carbone *et al.*, 2003; Easterling *et al.*, 2003; Timsina and Humpreys, 2006). (Bouman & Van Laar, 2006) simulated the impact of climate change in Asia.

The Decision Support System for Agrotechnology Transfer (DSSAT) is a software program that integrates the impact of crop phenotype, soil, weather, and crop management system through a database system and enables users to simulate experiments on desktop computers in a minute that would otherwise require a significant amount of time to conduct (Abayechaw, 1989). According to (Salvacion & Salvacion, 2011), through its various independent programs that work together, DSSAT lets the user to examine the "what if" outcomes of various management options and tactics. These applications comprise databases and crop simulation models that provide information on genotypes, weather, soil, experiment conditions, and measurements. The software also enables users to create inputs for each program, compare simulation results with observations, and decide whether to make changes to the models in order to increase accuracy. Additionally, DSSAT programs' multi-year simulation option enables users to evaluate the risk connected to various crop production techniques. Conversely, for use in climate change impact studies, DSSAT also features a built-in feature that allows users to specify changes to weather variables without actually altering the original weather file. Recent software improvements have added the ability to read historical atmospheric carbon dioxide data directly from Mauna Loa, Hawaii (Hunt et al., 2006)

Crop growth simulation models are emerging technological tools with potential uses for interpreting research (Boote *et al.,* 1996, and for production management to monitor irrigation and nitrogen (N) uses (Boote et al., 2013). It is crucial that crop growth models are adequately parameterized using the most recent data from the literature before being calibrated and validated with field measurements to maintain their robustness of prediction, especially in the setting of environmental stresses like increased temperature. There are several tomato crop growth models, some of which are tailored for greenhouse production and others for systems that use field cultivation. Examples are TOMGRO (Dayan, 1993) TOMSIM (Heuvelink, 1995), TOMPOUSSE (Gary *et al., 1997*), the model of Marcelis *et al.,* (2009), and CROPGRO-Tomato (Boote and Scholberg, 2006; Scholberg *et al.,* 1997). The CROPGRO- Scholberg et al. (1997) modified the tomato model to replicate tomatoes grown in fields. However, there wasn't much data available to calibrate temperature response functions during the initial model adaption.

2.16.1: Importance of Applying CROPGRO for Tomatoes

Farmers and extension personnel worldwide should be helped by modeling the growth of field-grown tomatoes (Lycopersicon esculentum Mill.) to identify the best crop management practices for particular locales and production systems (Lichtfouse, 2010). Researchers and producers have grown to rely heavily on the CROPGRO growth simulation model as a tool for management and production improvement ((Boote & Scholberg, 2006)). The models give a technique to extrapolate to other places with distinct environmental characteristics by synthesizing the data from numerous experiments or production fields conducted at various locations (Faye *et al.*, 2018)

CHAPTER THREE

3.0: RESEARCH METHODOLOGY

3.1. Description of the Study Areas for the Field Survey

The study was conducted in the West Coast Region of the Gambia in 2021. The Region was originally known as Western Division, also known as Foni or Fonyi, was one of the five administrative divisions of the Gambia. Its capital is still Brikama. The region is located in the western part of the country, west of the Atlantic Ocean, north of the Big Banjul Region and Lower River Region and Senegal is located in the south. The region itself is divided into nine districts. These districts are Foni Bintang-Karenai, Foni-Bondali, Foni-Brefet, Foni-Jarrol, Foni-Kansala, Kombo Central, East, and Kombo North / Saint Mary. The area is 1,764 square kilometers and it has a population of 699,704 Population and Housing Census Preliminary (2013). The field survey was limited to only three different communities (Lamin, Sukuta and Banjulnding) where the intensification of vegetable gardening are so high plus Horticulture Research Programme and Regional Directorate of Agricultural Extension Services. The area lies between a latitude of 13.2229° N, and a longitude of 16.5820° W (Ceesay, 2004).

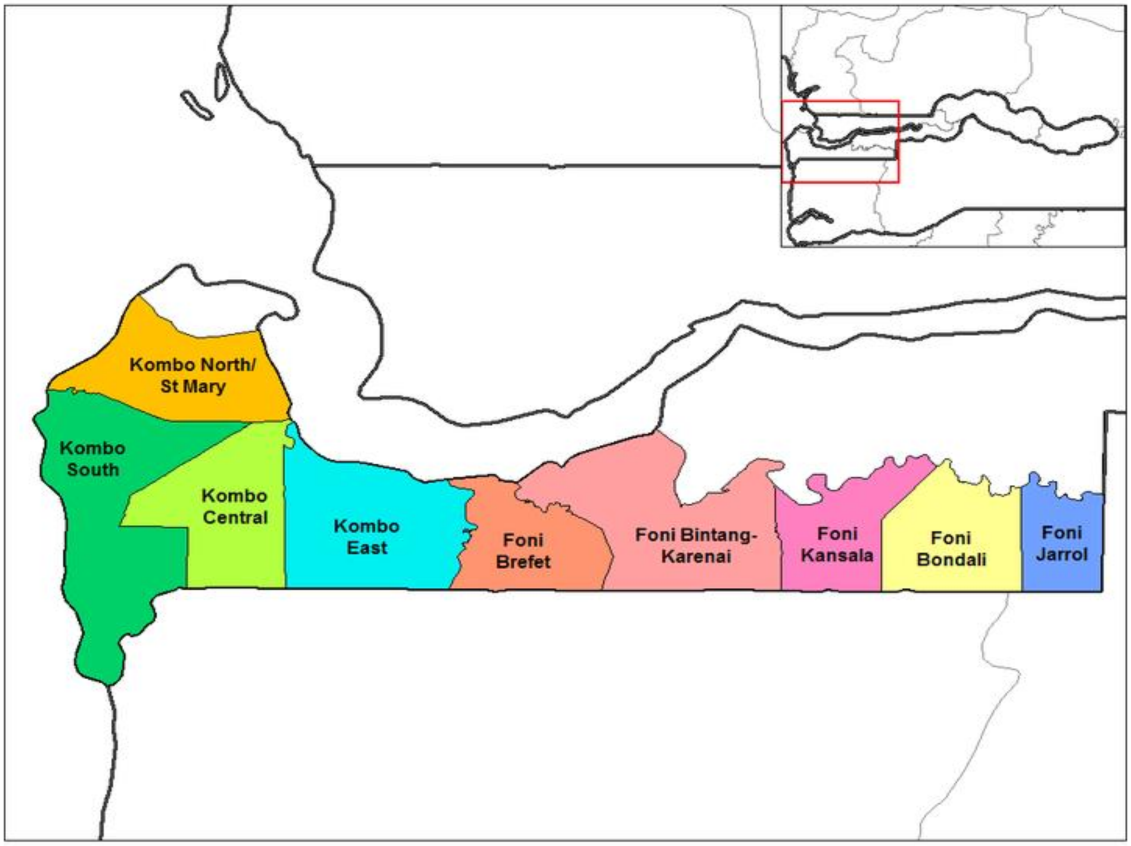


Figure 1: Map of West Coast Region of The Gambia

3.2. Data Collection Details from the Field Survey

A comprehensive design structured questionnaire was developed and used as a tool for guiding the proceedings of Key Informant Interviews and Focus Group Discussions (FGD) in the selected communities. This was followed by recruitment of field enumerators and training on how to translate the questionnaires into different local languages in order to ensure that the data that is going to be obtained from the respondents are reliable and accurate. Prior to the field data collection, the enumerators were deployed to the non-sample tomato growing community for pretesting of questionnaires. This has helped and determined the strengths and weaknesses of the survey concerning the question format and wording, order and as well as the ability and capability of the enumerators. Five persons were involved in the survey exercise i.e.; 4 Enumerators and 1 Driver.

3.3: Sampling Methods and Techniques

For the Key Informant Interviews, district field agric extension workers were involved in the selection process of communities and sampling of respondents. A selection criteria was established and used to select communities and respondents such as: level of tomato production and respondents adequate knowledge about climate change etc. This was used as a criteria because most of the farmers will cultivate only one or two small plots and don’t know about climate change due to their age. Five vegetable gardens were identified within the district in the West Coast Region and 20 farmers were selected in each community garden which was later reduced to 10 respondents per orchard using the method to avoid biasness. A total number of 50 respondents were interviewed. However, similar method was also used for Focus Group discussions.

3.3.1: Key Informant Interview

Four field enumerators were assigned to administer fifty set of questionnaires to the selected respondents in each vegetable garden. Respondents were also free to give answers to the questions without the enumerators leading them.

3.3.2: Focus Group Discussions (FDGs)

However, one FDG was held in each community garden, a minimum of 30 participants were selected which comprises of women, men and youths. During the FDGs, the selected tomato producers in each orchard were divided into two sub-groups and the facilitators were assigned to each group and aid the FDG proceedings. After the FDGs, all the participants were converged in a plenary session during which the findings of the FDGs were presented for adoption by the entire participants.

3.4: Data Analysis

STATA VERSION 14 was used for data analyzes and generates frequencies and percentages.

3.5: Description of the Area for Soil Sampling and Field Experiment

The soil samples were collected from Horticulture Research field, located in Yundum in the West Coast Region of The Gambia in 2021 and 2022. It is a small town in The Gambia, south of the capital, Banjul. It is situated adjacent to the country's international airport, located in Busumbala Consequency in the Southern part of West Coast Region of The Gambia. The area lies between latitudes 13.3342° N, 16.6704° W. Yundum falls under the Sudanian-Guinean Zone lies within the 900 to 1200 mm rainfall isohyets. The growing season is 120-150 days and in normal seasons full crop water requirements are met throughout the growing season. The principal crops cultivated in this agro-ecology are early millet, groundnut, Upland rice vegetables, maize, cowpea and sesame. The soil scheme for the site was sandy loamy. (ANR, 2013).

3.5.1: Methods used During Soil Sample Collection

Prior to planting, first composite sample collection of soil was carried-out by sampling soils from five diagonal points into one homogenous sample followed by second soil sampling which was done after the end of the two seasons from all the individual treatment plots and determined the effects of different fertilizers on soil fertility. The following apparatus were used for soil samples collection from the field i.e., a manual auger used and drilled the soil samples from the surface ata depth between 30cm randomly based on research needs. Soil samples were taken with soil auger The collected samples were put in a nylon bags with clear labels using the permanent makers to avoid mixture and then packed in a bucket .The samples were further taken to National Agricultural Research Institute (NARI) The Gambia, for analyzing of physical properties such as soil moisture, texture (sand, loamy and clay soil) and chemical properties (Carbon, Nitrogen and Phosphorus, pH and Cation Exchange Capacity) to Senegal (Bambeh Soil Lab).

3.6: Experimental Design and Field Layout

The design of the experiment was a split-plot design with three replications and four treatments. Mongal F1 and Thorgal F1 were the tomato cultivars used and fertilizers options applied were Leucaena leucocephala leaves (5kg/plot), Poultry bedding (5kg/plot) leucocephala leaves + Poultry bedding (5kg/plot) which means half of five kilos each and Nitrogen fertilizer (0.05kg/plot). The sizes of the plots were 1x5m/plot (24sub-plots) with a total dimension of 12m x 17m (204mq)

Table 1: The Sketch of the Experimental Layout (Split-plot Design)

12 m

17 m

Main Plot V1					Main Plot V2			
Sub-Plots					Sub-Plots			
REP1								
V1 LL1	V1 PB+L1	V1 PB1	V1 N1		V2 PB2	V2 N2	V2 LL2	V2 PB+L2
REP2								
V2 N2	V2 LL2	V2 PB+L2	V2 PB2		V1 PB+L1	V1 PB1	V1 LL1	V1 N1
REP3								
V1 PB1	V1 LL1	V1 N1	V1 PB+L1		V1 N2	V1 PB+L2	V1 PB2	V1 LL2

Note: N=Nitrogen, LL= Leucaena Leaves, PB= Poultry Bedding and PB+LL= Poultry Bedding+Leucaena Leave

3.6.1: Nursery and Nursery Management Practices

A size of 1x5mq bed was cleared, prepared and sown with tomato seeds of Mongal F1 and Thorgal F1. Both rainfall and irrigation of seedlings (early morning and late afternoon) were carried out following germination using watering can. A week after seedlings emerged from the soil, the entire plot was covered with a black nylon net for prevention of birds and other domestic animals attack. The two tomato varieties were later spread with maned chemical when nematodes infestation was realized at two weeks old.

3.6.2: Treatment Application and Agronomic Practice

After pre-planting operations were done firstly, the experimental field was irrigated which made the soil moist or soft for possible plot demarcation, this was followed by application of the treatments of organic materials such as fresh leaves of *Leucaena leucocephala* and poultry bedding then the plots were all tilled and allowed for natural decomposition to take place for atleast three weeks before transplanting of tomato seedlings. While Nitrogen fertilizer was applied one week after transplanting. The seedlings were transplanted after reaching three weeks old into their permanent beds at spacing of 60 cm x 60 cm and each bed consisted of two rows of twenty plants. Weeds were regularly removed with a local hand hoe as and when necessary and lower yellowish leaves pruned just after and data on number of leaves at the vegetative stage had been scored. Tomato plants were also supported with Bamboo sticks for staking. This agronomic practice had provided each plant the ability to grow without bending and also prevented the fruits from rotten and allows the tomato plants to get the necessary sunlight it needs to continue growing. The plants were spread with maned at reproductive stage when discoloration and dropping of leaves has started. This was effective in minimizing the population of nematodes and red spider mites. Fruits were harvested by hand picking when they had reached their physiological maturity (fully ripe) stage. Harvesting was done 3 times at an interval of 5 days until fruits of all cultivars had been picked.

3.6.3: Field Data Collections Details on Agronomic Traits

Periodic data collections on the growth and yield of tomatoes were conducted at different stages of crop growth and development such as vegetative stage and reproductive stage were carried-out by counting, weighing and measuring of parameters with the use of suitable data collection tools such as measuring tapeline, digital weighing scale and Vernier caliper. Data were collected from the10 tagged plants in a zigzag method. The climatic conditions (mean monthly temperatures, sunshine and rainfall (for field experiment only) prevalent in the experimental sites were recorded.

Table 2: Agronomic Parameters Collected

N0	Parameters	Descriptions
1	Plant height	This was determined as the mean height (cm) of ten tagged plants measured from the soil level to the tip of the shoot at vegetative stage (@2weeks) intervals of the crop growth using a meter rule.
2	Stem diameter (SD):	This was determined as the mean diameter (cm) of ten tagged plants measured at about 10 cm from the base of the plant using Vernier caliper at vegetative stage (30 DAT) of the crop.
3	Number of leaves per plant (NL):	This was determined as the mean number of leaves of ten tagged plants counted at vegetative (30 DAT) growth stage of the crop.
4	Number of primary branches per plant (NPB):	The number of primary branches of ten tagged plants were counted at the end of the growing season and the mean number of branches per plant determined.
5	Number of days to first flowering (NFF):	This was determined by counting the number of days from transplanting to first flower emergence of each genotype per replication
6	Number of days to 50 % flowering (FPF):	This was determined by counting the number of days from transplanting until 50 % of the tagged plants per genotype had flowered.
7	Number of days to fruit set (NFS):	This was determined by counting the number of days from transplanting to first fruit appearance.
8	Number of days to 50 % fruit set (FPFS):	This was determined by counting the number of days from transplanting until 50 % of tagged plants per plot had fruited.

9	Number of days to fruit maturity (DFM):	This was determined by counting the number of days from transplanting until 50 % of the tagged plants had at least one fruit ripened (at breaker stage)
10	Number of trusses per plant (TPP):	The number of trusses per plant was counted on tagged plants and the mean number of trusses per plant were determined
11	Number of flowers per truss (FPT):	The number of flowers per truss was counted for 10 trusses on each of the tagged plants and the mean number determined
12	Number of fruits per truss (NFPT):	The number of fruits per truss was counted for each of the ten tagged plants and the mean number per truss
13	Number of fruits per plant (FPP):	Number of fruits per plant was determined by counting the number of harvested fruits from each of the ten recorded plants and the mean number determined.
14	Fruit weight per plant (FWP):	Mean fruit weight (g) per plant was determined by weighing the harvested fruits from the ten tagged plants using an electronic balance and the mean determined
15	Fruit yield per plant (YPP):	The mean fruit weight for each of the ten plants were used to calculate yield per hectare and converted to yield in tonnes per hectare (t/ha)

3.7: Data Analysis

The data was analysed with the use of SAS version 3.5.2 software. Mean comparisons were carried-out and determination of significances at set probability levels.

3.8: Adapting the DSSAT Crop Simulation Model for Most Commonly used Tomato Cultivars at Nitrogen Fertilizer and Different Organic Amendment Levels in The Gambia.

3.8.1: Materials and Methods.

The experiment was conducted in Yundum to fulfil the objectives of the research, it focuses on three organic and nitrogen fertilizer with different varieties in the year 2021 and 2022 respectively.

3.8.2: Treatment Details

Two tomato varieties were used for the experiments (Mongal F1 and Thorgal F1) with different nitrogen and three organic fertilizer application (0.05kg%, and 5kg of Leucaena leaves, poultry manure and combination of Leucaena leaves + poultry manure) and nitrogen fertilizer as a control (July, August, September and October 2021 and June, July and August and September 2022).

3.8.3: Inputs data of the Model

- Weather Directory File

The file WTH.DIR contains a list of weather data for several years. Weather files created for the years 2021 and 2022 experiments for the location of study in Yundum was included in the list of historical weather files. The historical data from 1980 to 2021 includes the daily solar radiation, minimum and maximum temperature and rainfall.

- Soil properties directory file

The file SOIL.SOL contains the list of different soils with their physical and chemical properties. The soil conditions of Yundum was included in soil file.

- Soil profile initial conditions

The soil profile initial condition file contained the initial values of soil water, soil pH and soil nitrogen data depending on the local situation, the appropriate data were inputted.

- Fertilizer management file

The fertilizer management file contained the date, form and amount of nitrogen application. For this particular research nitrogen fertilizer was used and the information was entered as required.

- Treatments (Organic Amendments)

For each cultivar 3 different organic treatments were applied on a plot. All the treatments were incorporated into the DSSAT treatment window.

- Field observed data

The field observed data window is meant for entry of observed data on crop performance at the field. It enables the model to compare the simulated and the observed data. As needed the observed data on yield and yield components were incorporated into this window.

Table 3: Tomato Cultivar Coefficients Crgro08 Model

N0	PARAM	Description of the Coefficients
1	EXPNO	Number of experiments used to estimate cultivar parameters
2	ECO#	Code for the ecotype to which this cultivar belongs (see *.eco file)
3	CSDL	Critical Short Day Length below which reproductive development progresses with no daylength effect (for shortday plants) (hour)
4	PPSEN	Slope of the relative response of development to photoperiod with time (positive for shortday plants) (1/hour)
5	EM-FL	Time between plant emergence and flower appearance (R1) (photothermal days)
6	FL-SH	Time between first flower and first pod (R3) (photothermal days)
7	FL-SD	Time between first flower and first seed (R5) (photothermal days)
8	SD-PM	Time between first seed (R5) and physiological maturity (R7) (photothermal days)
9	FL-LF	Time between first flower (R1) and end of leaf expansion (photothermal days)
10	LFMAX	Maximum leaf photosynthesis rate at 30 C, 350 vpm CO2, and high light (mg CO2/m2-s)
11	SLAVR	Specific leaf area of cultivar under standard growth conditions (cm2/g)
12	SIZLF	Maximum size of full leaf (three leaflets) (cm2)

13	XFRT	Maximum fraction of daily growth that is partitioned to seed + shell
14	WTPSD	Maximum weight per seed (g)
15	SFDUR	Seed filling duration for pod cohort at standard growth conditions (photothermal days)
15	SDPDV	SDPDV Average seed per pod under standard growing conditions (#/pod)
16	PODUR	Time required for cultivar to reach final pod load under optimal conditions (photothermal days)
17	THRSH	Threshing percentage. The maximum ratio of (seed/(seed+shell)) at maturity. Causes seed to stop growing as their dry weight increases until the shells are filled in a cohort.
18	SDPRO	Fraction protein in seeds (g(protein)/g(seed))
19	SDLIP	Fraction oil in seeds (g(oil)/g(seed))

3.8.4: Adaptation of the CROPGRO Model for Tomato

The CROPGRO model version 4.8 is a (Scholberg, 1996; Boote *et al.,* 1998) was the inbuilt model used for this research. Adaptation is the process of adjusting some model parameters to local conditions which is geared towards enabling closeness between the observed and the simulated values. The model was adapted with the data collected during experimental periods of (July, August, September and October 2021 and June, July and August and September 2022). Four different fertilizer rates were applied on Mongal F1 and Thorgal F1. To check the accuracy of the model simulation, the data obtained from the experimental field such as the available data on tomato yield, and fertilizer types were compared with simulated values.

3.8.5: Evaluation of the Model

Evaluation of the model is the comparison of the results of model simulations with observations from crops that were not used for the adaptation. The experimental data sets of August 2021, July and September 2022 were used for the evaluation of the model. Different statistical measures were determined.

CHAPTER FOUR

4.0: RESULTS AND DISCUSSIONS

4.1: Physical and Chemical Content of the three Composite Samples (Soil, Leuceana litters and Poultry Manure)

The interpretation of the results from (Table 4) indicated that, the soil was in a state of alkaline conditions which is a known threat to crop plant growth and production. It affects the amount of nutrients and chemicals that are soluble in soil water and the amount of nutrients available to plants. The soil electrical conductivity (EC) for the study area was very low (Non Saline) which is not very suitable for tomato production. Low EC's are often found in sandy soils with low organic matter levels and too low EC levels indicate low available nutrients. For the case of organic matter content, the result depicted low for the soil but fairly high in Leucaena leaves and poultry manure. Its deficiency may be caused by the decline of soil organic matter in the study area due to continues cultivation and improper practice of the land use (tillage). The result for nitrogen and calcium were also low in the soil and Leucaena leaves. Furthermore, the result also indicates low content of magnesium for the soil, Leucaena leaves and poultry manure. Potassium was also very low for the soil and poultry manure after analysis in table 4.

Table 4: Results of Three Composite Sample

IDS	Soil	Leucaena leaves	Poultry Manure
pHeau 1 / 2, 5	7.5	-	-
EC 1/ 10 µs/Cm	0.04	-	-
%C	0,272	-	-
MO%	0,469	3	2.39
Nmeq/100g	0.17	3.15	2.5
Ca meq/100g	3,375	1.4	3.8
Mg meq/100g	0,15	0.88	1.5
Na meq/100g	0,058	0.57	-
K meq/100g	0,042	-	0.59
Pppm	26	-	-

4.2: Interpretation of Soil Physical Traits

The interpretation from the physical analysis indicated that, the soil was sandy loamy and found to be in a state of strongly acidic conditions which is an ideal soil for the cultivation of tomatoes. However, the results depicted to have significant effects on the soil after treatments application because the initial soil pH was at 7.5 which was alkaline and now reduced to 4.9 of strongly acid. This soil condition slows tomato plant growth and reduce your harvest. Soil that is too acidic (or too basic) will also lead to nutrient deficiencies, causing problems such as blossom end rot on tomato fruit. However, electronic conductivity had shown that the sandy loamy soil were more of non-saline (1-1.8) except for only that indicated very slightly saline soils (2.2). This means that the soil is suitable for cultivating tomatoes since the said crop is sensitive to salt and they cannot survive under high salinity conditions. However, the organic matter content indicated very low (<1%) and it has impacted on tomatoes during production even though organic and inorganic treatments were applied. This was due to low soil fertility and as well as continues cultivation pressure on the land in (Table 5).

Table 5: Results Obtained from the Individual Treatment Soil Samples for the Physical Parameters

TREATMENTS	Soil pH Water 1:2	Soil pH .01 CaCl2 1:2	EC mmhos/cm 1:2	Organic Matter %	SOIL TEXTURAL CLASSIFICATION % Sand	% Clay	%Silt	
Leucaena Leaves	6.3	5.0	1.5	0.27	75.8	5.21	15.7	sandy loamy
Poultry Bedding + Leucaena Leaves	6.1	5.1	2.2	0.21	75.8	5.88	18.3	sandy loamy
Poultry Bedding	6.3	5.1	1.8	0.25	74.8	5.21	19.6	sandy loamy
Nitrogen	6.1	4.9	2.1	0.29	76.8	5.88	17.3	sandy loamy

4.3: Interpretation of Individual Treatment Soil Samples from NARI Horticulture Unit

The (Table 6) below presents the results of chemical analysis after first season treatments application. However, the soil carbon reported low compared to the initial results according to the analysis. Furthermore, the sandy loamy soil depicted low low in nitrogen (0.05) after application of organic fertilizers, which has little or no influence on leaf number per plant, plant height, fruit number per plant, fruit mean weight and total yield per plant in tomato crops. Contrarly the result from calcium has increases from 3.3% to (7.37%). Magnesium has also significant increment from (0.15 to 2.62%) as Magnesium helps in speed up the enzyme activity and play important role in energy transport reactions. Potassium also achieved significant increase from (0,042 to 3.08%). In conclusion, generally some macro elements had shown significant increase level of nutrients in the experimental plots but contrary, it has not impacted on the tomato cultivars during the production period because it has causes tomatoes to produce numerous of brittle and yellow leaves which has also affected the yield. (Frías-Moreno et al., 2020) found that low N supply can greatly reduce vegetative growth phase of tomatoes.

Table 6: Results Obtained from the Individual Treatment Soil Samples for the Chemical Parameters

Treatments	BASES ECHANGEABLES(meq/100g)					
	C (%)	**Azote (%)**	**Ca**	**Na**	**Mg**	**K**
Leucaena Leaves	0,43	0,04	6,94	0,04	2,06	2.90
Poultry Bedding + Leucaena Leaves	0,53	0,05	7,37	0,04	2,06	3.08
Poultry Bedding	0,55	0,05	6,81	0,04	2,12	3,04
Nitrogen	0.33	0,05	6,93	0,04	2,62	3.17

4.4: SURVEY RESULTS

4.4.1: Personal Information

The results from (Table 7) depicted that (70%) of the respondents were female and (30.00%) male. Which means female are the main dominant tomato producers in The Gambia. For the case of age, (34%) of the farmers reported to have attained an age bracket of (35-45) years followed by (26%) that falls in the age bracket between 45-55 which is not significantly different from those who had attained an age bracket of (22%) of 55 years above and (4%) was observed as the least age bracket between 15-25. In addition, (74%) of the respondents had gotten married; followed by (12%) without wives or husband's, only (8%) were divorced and (6%) widow. Furthermore, (60%) of the respondents interviewed were Mandinkas followed by Wollof (28%) and (12%) representing Jolas. The survey also revealed that (54%) of the respondents did not have formal education due to religious sensitivity and low income earning. Only (24%) had achieved tertiary, (14%) with Secondary and (6%) primary education. All the farmers interviewed were Muslims.

Table 7: Personal Infoormation of Respondents

Variables	Frequency	Percentage
	Gender	
Male	15	30
Female	35	70
	Age	
15-25	2	4
25-35	7	14
35-45	17	34
45-55	13	26
55 Above	11	22
	Marital Status	
Married	37	74
Single	6	12
Widow	3	6
Divorced	4	8
	Ethnicity	
Mandinka	30	60
Wollof	14	28
Jola	6	12
	Education	
Bible |	1	2
Koranic	27	54
Primary	3	6
Secondary	7	14
Tertiary	12	24
	Religion	
Muslim	49	98
Christian	1	2

4.4.2: Production Information on Tomato

The survey indicated that agriculture is a very important activity in the West Coast Region of the Gambia because almost all the communities are engaging into vegetable production more especially women's who are into tomato production. Years spent on tomato production, (86%) said to have spent 1-15years, followed by (12%) who had been cultivating tomatoes between 15-30years and the least percentage spent 30-45years on growing tomatoes. Significant numbers of the farmers are cultivating their tomatoes on sandy loamy soils. For the area under cultivation, (72%) are cultivatingtomatoesbetween0.1-0.25ha and the smallest percentage are cultivating an area between 0.75above (Table 8).

Table 8: Information on Tomato Production

Variables	Frequency	Percentage
Number of farmers growing tomato		
Yes	50	100
Duration of growing tomato		
1-15years	43	86
15-30years	6	12
30-45years	1	2
Scheme of the soil		
Sandy loamy	39	78
Sandy soil	11	22
Area under cultivation		
0.1-0.25ha	36	72
0.25-0.5ha	13	26
0.75above	1	2

4.4.3: Type of Tomato Varieties Cultivated in the Study Area

The findings in (Table 9) revealed that (88%) of the tomatoes growers are cultivating improve Tomato varieties such as (Monga, Thorgal and Mbolo etc) followed by (12%) said they are still growing local varieties. However, (84%) of the farmers said they are sourcing their seeds from agro-chemical seed stores through purchasing while (14%) sourced from their own seed stores and only(1%) received as a gift. For the method of watering, large majority (58%) are depending on the rainfall where (42%) are using irrigation. For the period of sowing seeds, (38%) do transplant their seedlings immediately after the first heavy rain dropped, while (52%) are relying on the first two heavy rains and (10%) observed transplanting a week after the beginning of the raining season. For the case of sowing (86%) reported using row sowing method and only (14) are broadcasting their seeds.

Table 9: Common Varietal Information

Variables	Frequency	Percentage
Tomato varieties commonly grown		
Local	6	12
Improved	44	88
Source of seeds		
Gift	1	2
Own Seeds	7	14
Purchased	42	84
Method of watering		
Only irrigation	21	42
Rainfall and Irrigation	29	58
If raining season, period of Sowing Tomato seeds		
A week after the beginning of the raining season	5	10
After the first heavy rain	19	38
After two heavy rain	26	52
Method of sowing		
Broadcasting	7	14
Row Sowing	43	86

4.4.4: Farm Inputs Used During Tomato Production

The survey findings revealed the following inputs applied during tomato production. All the tomato growers are applying fertilizers on their plots Furthermore, (44%) of the respondents informed that fertilizers are normally purchased by themselves followed by (27%) who said they received their seeds as a gift, (18%) through purchased and gift compare to minorities indicated they sourced fertilizers either from agriculture and NGOs. However, the results also stated that tomato growers are using different types of fertilizers and the most common type is chemical fertilizers used by (42%) which is not significantly different from (36%) applying animal dung and others revealed using both Chemical fertilizer + animal dung. Majority of the tomato growers applied these different fertilizers in the middle of the season through broadcasting. In addition, (82%) of the respondents reported that synthetic pesticides are commonly used by many farmers but a small percentage also indicated using botanicals and ash and it is applied on tomatoes in the mid-season through spraying (Table 10).

Table 10: Tomato Production Inputs

Application of fertilizers		
Yes	50	100%
Sources of fertilizers		
Agriculture	3	6
Gift	12	26%
Purchased + Gift	10	18%
NGOs	1	2%
Purchased	21	44%
Purchase +Agriculture & NGOs	1	2%
Purchase + agriculture	1	4%
Types of fertilizer applied		
Animal Dung	18	36%
Chemical Fertilizer	21	42%
Chemical fertilizer + animal dung	11	22%
Time of application		

Before + Mid season	11	22%
Before the season	10	20%
Mid-Season	28	56%
Mid season + Late season	1	2%
Method of application		
Row application	18	36%
Broadcasting	32	64%
Pesticides Application		
No	6	12%
Yes	44	88%
Sources of pesticides		
Agriculture	3	6%
Locally Prepared	1	2%
Purchased	46	92%
Type of pesticides applied		
Botanicals	6	12%
Synthetic pesticide	41	82%
Ash	3	6%
Time of application		
Before the season	3	6%
Late season	6	12%
Mid-Season	40	80%
Mid season + Late season	1	2%

4.4.5: Agronomic Practices and Yield Obtained

Weeding is one of the most important activities carried-out during crop production. The results obtained from the survey revealed that all the farmers weed their tomato plots, where (84%) of the respondents are manually weeding their tomato beds and few people are removing weeds through the application of herbicide and hand-picking methods. However, large numbers of the respondents are weeding their tomato plots either twice or three times. For the case of yield, the results depicted that (60%) of the tomato producers are obtaining 100-200kg as the highest yield followed by (23%) whose tomato yielded between 200-400kg and the lowest yields were resulted from 0-100kg by (17%) (Table 11).

Table 11: Information on Agronomic Practices and Yield Obtained

	Often weed your tomato field	
Variables	**Frequency**	**Percentage**
Yes	50	100%
	If yes ,method of weeding	
Manual	42	84%
Herbicide	3	6%
Hand-picking	5	10%
	Number of weeding	
Once	4	8%
Twice	25	50%
Three Times	21	42%
	Average Yield Obtained (Kg)	
0-100	8	17%
100-200	30	60%
200-400	12	23%

4.4.6: Farmer's Awareness of Climate Change

The findings in (Table 12) also investigated whether farmers are aware about climate change. The study depicted that (98%) of the tomato growers said they are seriously aware and also strongly believe that climate change is existing. Many climate elements were highlighted as a factor responsible for the declining of tomato production and as well as a results of low yielding, however, (46%) of the respondent interviewed seriously complained about continues heat generation which is as a result of high temperatures followed by (20%) experiencing high temperatures and low rainfalls and (10%) of the interviewee's did also mentioned High temperatures plus heavy winds. Minorities reported about observing either low rainfall, heavy winds and as well facing drought. For the case of year experienced the existence of climate change, significant number of respondents (68%) said they have been experiencing and facing tomato production challenges caused by climate change for the past five years now while (24%) indicated about 5-10years of experience and the lowest percentage of experiencing climate change resulted from (8%). The survey had continued on finding how tomato growers came to know about climate change, (76%) of the respondents informed that they have known the reality of climate change through personal experience followed by (24%) who said they heard it from the different social medias and only insignificant percent of (6%) said it was through personal experience plus social medias.

Table 12: Farmers Awareness of Climate Change

Variable	Frequency	Percentage
Yes	49	98
No	1	2
Believe in the Existence of climate change		
Yes	49	98
No	1	2
If yes, what makes you believe		
All the climate elements	2	4
Drought	1	2
Heavy rain	2	4
Heavy wind	3	6
High Temperatures	23	46
High temperature + Low rainfall	10	20
High temperatures + heavy wind	5	10
Low rainfall	4	8
Year realized the existence of climate change		
1-5years	34	68
5-10years	12	24
10years	4	8

Knowledge of the existence of climate change		
Personal experience	38	76
Personal experience + media	2	4
Through media	10	20

4.4.7: Impact of Climate Change on Tomato Production and Strategies

The survey reveals that (94%) of the respondents reported that their tomatoes are affected by numerous climate change elements while (6%) said their tomatoes are not disturbed by climate change. Furthermore, (28%) of the respondent indicated about severe rotting of tomato fruits at the reproductive stage which is due to high temperatures which is also similar to (20%) that observed dropping of flowers by heavy rain and wind. Some percentage raised about introduction of pests, severe discoloration of leaves and low yielding due to continues rain and heavy winds. For the case of adaptation strategies for the menace above, (64%) of the tomato growers said they have some options for climate change adaptation strategies and (36%) accentuated that they don't have any adaptation strategies. The findings also reveal that (56%) said they are using synthetic pesticide to control insect disease e.g. red spider mites followed by (14%) using planting of trees (wind breakers) to reduce heavy wind speed and (24%) said they are applying large quantity of fertilizers to improve the soil fertility Generally, farmers lamented that the strategies they used for adapting to climate change are very useful (Table 13).

Table 13: Climate Change Challenges and Adaptation Strategies for Tomatoes

Does climate change affects your tomatoes on the field		
Variables	**Frequency**	**Percentage**
No	3	6
Yes	47	94
Effects of climate change on tomatoes		
Dropping of flowers by rain and wind	10	20
Fallen of tomato plant due to heavy wind	5	10

Introduction of pests	8	16
Low yielding due to continues rain and heavy winds	1	2
Severe discoloration of leaves	6	12
Severe rotting of tomato fruits	14	28
Stunted growth due to high temperatures	6	12
Strategies of adapting to climate change		
No	18	36
Yes	32	64
If yes, mention adaptation strategies		
Application of large quantity of fertilizers	12	24
Planting of trees (wind Breakers)	7	14
Practice of staking	3	6
Use of synthetic Pesticide	28	56
Usefulness of the Strategies		
No	6	12
Yes	44	88
Degree of usefulness		
High	24	48
Low	6	12
Medium	20	40

4.4.8: Response of Tomato Varieties to Growth and Yield Parameters

The results in (Table 14) indicated significant differences between the varieties for the following parameters highlighted in the table below. However, Mongal F1 tomato cultivar had more plant (1.23) survived after transplanting under the different stresses during the wet season than Thorgal F1 (1.13). For the case of plant height, the tallest plants were recorded from Thorgal F1 while the shortest plants were observed from Mongal F1. In addition, Mongal F1 had grown better by producing largest stem girth than Thorgal F1. Concerning about days to fruit maturity, Thorgal F1 was little bit faster to reached maturity stage as compared to Mongal. Furthermore, considering the number of fruits per plot, Mongal F1 had recorded more fruits than Thorgal F1 after harvesting. Also for fruit diameter, Mongal F1 had produces large size of fruits than Thorgal F1.

Table 14: Means Performance of Tomato Cultivars on Agronomic Traits

Tomato cultivars	**Agronomic parameters**					
	PP	**PH@6W**	**SG**	**DFM**	**NFPP**	**FD**
Mongal	1.23	1.69	0.30	1.79	1.70	0.59
Thorgal	1.13	1.79	0.23	1.81	1.40	0.49

4.4.9: Mean Performance of two Tomato Cultivars for Growth Traits from Second Season

The mean values for growth parameters for tomato cultivars are presented in (Table 15). The results indicated significant (P<0.05%) differences between the cultivars and among the treatments for some parameters. The highest mean value plant height of (38.32 cm) was recorded from Mongal F1 while the lowest mean value (33.56 cm) observed from Thorgal F1. Similar trend has appeared for stem girth where Mongal F1 has the largest stem diameter of (1.4) and the smallest stem diameter was depicted from Thorgal F1. In additional, the highest mean value primary plant branches of (5.58) was recorded from Mongal F1 while the lowest mean value (4.66) was observed from Thorgal F1. The highest mean value of 36 days was used by Mongal F1 to reach at 50% flowering and Thorgal F1 got 32 days before reaching at 50% flowering.

However, for the case of treatments, significant differences had existed among them. The finding indicated that, poultry bedding has recorded the highest mean value of (38.65) in terms of adding nutrient supply in the soil followed by Leucaena leaves (37.63) for enhancing tomato growth and development and the lowest mean values were observed from Leucaena leaves + poultry bedding and Nitrogen. For the case of stem girth also, Leucaena leaves recorded the highest mean values (1.33) seconded by poultry bedding and the lowest values were resulted from Nitrogen and Leucaena leaves +poultry bedding. More primary branches were reproduced by tomatoes after the application of Leuceana leaves, which is not significantly different from Leucaena leaves + poultry bedding and Poultry bedding alone. Less primary branches tomatoes was observed from Nitrogen. Finally, treatments application has effects on tomatoes for producing good number of trusses per plant, poultry bedding had highest mean values (11.00) followed by Leuceana leaves and Leucaena leaves + poultry bedding which did not show any significant differences but the lowest mean value was resulted from Nitrogen.

Table 15: Influence of Tomato Varieties to Agronomic Traits and Fertilizers

Agronomic Traits	**PH@4W**	**SG**	**PB**	**TPP**	**50%Flower**
Tomato Cultivars					
Mongal	38.32	1.45	5.58		36
Thorgal	33.56	1.25	4.66		32
Treatments					
Leucaena Leaves	37.63	1.33	6.00	9.83	
Poultry Bedding + Leucaena Leaves	35.43	1.15	5.16	9.66	
Nitrogen	32.06	1.20	4.00	7.33	
Poultry Bedding	38.65	1.30	5.33	11.00	

4.10: Mean Performance of Two Tomato Varieties for Yield Traits

The mean values for yield traits for tomato cultivars are present in (Table 16). The highest mean value for tomatoes in terms of days to fruits setting, Mongal F1 had took longer days (44) to formed fruits while Thorgal was little bit fast (41) days to established fruits. Mongal F1 had spent (62) days on the field to reach fruit maturity and Thorgal F1 took (65) days to fruit maturity. At harvest, more fruits were collected from (33) from Mongal F1 than Thorgal (23). Interms of fruit length and diameter also Mongal F1 had reproduce long and fat fruits (2.6) as compared to Thorgal (2.4) cm. The final yield parameter observed was the fruit weight per plant. Mongal had weighed more (1.90) kilos than Thorgal F1 (1.19) kilos. However, for the treatments, significant differences was depicted from only one parameter which is fruit length. Leucaena leaves had impacted on tomatoes more than the rest. This was followed by Nitrogen, poultry bedding and Leucaena leaves + poultry bedding.

Table 16: Mean Performance of Tomatoes and Fertilizers

Agronomic Traits	DFS	DFM	NFPP	FL	FD	FWPP
Tomato Cultivars						
Mongal	44	62	33.08	2.60	3.39	1.90
Thorgal	41	65	23.91	2.41	2.76	1.19
Treatments						
Leucaena Leaves				2.61		
Poultry Bedding + Leucaena Leaves				2.36		
Nitrogen				2.56		
Poultry Bedding				2.43		

4.11: Results from the Tomato CROPGRO Model

4.11.1: Rainfall Pattern and Distribution during 2021 Research Season

The (figure 2) below highlighted the period and amount of rain received by the tomatoes during the research. The trend shows high variations, as the highest amount of rains were dropped in the months of September and October and the lowest quantity of rains were observed between July and August even though transplanting of tomatoes were done in July. The interpretations further indicated that suffiecient water was supplied to tomatoes between September and October which is almost towarsd season ending while at germination and vegetative stages very little and erractic rains were received which had causes many menace to tomatoes like stunted growth, bearing of less leaves etc.

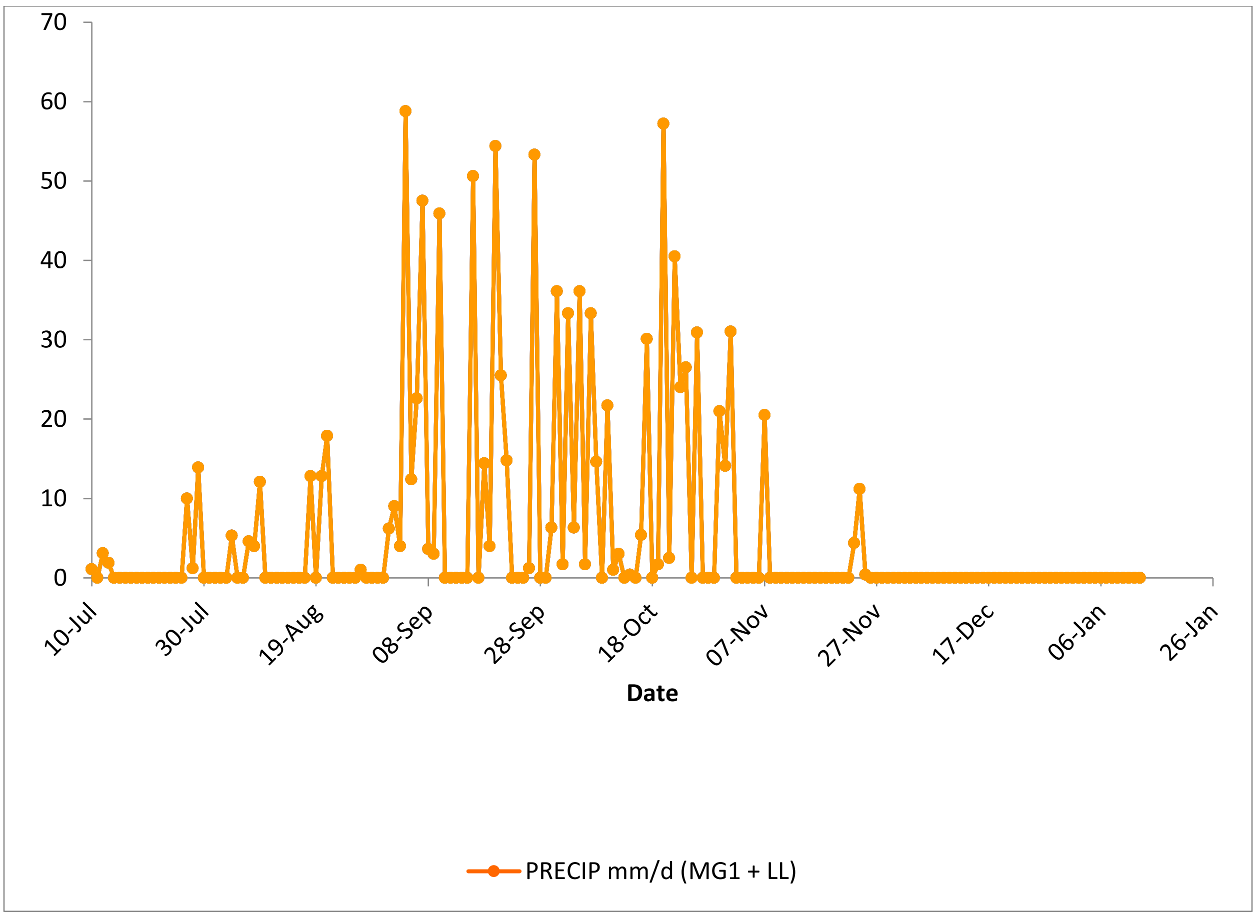


Figure 2: Showing Amount of Rainfall Receievd during 2021

4.11.2: Trend of Temperatures during 2021 Growing Season

The Graph captures different temperatures (minimum, average and maxmum) during the research period. Tomatoes had experienced the highest temperatures at 37 ºC in the month of July and declined in the month of September at 27 ºC. However, for the average temperatures, July was recorded as the highest at 30 ºC and the lowest was observed from September 23 ºC. Similar situation was also observed from minimun temperatures where July again happened to be the highest record of 25 ºC and dropped at 16 ºC in September. Both high or low temperatures can causes significant effects on tomatoes during production, as higher temperatures can causes flower dropings, induce low seed setting rate, and can seriously affect yield and quality of tomatoes while low temperatures can also disturb tomatoes in many ways like it can causes chlling injuries and also reduces pollen count and viability thus negatively affecting the fruit set and yield of tomatoes. (Figure 3).

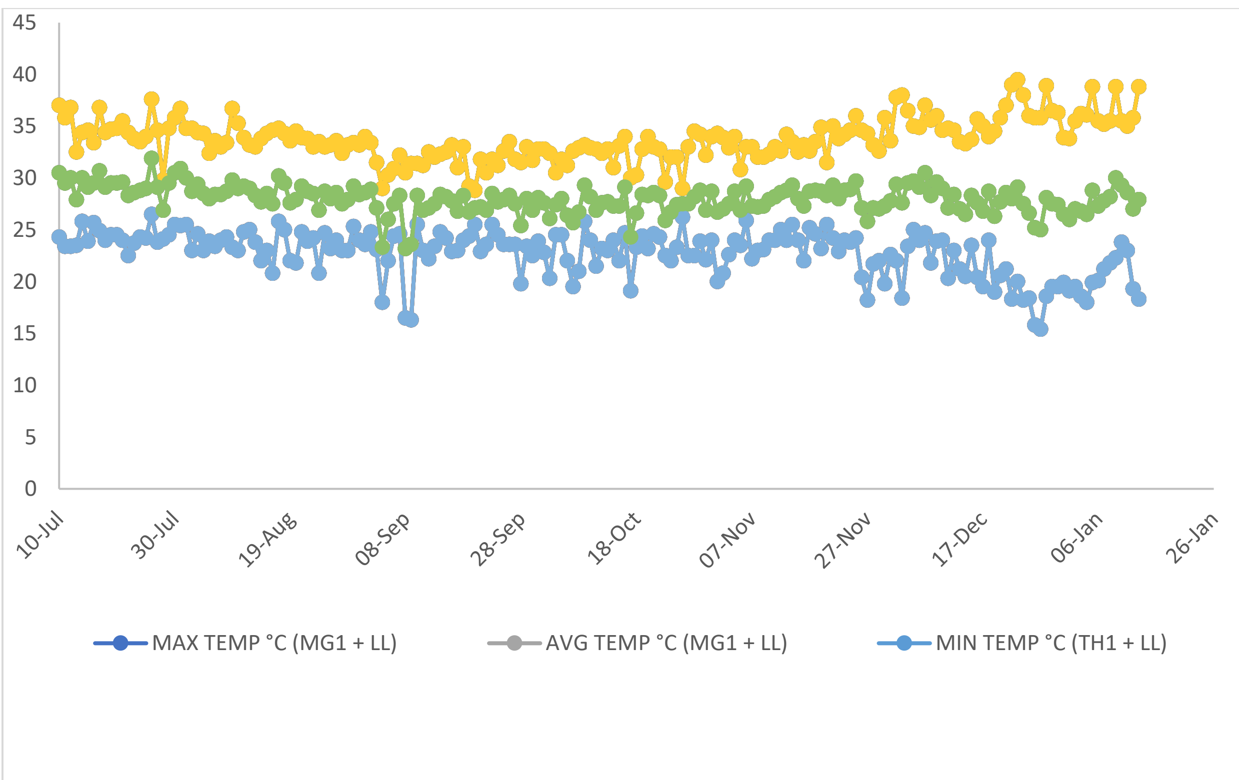


Figure 2: Monthly Tempeartures From 2021

4.11.3: Trend of Solar Radiation during 2021 Reseach Season for Tomatoes

The high monthly solar radiation recorded from (Fiqure 3) in 2021 growing season was observed during the months of July and November at 10.5 MJ/m^2 and lowest solar radiation was noticed in September 4.5 MJ/m^2. This is also very important to notice during the research period as constraining the intensity of solar radiation can significantly reduced photosynthesis, growth and yield of tomato plants.

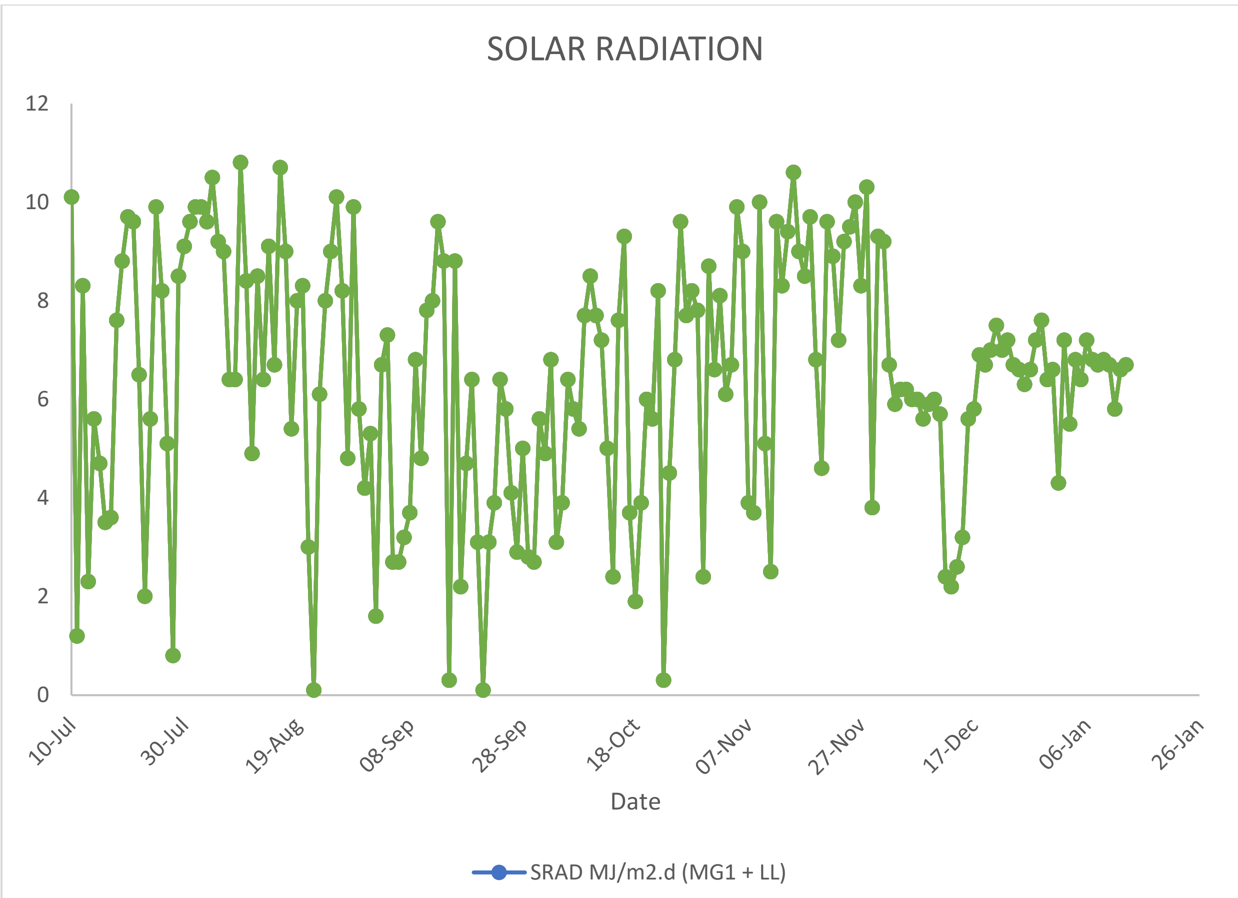
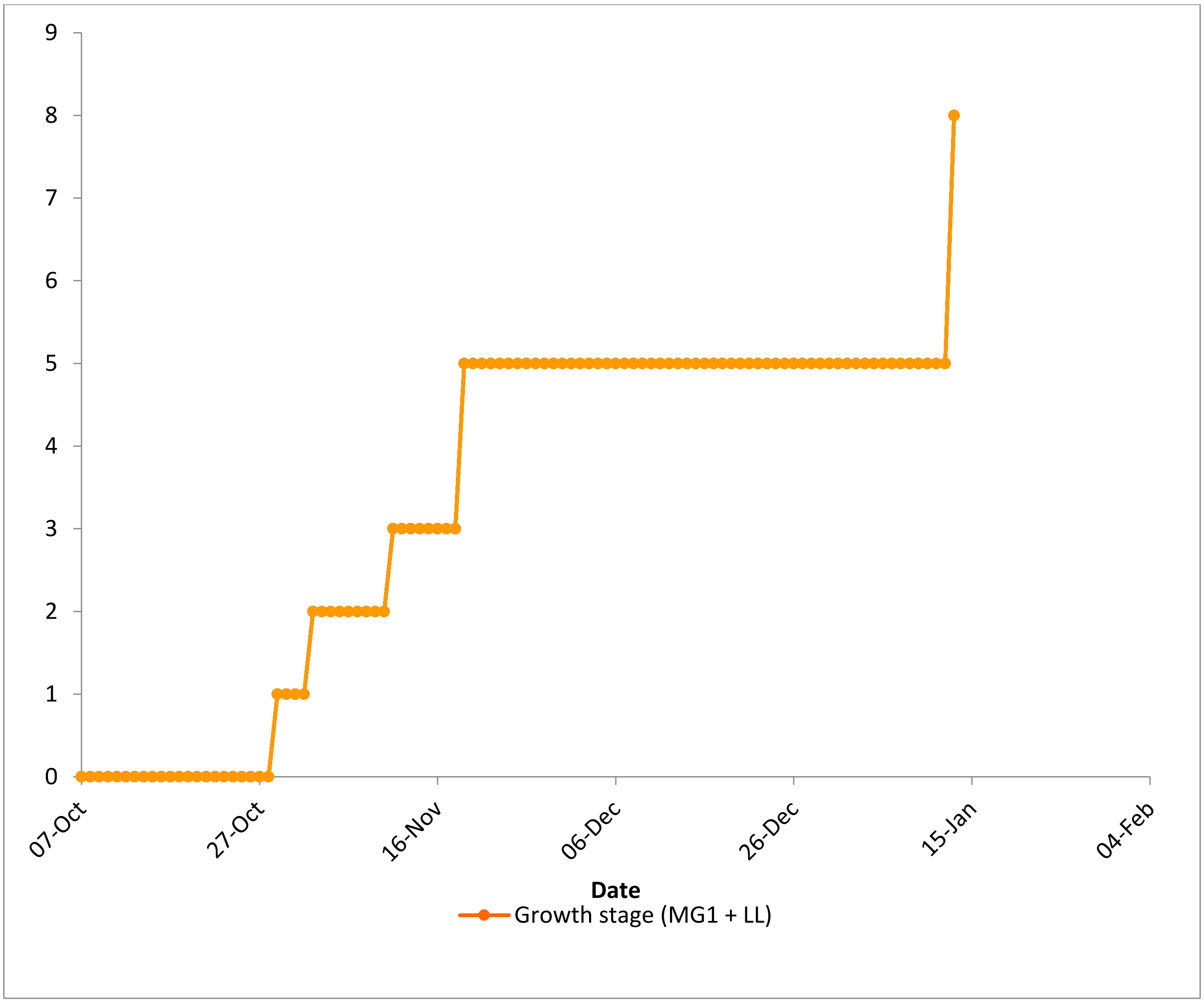


Figure 3: Monthly Solar Radiation From 2021

4.11.4: Growth Stages of Tomato during the 2021 Season

The graph presents the response of organic amendments (leucaena leaves, poultrly bedding and their combination) on the growth of Mongal F1 and Thorgal F1 tomato cultivars in Fiqure 4). Looking at the illustrasion below, it has dpeicted the same results for the two cultivars simply because the treatments did not imapcted well on cultivars during the two growing seasons (2021-2022). There were no rapid growth for both cultivars since after transplanting date in July to September. The cultivars started to grow from the first week of October to mid November.

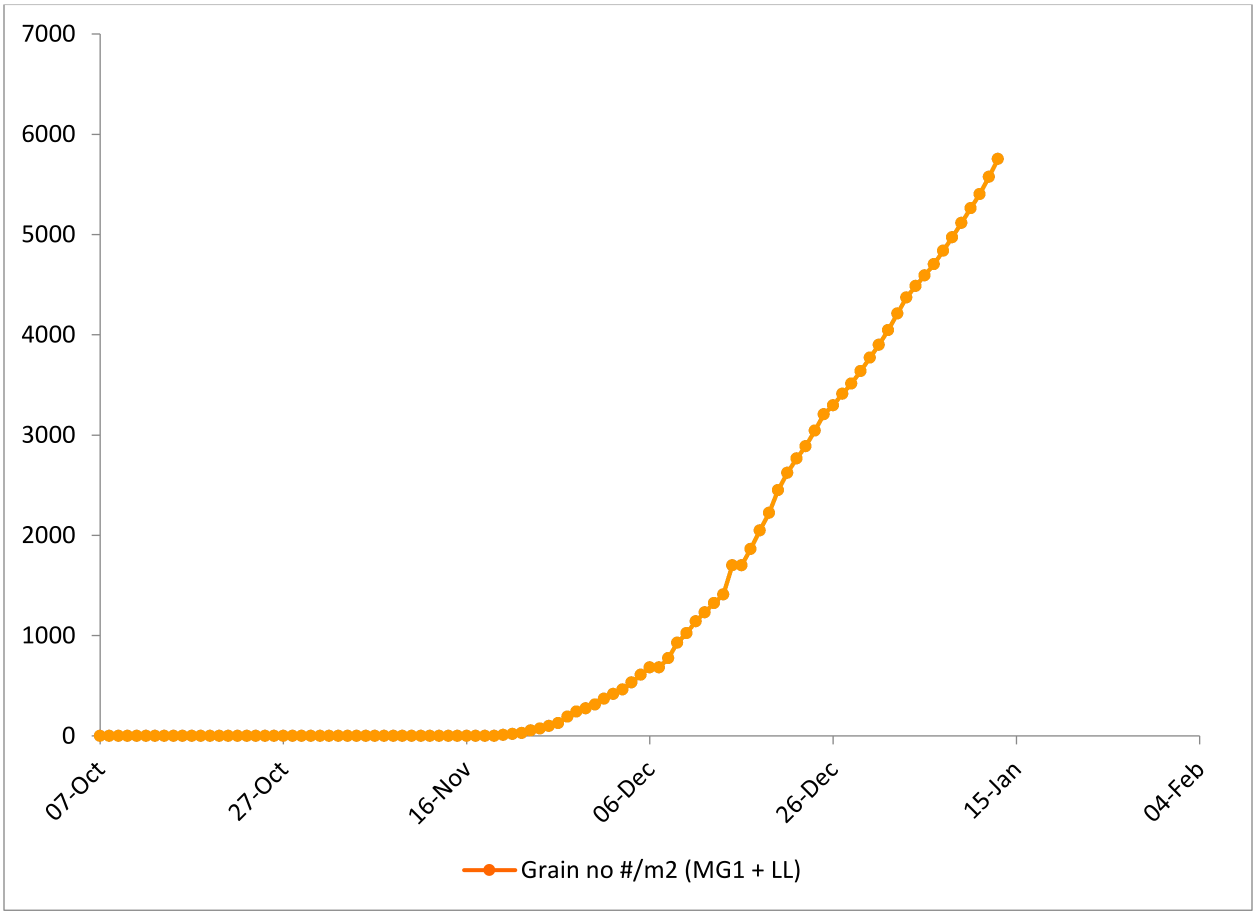


Days after Start of Simulation

Figure 4: Growth Stages of Tomatoes (Mongal F1 and Thorgal F1) after Application of Leucaena leaves, Poultry Bedding and Leucaena leaves + Poultry Bedding

4.11.5: Number of Fruits at Harvest

The fiqure 5 presents the influence of organic amendments (leucaena leaves, poultrly bedding and their combination) on the fruits number harvested from Mongal F1 and Thorgal F1 tomato cultivars. Similar observations were also recorded here interms of quantity of fruits scored from tomato cultivars at the reproductive stage. There was no much variations exited among the treatments after harvesting. And also, normal harvest date was not observed for both Mongal F1 and Thorgal F1 because of the longer period the cultivars took on the field due to poor growth rate at germination and vegetative stage. The highest fruit numbers recorded was at 6000 while the lowest quantity of 1000 fruits.

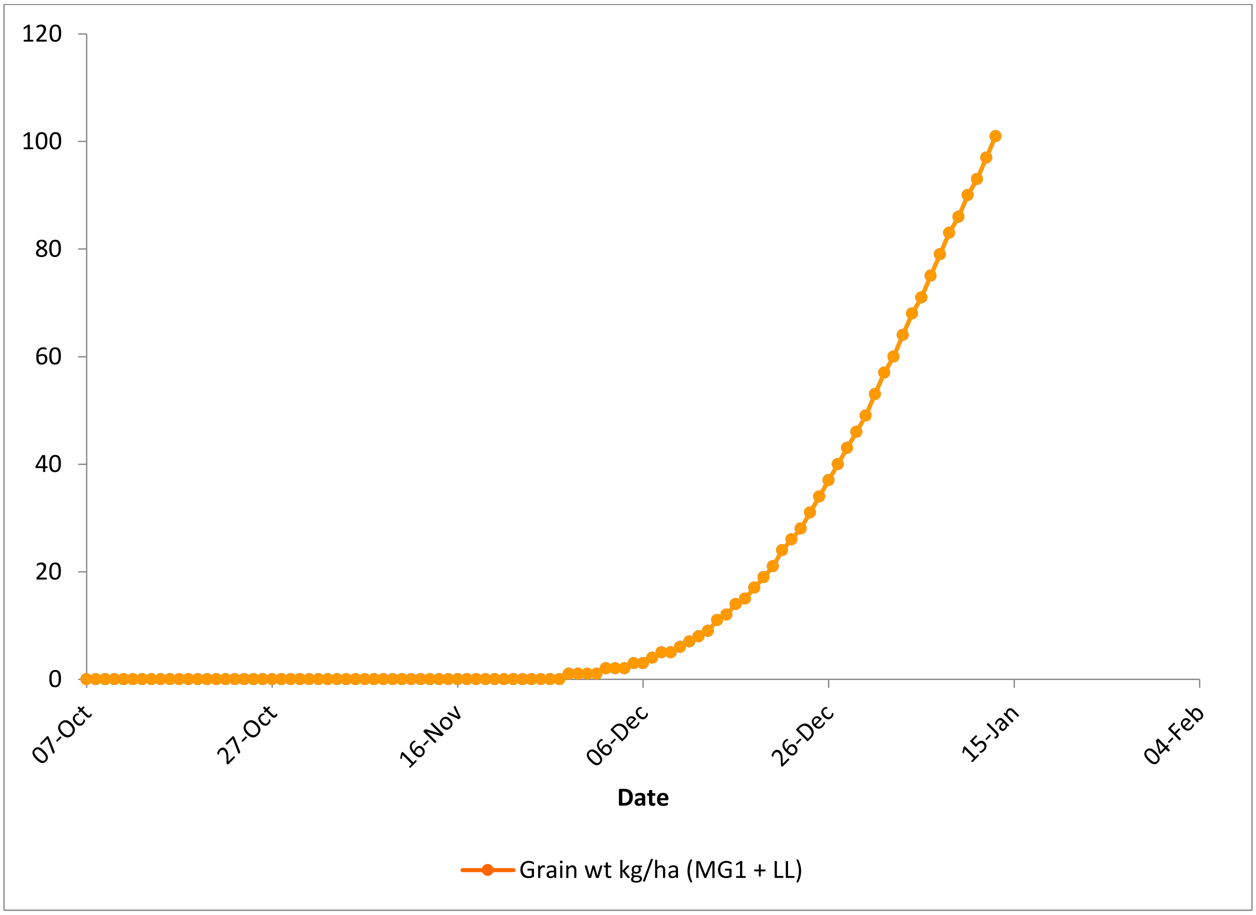


Days after Start of Simulation

Figure 5: Fruits Numbers of Tomatoes (Mongal F1 and Thorgal F1) after Application of Leucaena leaves, Poultry Bedding and Leucaena leaves + Poultry Bedding

4.11.6: Weight of Fruits at Harvest

The fiqure 6 presents the effects of organic amendments (leucaena leaves, poultrly bedding and their combination) on the fruits weight per plot recorded from Mongal F1 and Thorgal F1 tomato cultivars. However, similar trend was also recorded here interms of fruit weight per plot weighed from tomato cultivars at the final stage of production. The highest fruit yield was estimated at 100kg per plot whereas the lowest fruit weight recorded was 5kg per plot.



Days after Start of Simulation

Figure 6: Fruits Weight of Tomatoes (Mongal F1 and Thorgal F1) after Application of Leucaena leaves, Poultry Bedding and Leucaena leaves + Poultry Bedding

4.12: Analysis of climate parameters at Yundum (2013-2022)

4.12.1: Rainfall

The trend of rainfall figures at Yundum showed high variability, the highest rainfall for the period was observed in the month of September with about (105.8mm) as shown in (figure 7), followed by October (77.5mm) and (56.8mm) was also recorded from August respectively. The importance of monthly rainfall analysis is very key to agricultural crop production because it will inform farmers the percentage points of the distribution of the start, end and duration of rains. Furthermore, this analytical factor will also enable farmers to better cope with the scenarios of the climate, particularly the rainfall deficiency, as tomatoes are not drought tolerant cultivars. Inconsistent rains and moisture levels can causes fruits cracking, splitting and blossom end rot.

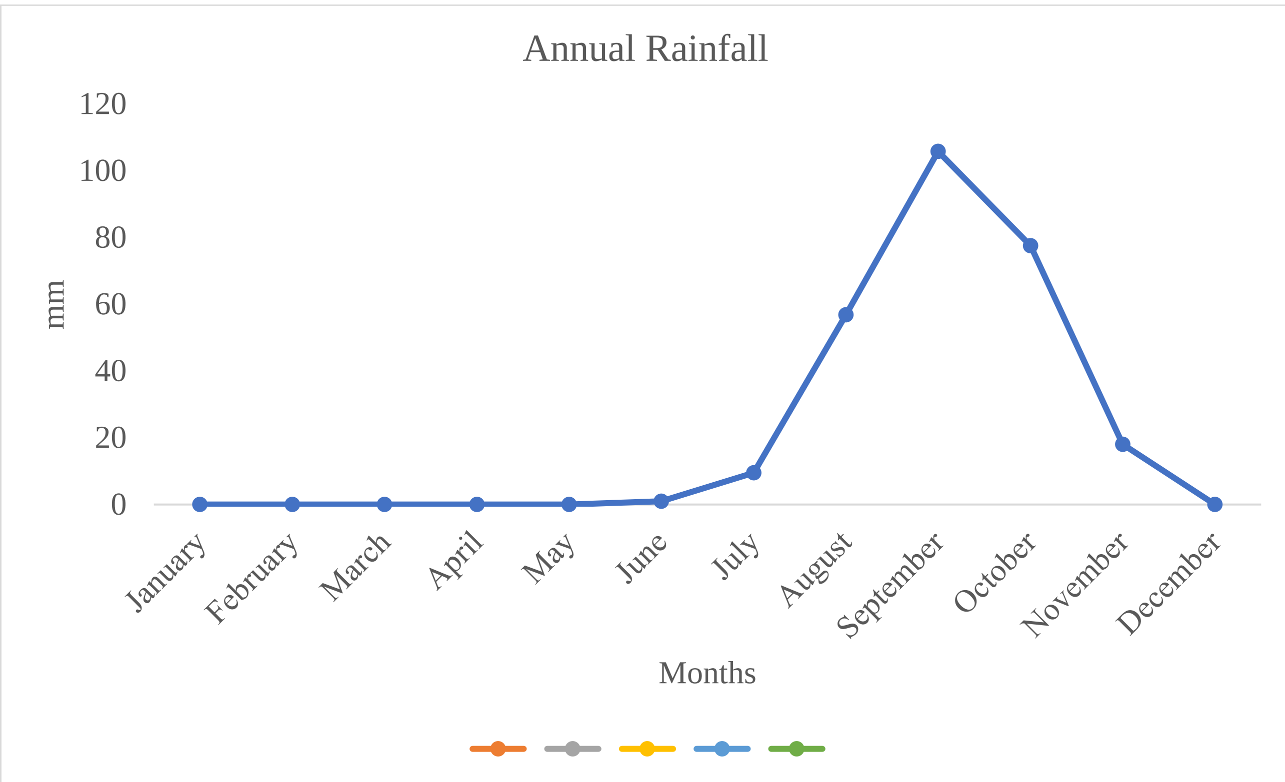


Figure 7: Average monthly Rainfall (mm) from 2013-2021

4.12.2: Temperatures

Temperature is an important abiotic stressor in tomato growth and development particularly under this current climate situation (Fiqure 8 & 9). The inter annual observation of variability of temperatures are eminent during the growing period of tomatoes, the average highest monthly minimum temperatures were observed in July and August but the trend remain steady for February, September to November. While the average highest monthly maximum temperature was report in April in the same study location. This is a clear manifestation of variability of temperatures for the wet season. The temperature of the month is usually calculated from the mean temperatures, which is obtained from the minimum and maximum temperatures.

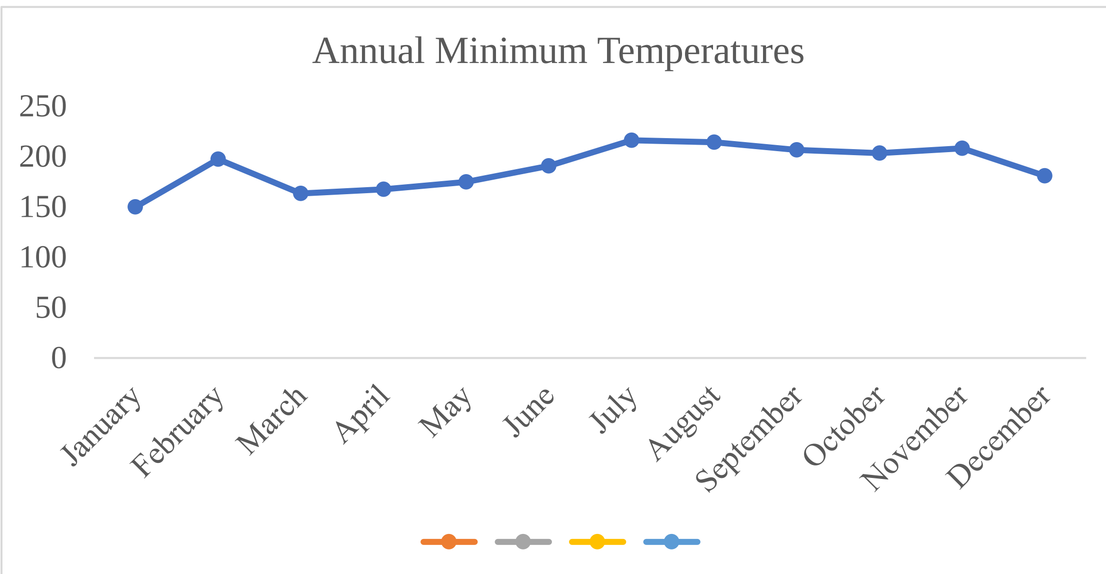


Figure 8: Average monthly Minimum Temperatures (mm) from 2013-2021

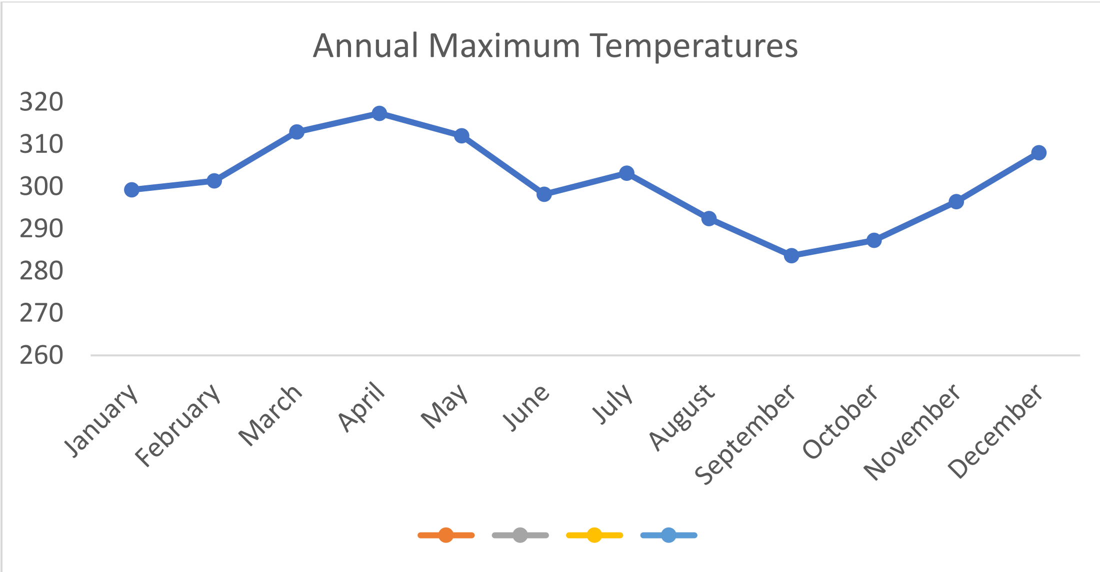


Figure 9: Monthly Maximum Tempeartures From 2013-2021

4.13: Discussions of Results

4.13.1: Initial and Current Soil Conditons after Treatment Application

Generally, the overall conditions of the Gambia soils are very low for both physical and chemical elements. This is as a results of continues cultivation and poor agronomic practices of the land such deep tillage systems. This statement is in an agreement with Agriculture and Natural Resources, The Gambia (2009) which reported that the soils of the Gambia are typically highly deficient in organic matter and chemical fertility, necessitating significant inputs of manure and fertilizer to improve agricultural yields and quality. However, for the experimental field in Yundum horticulture research site, the initial condition of the soil was in a state of alkaline condition at 7.5 pH which is a known threat to crop plant growth and yield. It affects the amount of nutrients and chemicals that are soluble in soil water and the amount of nutrients available to plants. According to Dobermann A and Fairhurst T. (2000) reported that, Alkalinity weakens plant growth by restricting water supply to the roots, thus obstructing root development. This is as a result of deficiencies in phosphorus and zinc, and possibly iron deficiency and boron toxicity. This effect also disturb tomato plants to have potential ability to extract essential nutrients from the soil when damaged by alkalinity. Alkaline soils, which are very common in semi-arid and arid climates, cover more than 25 % of the earth's surface. These soils are typically highly porous, freely draining and saturated with calcium carbonate (Lopez J, 2010). The soil electrical conductivity (EC) for the study area was very low (Non Saline) which is not very suitable for tomato production. Low EC's are often found in sandy soils with low organic matter levels and too low EC levels indicate low available nutrients.

For the case of organic matter content, the result depicted low for the soil but fairly high in Leucaena leaves and poultry manure. Its deficiency was caused by the decline of soil organic matter in the study area due to continues cultivation and improper practice of the land use (tillage). (European Soil Portal, 2009)report that loss of soil organic matter content can limit the soil's ability to provide nutrients for sustainable plant production. This may lead to lower yields and affect food security. Less organic carbon also means less food for the living organisms present in the soil, thus reducing soil biodiversity. Loss of soil organic matter reduces the water infiltration capacity of a soil, leading to increased run-off and erosion. In addition, the results for anitrogen calcium were also low in the soil and in Leucaena leaves. Soil nitrogen (N) defciencies can affect the photosynthetic N-use efciency (PNUE), mesophyll conductance (gm), and leaf N allocation (JingchaoTang *et al,* 2019). Low in calcium deficiencies in the soil affects plants in-terms of reduced height, fewer nodes, and less leaf area. Calcium deficiency is usually expressed as blossom-end rot of the fruit and as dieback of the growing tips. In most cases the Ca deficiency is not in the soil but is induced. The most likely cause is water stress on the plant resulting from inadequate or uneven watering, frequent and large variations in relative humidity, or a high level of salts (Personal Communication, 2022).

In addition, the result also indicates low content of magnesium for the soil, Leucaena leaves and poultry manure. (Kasinath et al., 2015)depicted that magnesium deficiency in tomato is first observed on older leaves (which become abnormally thin), and inter-venal chlorosis starts appearing. In advanced stages of deficiency, leaves become purplish-red and brittle, with a tendency to curl upward. (Myint et al., 2011) reported that magnesium (Mg) is an essential element for plant growth and also serves as the central core of the chlorophyll molecule in plant tissue. Thus, if Mg is deficient, the shortage of chlorophyll results in poor and stunted plant growth. Magnesium also helps to activate specific enzyme systems. Enzymes are complex substances that build, modify, or break down compounds as part of a plant's normal metabolism. Potassium was also very low for the soil and poultry manure after analysis. If action is not taken, its deficiencies in plants will cause brown scorching and curling of leaf tips as well as chlorosis (yellowing) between leaf veins. Purple spots may also appear on the leaf undersides. Plant growth, root development, and seed and fruit development are usually reduced in potassium-deficient plants.

Furthermore, after treatment application of (Leucaena leaves, poultry bedding and their combination) had shown some little effects on the soil because it has changed the soil pH from alikalinity to slightly acidity state and it has also inceases the soil fertility for both micro and macro elements as shown in table (4.2 and 4.3) respectfully. According to M.Fernández *et al* (2020) depicted that Leucaena cultivation increased soil nitrogen by 35 %, dehydrogenase activity by 98 %, and organic matter and carbon content (by 41 %) and it was also reported that incorporation of Leucaena green manure increase N uptake throughout the vegetative period and increased grain yield of rice significantly(Saraswat & Rai, 2011).The results found by (Ewulo et al., 2008)tated that poultry manure at 5 t ha -1 significantly increased tomato and dry matter yield, soil pH, N, P, K, Ca and Mg and nutrient uptakes.

4.13.2: Farmer's Awareness and Perception of Climate Change on Tomato Production

The findings reveal that tomato producers are strongly aware and also believed about the existence of climate change effects on tomatoes. They have mentioned numerous of climate elements as a factor responsible for the declining of tomato production and as well as a results of low yielding such as continues heat generation, and combinaed effects of high temperatures and low rainfalls and high temperatures coupled with heavy winds. Low rainfall, heavy winds and as well drought were considered as a minor by some farmers. These are due to continues increase in temperature and deforestation. Similar study was conducted by (Guodaar et al., 2017) reported that respondents observed temperature rise (90.2%), decrease in rainfall (87.3%), prolonged drought (87.3%), increase in solar radiation (74.6%) and an unpredictable rainfall pattern (73.5%). For the case of year experienced the existence of climate change, significant number of respondents said they have been experiencing quite numerous of tomato production challenges caused by climate change for the past five years now while small percent indicated 5-10years of experience. In addition, (Adebisi-Adelani & Oyesola, 2014)published a study report from Nigeria which indicated that tomato farmers have been experiencing climate change effects on tomatoes since year 2000. Tomato growers came to know about climate change, through personal experience followed by social Media and through personal experience plus social media as a results of change of growing season, prolonged of drought higher temperatures and heavy winds. Furthermore, similar study was conducted by (Bagagnan *et al.,* 2019) revealed that farmers generally perceive an increase in the frequency of extreme weather events and a decrease in the duration of the growing season.

4.13.3: Impact of Climate Change on Tomato Production

The findings reveals that most of the farmers reported that tomatoes are affected by numerous of climate change elements while few respondents said tomatoes are not disturbed by climate change. Furthermore, good number of the respondents indicated about severe rotting of tomato fruits at the reproductive stage which is due to high temperature, which is also similar to those observing dropping of flowers by rain and wind. Some percentage raised about introduction of disease, severe discoloration of leaves and low yielding due to continues rain and heavy winds. Report from Nepal (2021) stated that climate change had detriment effect on tomatoes. Tomato production and yield falls drastically in the area due to the incidence of disease increase such as late blight by fungal manifestation, black spot and burning (yellowing) of plants. A study reveals that low temperature, high rainfall during flowering stage and blight diseases and other fungal infestations limits the growth of tomato in an open field in high hill region (Bhandari et al., 2021). Finding from (Silva et al., 2017) also reported that temperatures below 10 °C plant growth will be reduced significantly and higher air temperatures, above 30 °C, can reduce fruit production. The further stated that tomato plants were subjected to different types of stresses, such as drought, wet, heat and cold, which result in disturbances in physiological and biochemical processes of development and plant growth.

4.13.4: Climate Change Adaptation Strategies used by Tomato Growers

For adaptation strategies, large number of the tomato growers said they have some strategies to climate change adaptation strategies while others accentuated that they don't have any adaptation strategies. The findings reveal that many of the farmers are using synthetic pesticide to control insect disease e.g. red spider mites and planting of trees (wind breakers) to reduce heavy wind speed as well as application of large quantity of fertilizers to improve the soil fertility in which many lamented that the strategies are very useful. Agriculture and Food Systems Institute (2020) concluded to have shift the cultivation of tomatoes to early planting, which has avoided or reduces exposure of tomatoes to increasing heat stress during the growth period. (Benabderrazik et al., 2022) said that a set of soil and water management practices have been adopted by farmers as response mechanisms: crop rotation, intercropping, supplementary fertilization, water tanks, or water retention ditches were the most important and common strategies employed in response to the changing climate.

4.13.5: Performance of Two Hybrids during the Two Raining Seasons

The wet season production of vegetables are confronting serious challenges particularly tomato which makes it impossible for many farmers to grow tomatoes during the wet season but instead only in the dry season. This decline has impacted the country for not meeting nutritional demand for tomato and translated to infiltration of high price which are unaffordable to many people in

The Gambia. However, the response of the two tomato cultivars were impressive during the wet season. The present study reveals significant variations between the cultivars. Mongal F1 tomato cultivar had generally performed better under the different stresses during the wet season than Thorgal F1. This was due to its resistance of tolerating numerous of weather stress. Similar result was concluded by SOME Koussao *et al* (2019) who also stated that, based on data from two years of farmer field trials the variety Mongal has been found to be well suited for rainy season cultivation in Burkina Faso.Sané et al., (2021) also reported that at high concentration of salt stress conditions, the final germination rates, the most significantly high, are obtained from seeds of the *Lady Nema* and *Mongal* varieties. For Thorgal F1, (Liaquat Hossain et al., 2007) also stated that among the seven cultivars tested, local Tounvi and improved Thorgal appeared as the most-salt resistant cultivars.

4.13.6: Response of Tomatoes to Organic and Chemical Fertilizer Application in 2021 and 2022 Seasons

The applications of organic manure (poultry manure, leucaena leaves plus their combination) had highly increases nutrient supply in the soil which has enhanced tomato growth and development. For instance its increment had impacted on plant survival rate, stem girth, primary branches, number of trusses and fruits length compared to Nitrogen fertilizer. Similar study was done by (Ezekiel Taiwo, 2020), indicated that the applications of organic fertilizers highly increase plant height, number and length of leaves, number of branches, number of flowers and fruits of tomatoes. Contrarily, the findings from (Mignoni et al., 2018) reported that the application of Leucaena litters was very inhibitory to seedling growth of tomato than rice. (Liaquat Hossain et al., 2007) pointed out that the highest grain yield was obtained from Leucaena leucocephala treated plots than plots applied chemical fertilizer solely. In addition, similar study was conducted on Oil palm where Imogie, A. E., (2008) reported that fresh fruit bunch yields were significantly increased by L. leucocephala over the control for the 3 year period. Akande and Adediran (2004) found that poultry manure at 5 t ha -1 significantly increased tomato and dry matter yield, soil pH, N, P, K, Ca and Mg and nutrient uptakes (B. S. Ewulo, 2008). Poultry manure compost is comparably better than NPK fertilizer in improving soil fertility status for tomato plant (Kisetu & Heri, 2014). Conclusion made by (Ilodibia & Chukwuma, 2015) found that the applications of poultry manure at the rate of 10 t ha^{-1} significantly resulted in enhanced and optimum growth and yield of tomato. It can therefore be recommended for tomato production in the tropical rainforest. (Beyene & Mulu, 2019).(Beyene & Mulu, 019) revealed that, nitrogen fertilizer rate at 100 and 150 kg per hectare provided 28.23 and 28.74 t/ha fruit yield. Nitrogen application resulted in greater values of plant height, leaf area, number of leaves and stem diameter of fodder maize, fresh and dry forage yield were also increased due to addition of nitrogen (Biswas et al., 2015). Nitrogen applied at the rate of 150 kg/ha gave high yield, therefore 150 kg/ha would be beneficial for the farmers to obtain optimum growth and higher yield of BARI tomato – 9 (Beyene & Mulu, 2019)

5.0: CHAPTER FIVE

5.1: Conclusion and Recommendations

5.1.1: Conclusions

Generally, tomato farmers are aware and also strongly believed that climate change is existing where constant increase in temperature and decrease in rainfall, an unpredictable rainfall pattern and prolonged drought were mentioned to have been experienced as climate change effects for more than five years while minority indicated about 5-10years. These effects were known to tomato growers through personal experience. Climate change is causing severe dropping of flowers by rain and wind and rotting of tomato fruits as well as disease attack at the reproductive stage. For the case of adaptation strategies, great numbers of the farmers are using synthetic pesticide to control disease e.g. red spider mites, planting of trees (wind breakers) to reduce heavy wind speed and application of large quantity of fertilizers to improve the soil fertility. Mongal F1 tomato variety had performed better than Thorgal F1 for both growth and yield parameters. However, among the treatments, poultry bedding has increased soil fertility level followed by Leucaena leaves and the lowest mean values were observed from Leucaena leaves + poultry bedding and Nitrogen. For the case of treatments response to growth and yield parameters, such as (stem girth, primary branches, fruit length) Leucaena leaves recorded the highest mean values seconded by poultry bedding and the lowest values were resulted from Nitrogen and Leucaena leaves +poultry bedding, except for number of trusses per plant, poultry bedding performed better than all th rest.

5.2: Recommendations

1. The research is recommending for further study on the same topic in different agro-ecological zone using local and improved tomato varieties.

2. The study is also recommending investigations of comparing the performance of leucaena and gliricidial leaves on tomatoes and soil fertility.

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Appendix 1: Assessment of Farmers Perception about Climate Change Impact and Adaptation Strategies Use for Tomato Production in The Gambia

N0	GENERAL INFORMATION	
1	Name of the country	
2	Name of the region	
3	Name of the village	
4	Name of the respondent	
5	Contact of the respondent	
	SOCIO-DEMOGRAPHIC INFORMATION	
6	Gender of the respondent	1. Male 2. Female
7	Age of respondent	1. 15-25 2. 25-35 3. 35-45 4. 45-55 5. 55 Above
8	Marital status	1. Single 2. Married 3. Divorced 4. Widow
9	Ethnicity	1. Mandinka 2. Wolof 3. Fula 4. Jola 5. Others (specify)
10	Education	1. Primary 2. Secondary 3. Tertiary 4. Koranic
11	Religion	1. Muslim 2. Christian
	PRODUCTION/ INPUTS INFORMATION FOR TOMATO PRODUCTION	
12	Do you grow tomatoes	1. Yes 2. No
13	Type of soil scheme you normally grow tomatoes	1. Sand y soil 2. Sandy clay 3. Sandy loamy 4. Loamy
14	How long have you been growing tomatoes	1. 1-15yrs, 2. 15-30yrs, 3. 30-45yrs 4. 45yrs above
15	Area under cultivation	1. 0.1-0.25ha, 2. 0.25-0.5ha 3. 0.5-0.75ha 4. 0.75ha above
17	Name of the tomato varieties you commonly grow	1. Local 2. Improve
18	Source of seeds	1. Own seeds 2. Purchased 3. Gift 4. Others
19	Method of watering	1. Completely rainfall 2. Only irrigation 3. Both
20	If raining season, state the period you normally sow your tomato seeds	1. After the first heavy rain 2. After two heavy rain 3. A week after the beginning of the season 4. Others
21	Method of sowing	1. Broadcasting 2. Row sowing
22	Do you apply fertilizers on tomatoes	1. Yes 2. No
23	Sources of fertilizers	1. Purchase 2. Agriculture 3. NGOs 4. Others
24	Type of fertilizers apply	1. Chemical Fertilizer 2. Animal Dung 3. Plant residues 4. Others
25	Time of application	1. Before the season 2. Mid-season 3. Late season
26	Method of application	1. Broadcasting 2. Row application
27	Do you apply pesticides on your tomatoes	1. Yes 2. No
28	Sources of pesticides	1. Purchase 2. Agriculture 3. NGOs 4. Others
29	Type of pesticides apply	1. Synthetic pesticides 2. Botanicals 3. Ash 4. Others

30	Time of application	1. Before the season 2. Mid-season 3. Late season
31	Method of application	1. Spraying 2. Use of hands
32	Do you often weed your tomatoes	1. Yes 2. No
33	If yes, method of weeding	1. Manual 2. Herbicide 3. Hand-picking
34	Number of weeding	1. Once 2. Twice 3. Three times
	Average yield obtained	
	FARMERS PERCEPTION OF CLIMATE CHANGE	
35	Are you aware of climate change	1. Yes 2. No
36	Do you believe that climate change is existing	1. Yes 2. No
37	If yes, what's your believe	1. Drought 2. Flooding 3. Heavy wind 4. Low rainfall 5. High temperature
38	When did you realized the existence of climate change	1. 1-5yrs 2.5-10yrs 3. 10yrs above
39	How did you know the existence of climate change	1. Personal experience 2. Friend 3. Through Media 4. Others
IMPACT OF CLIMATE CHAMGE ON TOMATO PRODUCTION		
40	Is climate change affecting tomato production	1. Yes 2. No
41	Which period of the year does climate change affects tomatoes most	1. Raining season 2. Dry season
42	At what stage of production does it affects tomatoes	1. Germination 2. Vegetative 3. Reproductive
43	Which part of tomato plant is seriously affected by climate change	1. Leaves 2. Branches 3. Flowers 4. Fruits
44	Mention 3 effects of climate change on tomatoes	1. 2. 3.
	ADAPTATION STRATEGIES	
45	Do you have strategies of adapting climate change for tomato production	1. Yes 2. No
46	If yes, mention the climate change adaptation strategies used on tomatoes	1. 2. 3.
47	Are these adaptation strategies useful	1. Yes 2. No
48	If yes, please rate the degree of usefulness	1. Low 2. Medium 3. High

Appendix 2:

Le Système SAS

The GLM Procedure

Dependent Variable: PP1

Source	DDL	Somme des carrés	Carré moyen	Valeur F	Pr > F
Model	6	0.08940612	0.01490102	3.40	0.0233
Error	16	0.07003039	0.00437690		
Corrected Total	22	0.15943651			

R carré	Coeff Var	Racine MSE	PP1 Moyenne
0.560763	5.613686	0.066158	1.178515

Source DDL Type I SS Carré moyen Valeur F Pr > F (If Pr > F is <0,05 the difference is statistically significant, otherwise (even if equql to 0.05) not)

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.00723458	0.00361729	0.83	0.4554
Var	1	0.05207368	0.05207368	11.90	0.0033
Trt	3	0.03009787	0.01003262	2.29	0.1171

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.00761624	0.00380812	0.87	0.4378
Var	1	0.05390097	0.05390097	12.31	0.0029
Trt	3	0.03009787	0.01003262	2.29	0.1171

Le Système SAS

The GLM Procedure

Dependent Variable: PH2WAT1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.02551804	0.01275902	1.50	0.2535
Var	1	0.00841591	0.00841591	0.99	0.3351
Trt	3	0.02666737	0.00888912	1.04	0.4003

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Rep	2	0.02698511	0.01349255	1.58	0.2358
Var	1	0.00681361	0.00681361	0.80	0.3845
Trt	3	0.02666737	0.00888912	1.04	0.4003

Le Système SAS

The GLM Procedure

Dependent Variable: PH4WAT1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.03743906	0.01871953	1.68	0.2168
Var	1	0.00027587	0.00027587	0.02	0.8768
Trt	3	0.06971966	0.02323989	2.09	0.1417

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.03680204	0.01840102	1.66	0.2220
Var	1	0.00016517	0.00016517	0.01	0.9045
Trt	3	0.06971966	0.02323989	2.09	0.1417

Le Système SAS

The GLM Procedure

Dependent Variable: PH6WAT1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.28827044	0.14413522	18.68	<.0001
Var	1	0.03449891	0.03449891	4.47	0.0505
Trt	3	0.05500962	0.01833654	2.38	0.1083

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.26439647	0.13219823	17.13	0.0001
Var	1	0.03565421	0.03565421	4.62	0.0472
Trt	3	0.05500962	0.01833654	2.38	0.1083

Le Système SAS

The GLM Procedure

Dependent Variable: NL1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F

Rep	2	0.66574264	0.33287132	14.85	0.0002
Var	1	0.01359290	0.01359290	0.61	0.4474
Trt	3	0.10846766	0.03615589	1.61	0.2256

			Valeur		
Source	DDL	Type III SS	Carré moyen	F	Pr > F
Rep	2	0.63994875	0.31997437	14.28	0.0003
Var	1	0.01096817	0.01096817	0.49	0.4942
Trt	3	0.10846766	0.03615589	1.61	0.2256

Le Système SAS

The GLM Procedure

Dependent Variable: FLOW501

			Valeur		
Source	DDL	Type I SS	Carré moyen	F	Pr > F
Rep	2	0.03323229	0.01661615	8.56	0.0030
Var	1	0.00215953	0.00215953	1.11	0.3072
Trt	3	0.00107703	0.00035901	0.18	0.9051

			Valeur		
Source	DDL	Type III SS	Carré moyen	F	Pr > F
Rep	2	0.03451149	0.01725575	8.89	0.0025
Var	1	0.00229762	0.00229762	1.18	0.2928
Trt	3	0.00107703	0.00035901	0.18	0.9051

Le Système SAS

The GLM Procedure

Dependent Variable: SG1

			Valeur		
Source	DDL	Type I SS	Carré moyen	F	Pr > F
Rep	2	0.21769870	0.10884935	59.35	<.0001
Var	1	0.03400957	0.03400957	18.54	0.0005
Trt	3	0.00250501	0.00083500	0.46	0.7172

			Valeur		
Source	DDL	Type III SS	Carré moyen	F	Pr > F
Rep	2	0.22946669	0.11473335	62.56	<.0001
Var	1	0.03511761	0.03511761	19.15	0.0005
Trt	3	0.00250501	0.00083500	0.46	0.7172

Le Système SAS

The GLM Procedure

Dependent Variable: PB1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.07712876	0.03856438	0.65	0.5341
Var	1	0.00023317	0.00023317	0.00	0.9507
Trt	3	0.28777508	0.09592503	1.62	0.2236

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.07532193	0.03766097	0.64	0.5417
Var	1	0.00112050	0.00112050	0.02	0.8922
Trt	3	0.28777508	0.09592503	1.62	0.2236

Le Système SAS

The GLM Procedure

Dependent Variable: DFS1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.14938859	0.07469429	84.89	<.0001
Var	1	0.00124815	0.00124815	1.42	0.2510
Trt	3	0.00214678	0.00071559	0.81	0.5051

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.15124805	0.07562403	85.94	<.0001
Var	1	0.00144762	0.00144762	1.65	0.2179
Trt	3	0.00214678	0.00071559	0.81	0.5051

Le Système SAS

The GLM Procedure

Dependent Variable: DFM1

Source	DDL	Type I SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.00082476	0.00041238	1.54	0.2450
Var	1	0.00287587	0.00287587	10.72	0.0048
Trt	3	0.00018983	0.00006328	0.24	0.8700

Source	DDL	Type III SS	Carré moyen	Valeur F	Pr > F
Rep	2	0.00086665	0.00043333	1.62	0.2295
Var	1	0.00291456	0.00291456	10.87	0.0046
Trt	3	0.00018983	0.00006328	0.24	0.8700

Le Système SAS

The GLM Procedure

Dependent Variable: TPP1

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Rep	2	1.19672207	0.59836104	7.33	0.0055
Var	1	0.00590067	0.00590067	0.07	0.7915
Trt	3	0.11728499	0.03909500	0.48	0.7015

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Rep	2	1.23264068	0.61632034	7.55	0.0049
Var	1	0.00279617	0.00279617	0.03	0.8555
Trt	3	0.11728499	0.03909500	0.48	0.7015

Le Système SAS

The GLM Procedure

Dependent Variable: NFPP1

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Rep	2	1.02509725	0.51254863	6.39	0.0091
Var	1	0.61145562	0.61145562	7.63	0.0139
Trt	3	0.20569454	0.06856485	0.86	0.4842

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Rep	2	1.18844454	0.59422227	7.41	0.0053
Var	1	0.64901121	0.64901121	8.09	0.0117
Trt	3	0.20569454	0.06856485	0.86	0.4842

Le Système SAS

The GLM Procedure

Dependent Variable: FWPP1

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Rep	2	1.50959767	0.75479884	5.19	0.0183
Var	1	0.53681436	0.53681436	3.69	0.0727
Trt	3	0.08346911	0.02782304	0.19	0.9008

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Rep	2	1.58297046	0.79148523	5.44	0.0157
Var	1	0.52675981	0.52675981	3.62	0.0752
Trt	3	0.08346911	0.02782304	0.19	0.9008

Le Système SAS

The GLM Procedure

Dependent Variable: FL1

Source	DDL	Type I SS	Carré moyen Valeur	F	Pr > F
Rep	2	0.00866476	0.00433238	4.46	0.0289
Var	1	0.00373483	0.00373483	3.84	0.0676
Trt	3	0.00090940	0.00030313	0.31	0.8165

Source	DDL	Type III SS	Carré moyen Valeur	F	Pr > F
Rep	2	0.00941489	0.00470744	4.84	0.0226
Var	1	0.00379960	0.00379960	3.91	0.0655
Trt	3	0.00090940	0.00030313	0.31	0.8165

Le Système SAS

The GLM Procedure

Dependent Variable: FD1

Source	DDL	Type I SS	Carré moyen Valeur	F	Pr > F
Rep	2	0.09892776	0.04946388	31.05	<.0001
Var	1	0.05830695	0.05830695	36.60	<.0001
Trt	3	0.01576081	0.00525360	3.30	0.0475

Source	DDL	Type III SS	Carré moyen Valeur	F	Pr > F
Rep	2	0.10292387	0.05146193	32.30	<.0001
Var	1	0.05957845	0.05957845	37.39	<.0001
Trt	3	0.01576081	0.00525360	3.30	0.0475

Le Système SAS

The GLM Procedure

Dependent Variable: NR1

Source	DDL	Type I SS	Carré moyen Valeur	F	Pr > F

Rep	2	0.04861740	0.02430870	0.43	0.6585
Var	1	0.00649762	0.00649762	0.11	0.7393
Trt	3	0.03572249	0.01190750	0.21	0.8879

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Rep	2	0.04819656	0.02409828	0.43	0.6608
Var	1	0.00660322	0.00660322	0.12	0.7373
Trt	3	0.03572249	0.01190750	0.21	0.8879

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PP1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.004377
Valeur critique de t	2.11991
Plus petite différence significative	0.0585
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.22813	11	Monjal
B	1.13303	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PH2WAT1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.008521
Valeur critique de t	2.11991
Plus petite différence significative	0.0817
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.27542	12	Thorgal
A	1.23283	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PH4WAT1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.011113
Valeur critique de t	2.11991
Plus petite différence significative	0.0933
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.50764	11	Monjal
A	1.50265	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PH6WAT1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.007717
Valeur critique de t	2.11991
Plus petite différence significative	0.0777
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.78594	12	Thorgal
B	1.69390	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour NL1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.022409
Valeur critique de t	2.11991
Plus petite différence significative	0.1325
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	2.27815	11	Monjal
A	2.25172	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour FLOW501

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.001941
Valeur critique de t	2.11991
Plus petite différence significative	0.039
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.50873	12	Thorgal
A	1.49438	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour SG1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.001834
Valeur critique de t	2.11991
Plus petite différence significative	0.0379
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	0.29761	11	Monjal
B	0.23352	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PB1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.059113

Valeur critique de t 2.11991

Plus petite différence significative 0.2151

Moyenne harmonique des tailles de cellules 11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	0.5502	11	Monjal
A	0.5452	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour DFS1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 16

Erreur du Carré Moyen 0.00088

Valeur critique de t 2.11991

Plus petite différence significative 0.0262

Moyenne harmonique des tailles de cellules 11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.57336	12	Thorgal
A	1.56896	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour DFM1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 16

Erreur du Carré Moyen 0.000268

Valeur critique de t 2.11991

Plus petite différence significative 0.0145

Moyenne harmonique des tailles de cellules 11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.818184	12	Thorgal
B	1.795923	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour TPP1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.081641
Valeur critique de t	2.11991
Plus petite différence significative	0.2528
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.2255	12	Thorgal
A	1.1644	11	Monjal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour NFPP1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.080184
Valeur critique de t	2.11991
Plus petite différence significative	0.2506
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.6954	11	Monjal
B	1.3974	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour FWPP1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.145459
Valeur critique de t	2.11991
Plus petite différence significative	0.3375
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var

A	0.4151	11	Monjal
A	0.1424	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour FL1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.000972
Valeur critique de t	2.11991
Plus petite différence significative	0.0276
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	0.48520	11	Monjal
A	0.46215	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour FD1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16
Erreur du Carré Moyen	0.001593
Valeur critique de t	2.11991
Plus petite différence significative	0.0353
Moyenne harmonique des tailles de cellules	11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	0.58540	11	Monjal
B	0.48732	12	Thorgal

Le Système SAS

The GLM Procedure

Tests t (LSD) pour NR1

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	16

Erreur du Carré Moyen 0.056681

Valeur critique de t 2.11991

Plus petite différence significative 0.2107

Moyenne harmonique des tailles de cellules 11.47826

Note: Tailles des cellules inégales.

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Var
A	1.16329	12	Thorgal
A	1.12879	11	Monjal

Le Système SAS

APENDIX2: SECOND SEASON ANALZED RESULTS

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The GLM Procedure

Informations sur les niveaux de classe

Classe	Niveaux	Valeurs
Variet	3	R1 R2 R3
Rep	2	Monjal Thorgal
Trait	4	LL LLPB N PB

Number of observations 24

Le Système SAS

The GLM Procedure

Dependent Variable: PP

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	0.25000000	0.12500000	0.17	0.8477
Rep	1	3.37500000	3.37500000	4.58	0.0760
Variet*Rep	2	0.25000000	0.12500000	0.17	0.8477
Trait	3	2.12500000	0.70833333	0.96	0.4691
Rep*Trait	3	5.45833333	1.81944444	2.47	0.1592
Variet*Trait	6	1.75000000	0.29166667	0.40	0.8577

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	0.25000000	0.12500000	0.17	0.8477
Rep	1	3.37500000	3.37500000	4.58	0.0760
Variet*Rep	2	0.25000000	0.12500000	0.17	0.8477
Trait	3	2.12500000	0.70833333	0.96	0.4691
Rep*Trait	3	5.45833333	1.81944444	2.47	0.1592
Variet*Trait	6	1.75000000	0.29166667	0.40	0.8577

Le Système SAS 09:50 Tuesday, October 25, 2022

The GLM Procedure

Dependent Variable: PH2

Valeur

Source	DDL	Type I SS	Carré moyen	F	Pr > F
Variet	2	2.40333333	1.20166667	0.07	0.9291
Rep	1	6.40666667	6.40666667	0.40	0.5520
Variet*Rep	2	16.06333333	8.03166667	0.50	0.6311
Trait	3	28.10833333	9.36944444	0.58	0.6492
Rep*Trait	3	3.96333333	1.32111111	0.08	0.9675
Variet*Trait	6	48.41666667	8.06944444	0.50	0.7903

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Variet	2	2.40333333	1.20166667	0.07	0.9291
Rep	1	6.40666667	6.40666667	0.40	0.5520
Variet*Rep	2	16.06333333	8.03166667	0.50	0.6311
Trait	3	28.10833333	9.36944444	0.58	0.6492
Rep*Trait	3	3.96333333	1.32111111	0.08	0.9675
Variet*Trait	6	48.41666667	8.06944444	0.50	0.7903

Le Système SAS

The GLM Procedure

Dependent Variable: PH4

Valeur

Source	DDL	Type I SS	Carré moyen	F	Pr > F
Variet	2	6.3808333	3.1904167	0.18	0.8377
Rep	1	135.8504167	135.8504167	7.77	0.0317
Variet*Rep	2	62.2708333	31.1354167	1.78	0.2471
Trait	3	152.8245833	50.9415278	2.91	0.1228
Rep*Trait	3	146.7845833	48.9281944	2.80	0.1311
Variet*Trait	6	117.1191667	19.5198611	1.12	0.4485

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Variet	2	6.3808333	3.1904167	0.18	0.8377
Rep	1	135.8504167	135.8504167	7.77	0.0317
Variet*Rep	2	62.2708333	31.1354167	1.78	0.2471
Trait	3	152.8245833	50.9415278	2.91	0.1228
Rep*Trait	3	146.7845833	48.9281944	2.80	0.1311
Variet*Trait	6	117.1191667	19.5198611	1.12	0.4485

Le Système SAS

The GLM Procedure

Dependent Variable: PH6

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	1211.218675	605.609337	7.24	0.0251
Rep	1	0.451004	0.451004	0.01	0.9439
Variet*Rep	2	42.042008	21.021004	0.25	0.7856
Trait	3	225.503013	75.167671	0.90	0.4947
Rep*Trait	3	174.970679	58.323560	0.70	0.5869
Variet*Trait	6	165.302025	27.550337	0.33	0.8988

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	1211.218675	605.609337	7.24	0.0251
Rep	1	0.451004	0.451004	0.01	0.9439
Variet*Rep	2	42.042008	21.021004	0.25	0.7856
Trait	3	225.503013	75.167671	0.90	0.4947
Rep*Trait	3	174.970679	58.323560	0.70	0.5869
Variet*Trait	6	165.302025	27.550338	0.33	0.8988

Le Système SAS

The GLM Procedure

Dependent Variable: NL

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	70711.08333	35355.54167	11.76	0.0084
Rep	1	121.50000	121.50000	0.04	0.8473
Variet*Rep	2	147.25000	73.62500	0.02	0.9759
Trait	3	3987.50000	1329.16667	0.44	0.7314
Rep*Trait	3	1924.83333	641.61111	0.21	0.8836
Variet*Trait	6	16323.25000	2720.54167	0.91	0.5466

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	70711.08333	35355.54167	11.76	0.0084
Rep	1	121.50000	121.50000	0.04	0.8473
Variet*Rep	2	147.25000	73.62500	0.02	0.9759
Trait	3	3987.50000	1329.16667	0.44	0.7314
Rep*Trait	3	1924.83333	641.61111	0.21	0.8836
Variet*Trait	6	16323.25000	2720.54167	0.91	0.5466

Le Système SAS

The GLM Procedure

Dependent Variable: Flower

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	60.0833333	30.0416667	3.65	0.0919
Rep	1	130.6666667	130.6666667	15.87	0.0073
Variet*Rep	2	7.5833333	3.7916667	0.46	0.6516
Trait	3	33.5000000	11.1666667	1.36	0.3426
Rep*Trait	3	24.3333333	8.1111111	0.98	0.4604
Variet*Trait	6	36.2500000	6.0416667	0.73	0.6418

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	60.0833333	30.0416667	3.65	0.0919
Rep	1	130.6666667	130.6666667	15.87	0.0073
Variet*Rep	2	7.5833333	3.7916667	0.46	0.6516
Trait	3	33.5000000	11.1666667	1.36	0.3426
Rep*Trait	3	24.3333333	8.1111111	0.98	0.4604
Variet*Trait	6	36.2500000	6.0416667	0.73	0.6418

Le Système SAS

The GLM Procedure

Dependent Variable: SG

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	3.65083333	1.82541667	398.27	<.0001
Rep	1	1.08375000	1.08375000	236.45	<.0001
Variet*Rep	2	1.14250000	0.57125000	124.64	<.0001
Trait	3	0.13125000	0.04375000	9.55	0.0106
Rep*Trait	3	0.07125000	0.02375000	5.18	0.0420
Variet*Trait	6	0.25250000	0.04208333	9.18	0.0081

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	3.65083333	1.82541667	398.27	<.0001
Rep	1	1.08375000	1.08375000	236.45	<.0001
Variet*Rep	2	1.14250000	0.57125000	124.64	<.0001
Trait	3	0.13125000	0.04375000	9.55	0.0106
Rep*Trait	3	0.07125000	0.02375000	5.18	0.0420
Variet*Trait	6	0.25250000	0.04208333	9.18	0.0081

Le Système SAS

The GLM Procedure

Dependent Variable: PB

Source	DDL	Type I SS	Carré moyen	F Valeur	Pr > F
Variet	2	4.00000000	2.00000000	3.00	0.1250
Rep	1	5.04166667	5.04166667	7.56	0.0333
Variet*Rep	2	0.33333333	0.16666667	0.25	0.7865
Trait	3	12.45833333	4.15277778	6.23	0.0284
Rep*Trait	3	1.12500000	0.37500000	0.56	0.6593
Variet*Trait	6	7.66666667	1.27777778	1.92	0.2242

Source	DDL	Type III SS	Carré moyen	F Valeur	Pr > F
Variet	2	4.00000000	2.00000000	3.00	0.1250
Rep	1	5.04166667	5.04166667	7.56	0.0333
Variet*Rep	2	0.33333333	0.16666667	0.25	0.7865
Trait	3	12.45833333	4.15277778	6.23	0.0284
Rep*Trait	3	1.12500000	0.37500000	0.56	0.6593
Variet*Trait	6	7.66666667	1.27777778	1.92	0.2242

Le Système SAS

The GLM Procedure

Dependent Variable: DFS

Source	DDL	Type I SS	Carré moyen	F Valeur	Pr > F
Variet	2	113.2500000	56.6250000	17.65	0.0031
Rep	1	51.0416667	51.0416667	15.91	0.0072
Variet*Rep	2	5.0833333	2.5416667	0.79	0.4951
Trait	3	16.4583333	5.4861111	1.71	0.2635
Rep*Trait	3	1.1250000	0.3750000	0.12	0.9469
Variet*Trait	6	14.4166667	2.4027778	0.75	0.6328

Source	DDL	Type III SS	Carré moyen	F Valeur	Pr > F
Variet	2	113.2500000	56.6250000	17.65	0.0031
Rep	1	51.0416667	51.0416667	15.91	0.0072
Variet*Rep	2	5.0833333	2.5416667	0.79	0.4951
Trait	3	16.4583333	5.4861111	1.71	0.2635
Rep*Trait	3	1.1250000	0.3750000	0.12	0.9469
Variet*Trait	6	14.4166667	2.4027778	0.75	0.6328

Le Système SAS

The GLM Procedure

Dependent Variable: DFM

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	12.33333333	6.16666667	1.85	0.2367
Rep	1	60.16666667	60.16666667	18.05	0.0054
Variet*Rep	2	17.33333333	8.66666667	2.60	0.1537
Trait	3	4.00000000	1.33333333	0.40	0.7583
Rep*Trait	3	0.50000000	0.16666667	0.05	0.9838
Variet*Trait	6	5.00000000	0.83333333	0.25	0.9421

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	12.33333333	6.16666667	1.85	0.2367
Rep	1	60.16666667	60.16666667	18.05	0.0054
Variet*Rep	2	17.33333333	8.66666667	2.60	0.1537
Trait	3	4.00000000	1.33333333	0.40	0.7583
Rep*Trait	3	0.50000000	0.16666667	0.05	0.9838
Variet*Trait	6	5.00000000	0.83333333	0.25	0.9421

Le Système SAS

The GLM Procedure

Dependent Variable: TPP

Source	DDL	Type I SS	Valeur Carré moyen	F	Pr > F
Variet	2	68.58333333	34.29166667	6.07	0.0362
Rep	1	22.04166667	22.04166667	3.90	0.0957
Variet*Rep	2	14.08333333	7.04166667	1.25	0.3528
Trait	3	42.45833333	14.15277778	2.50	0.1561
Rep*Trait	3	75.45833333	25.15277778	4.45	0.0571
Variet*Trait	6	49.41666667	8.23611111	1.46	0.3296

Source	DDL	Type III SS	Valeur Carré moyen	F	Pr > F
Variet	2	68.58333333	34.29166667	6.07	0.0362
Rep	1	22.04166667	22.04166667	3.90	0.0957
Variet*Rep	2	14.08333333	7.04166667	1.25	0.3528
Trait	3	42.45833333	14.15277778	2.50	0.1561
Rep*Trait	3	75.45833333	25.15277778	4.45	0.0571

Variet*Trait	6	49.41666667	8.23611111	1.46	0.3296

Le Système SAS

The GLM Procedure

Dependent Variable: NFPP

Source	DDL	Type I SS	Carré moyen Valeur	F	Pr > F
Variet	2	1030.750000	515.375000	17.78	0.0030
Rep	1	504.166667	504.166667	17.39	0.0059
Variet*Rep	2	256.083333	128.041667	4.42	0.0662
Trait	3	75.666667	25.222222	0.87	0.5066
Rep*Trait	3	112.833333	37.611111	1.30	0.3584
Variet*Trait	6	224.583333	37.430556	1.29	0.3821

Source	DDL	Type III SS	Carré moyen Valeur	F	Pr > F
Variet	2	1030.750000	515.375000	17.78	0.0030
Rep	1	504.166667	504.166667	17.39	0.0059
Variet*Rep	2	256.083333	128.041667	4.42	0.0662
Trait	3	75.666667	25.222222	0.87	0.5066
Rep*Trait	3	112.833333	37.611111	1.30	0.3584
Variet*Trait	6	224.583333	37.430556	1.29	0.3821

Le Système SAS

The GLM Procedure

Dependent Variable: FWPP

Source	DDL	Type I SS	Carré moyen Valeur	F	Pr > F
Variet	2	7.67360833	3.83680417	37.31	0.0004
Rep	1	3.07450417	3.07450417	29.90	0.0016
Variet*Rep	2	0.84565833	0.42282917	4.11	0.0751
Trait	3	0.43541250	0.14513750	1.41	0.3283
Rep*Trait	3	0.67664583	0.22554861	2.19	0.1897
Variet*Trait	6	0.92092500	0.15348750	1.49	0.3195

Source	DDL	Type III SS	Carré moyen Valeur	F	Pr > F
Variet	2	7.67360833	3.83680417	37.31	0.0004
Rep	1	3.07450417	3.07450417	29.90	0.0016
Variet*Rep	2	0.84565833	0.42282917	4.11	0.0751
Trait	3	0.43541250	0.14513750	1.41	0.3283
Rep*Trait	3	0.67664583	0.22554861	2.19	0.1897
Variet*Trait	6	0.92092500	0.15348750	1.49	0.3195

Le Système SAS

The GLM Procedure

Dependent Variable: FL

Valeur

Source	DDL	Type I SS	Carré moyen	F	Pr > F
Variet	2	4.10583333	2.05291667	81.66	<.0001
Rep	1	0.20166667	0.20166667	8.02	0.0299
Variet*Rep	2	0.00583333	0.00291667	0.12	0.8924
Trait	3	0.21500000	0.07166667	2.85	0.1272
Rep*Trait	3	0.14166667	0.04722222	1.88	0.2342
Variet*Trait	6	0.17750000	0.02958333	1.18	0.4242

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Variet	2	4.10583333	2.05291667	81.66	<.0001
Rep	1	0.20166667	0.20166667	8.02	0.0299
Variet*Rep	2	0.00583333	0.00291667	0.12	0.8924
Trait	3	0.21500000	0.07166667	2.85	0.1272
Rep*Trait	3	0.14166667	0.04722222	1.88	0.2342
Variet*Trait	6	0.17750000	0.02958333	1.18	0.4242

Le Système SAS

The GLM Procedure

Dependent Variable: FD

Valeur

Source	DDL	Type I SS	Carré moyen	F	Pr > F
Variet	2	4.95083333	2.47541667	26.96	0.0010
Rep	1	2.34375000	2.34375000	25.53	0.0023
Variet*Rep	2	0.15250000	0.07625000	0.83	0.4804
Trait	3	0.14791667	0.04930556	0.54	0.6739
Rep*Trait	3	0.14791667	0.04930556	0.54	0.6739
Variet*Trait	6	0.12583333	0.02097222	0.23	0.9523

Valeur

Source	DDL	Type III SS	Carré moyen	F	Pr > F
Variet	2	4.95083333	2.47541667	26.96	0.0010
Rep	1	2.34375000	2.34375000	25.53	0.0023
Variet*Rep	2	0.15250000	0.07625000	0.83	0.4804
Trait	3	0.14791667	0.04930556	0.54	0.6739

Rep*Trait	3	0.14791667	0.04930556	0.54	0.6739
Variet*Trait	6	0.12583333	0.02097222	0.23	0.9523

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.736111
Valeur critique de t	2.44691
Plus petite différence significative	1.0497

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	18.7500	8	R3
A	18.6250	8	R2
A	18.5000	8	R1

Le Système SAS

The GLM Procedure

Tests t (LSD) pour PH2

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	16.14611
Valeur critique de t	2.44691
Plus petite différence significative	4.9161

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	18.375	8	R1
A	18.250	8	R2
A	17.650	8	R3

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The GLM Procedure

Tests t (LSD) pour PH4

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	17.48486
Valeur critique de t	2.44691
Plus petite différence significative	5.1159

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	36.588	8	R1
A	35.925	8	R3
A	35.325	8	R2

The GLM Procedure

Tests t (LSD) pour PH6

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	83.65123
Valeur critique de t	2.44691
Plus petite différence significative	11.19

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	68.175	8	R3
B	53.761	8	R2
B	52.525	8	R1

The GLM Procedure

Tests t (LSD) pour NL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3005.403
Valeur critique de t	2.44691
Plus petite différence significative	67.072

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	256.63	8	R3
B	155.13	8	R2
B	131.50	8	R1

The GLM Procedure

Tests t (LSD) pour Flower

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	8.236111

Valeur critique de t 2.44691

Plus petite différence significative 3.5112

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement		Moyenne	Nb	Variet
	A	36.375	8	R1
B	A	34.375	8	R2
B		32.500	8	R3

The GLM Procedure

Tests t (LSD) pour SG

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.004583

Valeur critique de t 2.44691

Plus petite différence significative 0.0828

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	1.75000	8	R3
B	1.18750	8	R1
C	0.80000	8	R2

The GLM Procedure

Tests t (LSD) pour PB

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.666667

Valeur critique de t 2.44691

Plus petite différence significative 0.9989

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement		Moyenne	Nb	Variet
	A	5.6250	8	R2
B	A	5.1250	8	R1
B		4.6250	8	R3

The GLM Procedure

Tests t (LSD) pour DFS

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 3.208333

Valeur critique de t 2.44691

Plus petite différence significative 2.1914

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	45.2500	8	R1
A	43.3750	8	R2
B	40.0000	8	R3

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The GLM Procedure

Tests t (LSD) pour DFM

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 3.333333

Valeur critique de t 2.44691

Plus petite différence significative 2.2337

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	65.0000	8	R1
A	64.2500	8	R2
A	63.2500	8	R3

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The GLM Procedure

Tests t (LSD) pour TPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 5.652778

Valeur critique de t 2.44691

Plus petite différence significative 2.9088

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	11.625	8	R3
B A	9.250	8	R2
B	7.500	8	R1

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The GLM Procedure

Tests t (LSD) pour NFPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	28.98611
Valeur critique de t	2.44691
Plus petite différence significative	6.5869

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	37.750	8	R3
B	24.375	8	R2
B	23.375	8	R1

The GLM Procedure

Tests t (LSD) pour FWPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.102824
Valeur critique de t	2.44691
Plus petite différence significative	0.3923

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	2.3475	8	R3
B	1.2075	8	R2
B	1.0963	8	R1

The GLM Procedure

Tests t (LSD) pour FL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.025139
Valeur critique de t	2.44691
Plus petite différence significative	0.194

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	2.83750	8	R3

A	2.76250	8	R1
B	1.92500	8	R2

The GLM Procedure

Tests t (LSD) pour FD

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.091806
Valeur critique de t	2.44691
Plus petite différence significative	0.3707

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Variet
A	3.6375	8	R3
B	3.0750	8	R1
C	2.5250	8	R2

The GLM Procedure

Tests t (LSD) pour PP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.736111
Valeur critique de t	2.44691
Plus petite différence significative	0.8571

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	19.0000	12	Monjal
A	18.2500	12	Thorgal

The GLM Procedure

Tests t (LSD) pour PH2

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	16.14611
Valeur critique de t	2.44691
Plus petite différence significative	4.014

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	18.608	12	Thorgal
A	17.575	12	Monjal

The GLM Procedure

Tests t (LSD) pour PH4

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	17.48486
Valeur critique de t	2.44691
Plus petite différence significative	4.1771

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	38.325	12	Monjal
B	33.567	12	Thorgal

The GLM Procedure

Tests t (LSD) pour PH6

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	83.65123
Valeur critique de t	2.44691
Plus petite différence significative	9.1365

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	58.291	12	Monjal
A	58.017	12	Thorgal

The GLM Procedure

Tests t (LSD) pour NL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3005.403
Valeur critique de t	2.44691
Plus petite différence significative	54.764

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	183.33	12	Monjal
A	178.83	12	Thorgal

The GLM Procedure

Tests t (LSD) pour Flower

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	8.236111
Valeur critique de t	2.44691
Plus petite différence significative	2.8668

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	36.750	12	Thorgal
B	32.083	12	Monjal

The GLM Procedure

Tests t (LSD) pour SG

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.004583
Valeur critique de t	2.44691
Plus petite différence significative	0.0676

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	1.45833	12	Monjal
B	1.45833	12	Thorgal

The GLM Procedure

Tests t (LSD) pour PB

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.666667
Valeur critique de t	2.44691
Plus petite différence significative	0.8156

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	5.5833	12	Monjal
B	4.6667	12	Thorgal

The GLM Procedure

Tests t (LSD) pour DFS

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3.208333
Valeur critique de t	2.44691
Plus petite différence significative	1.7893

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	44.3333	12	Thorgal
B	41.4167	12	Monjal

The GLM Procedure

Tests t (LSD) pour DFM

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3.333333
Valeur critique de t	2.44691
Plus petite différence significative	1.8238

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	65.7500	12	Thorgal
B	62.5833	12	Monjal

The GLM Procedure

Tests t (LSD) pour TPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6

Erreur du Carré Moyen 5.652778

Valeur critique de t 2.44691

Plus petite différence significative 2.3751

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	10.4167	12	Monjal
A	8.5000	12	Thorgal

The GLM Procedure

Tests t (LSD) pour NFPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 28.98611

Valeur critique de t 2.44691

Plus petite différence significative 5.3782

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	33.083	12	Monjal
B	23.917	12	Thorgal

The GLM Procedure

Tests t (LSD) pour FWPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.102824

Valeur critique de t 2.44691

Plus petite différence significative 0.3203

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	1.9083	12	Monjal
B	1.1925	12	Thorgal

The GLM Procedure

Tests t (LSD) pour FL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.025139

Valeur critique de t 2.44691

Plus petite différence significative 0.1584

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	2.60000	12	Monjal
B	2.41667	12	Thorgal

The GLM Procedure

Tests t (LSD) pour FD

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.091806

Valeur critique de t 2.44691

Plus petite différence significative 0.3027

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Rep
A	3.3917	12	Monjal
B	2.7667	12	Thorgal

The GLM Procedure

Tests t (LSD) pour PP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha 0.05

Erreur Degrés de Liberté 6

Erreur du Carré Moyen 0.736111

Valeur critique de t 2.44691

Plus petite différence significative 1.2121

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	19.0000	6	PB
A	18.6667	6	LL
A	18.6667	6	N
A	18.1667	6	LLPB

The GLM Procedure

Tests t (LSD) pour PH2

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	16.14611
Valeur critique de t	2.44691
Plus petite différence significative	5.6766

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	19.183	6	LLPB
A	18.867	6	LL
A	17.917	6	N
A	16.400	6	PB

The GLM Procedure

Tests t (LSD) pour PH4

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	17.48486
Valeur critique de t	2.44691
Plus petite différence significative	5.9073

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement		Moyenne	Nb	Trait
	A	38.650	6	PB
B	A	37.633	6	LL
B	A	35.433	6	LLPB
B		32.067	6	N

The GLM Procedure

Tests t (LSD) pour PH6

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	83.65123
Valeur critique de t	2.44691
Plus petite différence significative	12.921

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	62.933	6	LLPB
A	57.733	6	LL
A	57.565	6	PB

A	54.383	6	N

The GLM Procedure

Tests t (LSD) pour NL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3005.403
Valeur critique de t	2.44691
Plus petite différence significative	77.448

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	198.67	6	N
A	187.67	6	LLPB
A	172.17	6	LL
A	165.83	6	PB

The GLM Procedure

Tests t (LSD) pour Flower

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	8.236111
Valeur critique de t	2.44691
Plus petite différence significative	4.0543

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	36.333	6	LL
A	34.333	6	N
A	33.833	6	PB
A	33.167	6	LLPB

The GLM Procedure

Tests t (LSD) pour SG

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.004583
Valeur critique de t	2.44691

Plus petite différence significative 0.0956

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	1.33333	6	LL
A	1.30000	6	PB
B	1.20000	6	N
B	1.15000	6	LLPB

The GLM Procedure

Tests t (LSD) pour PB

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.666667
Valeur critique de t	2.44691
Plus petite différence significative	1.1535

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	6.0000	6	LL
A	5.3333	6	PB
A	5.1667	6	LLPB
B	4.0000	6	N

The GLM Procedure

Tests t (LSD) pour DFS

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3.208333
Valeur critique de t	2.44691
Plus petite différence significative	2.5304

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	44.000	6	LL
A	43.000	6	PB
A	42.833	6	LLPB
A	41.667	6	N

The GLM Procedure

Tests t (LSD) pour DFM

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	3.333333
Valeur critique de t	2.44691
Plus petite différence significative	2.5793

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	64.833	6	LL
A	64.167	6	N
A	63.833	6	LLPB
A	63.833	6	PB

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The GLM Procedure

Tests t (LSD) pour TPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	5.652778
Valeur critique de t	2.44691
Plus petite différence significative	3.3588

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement		Moyenne	Nb	Trait
	A	11.000	6	PB
B	A	9.833	6	LL
B	A	9.667	6	LLPB
B		7.333	6	N

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The GLM Procedure

Tests t (LSD) pour NFPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	28.98611
Valeur critique de t	2.44691
Plus petite différence significative	7.6059

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	31.167	6	PB

A	28.833	6	LLPB
A	27.667	6	N
A	26.333	6	LL

The GLM Procedure

Tests t (LSD) pour FWPP

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.102824
Valeur critique de t	2.44691
Plus petite différence significative	0.453

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	1.7500	6	LLPB
A	1.5417	6	LL
A	1.5400	6	N
A	1.3700	6	PB

The GLM Procedure

Tests t (LSD) pour FL

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.025139
Valeur critique de t	2.44691
Plus petite différence significative	0.224

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement		Moyenne	Nb	Trait
	A	2.61667	6	LL
B	A	2.56667	6	N
B	A	2.48333	6	PB
B		2.36667	6	LLPB

The GLM Procedure

Tests t (LSD) pour FD

Note: This test controls the Type I comparisonwise error rate, not the experimentwise error rate.

Alpha	0.05
Erreur Degrés de Liberté	6
Erreur du Carré Moyen	0.091806

Valeur critique de t 2.44691

Plus petite différence significative 0.428

Les moyennes avec la même lettre ne sont pas très différentes.

T Groupement	Moyenne	Nb	Trait
A	3.2000	6	LLPB
A	3.0833	6	PB
A	3.0500	6	LL
A	2.9833	6	N

Plate 1: Mongal F1 Tomato Variety

Plate 2: Thorgal F1 Tomato Variety