

**EFFECTS OF DIFFERENT FORMS OF NITROGEN IN DILUTE SEA SALT ON
THE GERMINATION AND GROWTH, OF VIGNA UNGUICULATA L. WALP IN
A HYDROPONIC SYSTEM**

LILLIAN MUZAKI

J21B26/006

**A DISSERTATION SUBMITTED TO THE FACULTY OF AGRICULTURAL SCIENCES IN
PARTIAL FULFILLMENT FOR THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF
BACHELOR OF AGRICULTURAL SCIENCE AND ENTREPRENEURSHIP OF UGANDA
CHRISTIAN UNIVERSITY**

April, 2025



**UGANDA CHRISTIAN
UNIVERSITY**

A Centre of Excellence in the Heart of Africa

ABSTRACT

Hydroponic growth systems are a convenient platform for studying whole plant physiology. Major yield loss in cowpea (*Vigna unguiculata*) can be attributed to biotic and abiotic stresses. A cost effective and time saving screening protocol for cowpea abiotic stresses will enhance and expedite research on cowpea by breeders thereby enhancing its production and availability to meet increasing demand and population rise. Different crops have different forms of nitrogen they prefer, different crops grow differently in salt media which has trace elements needed by plants for growth, but because of associated salinity issues, different crops show different results.

In this study, the effect of different forms of nitrogen in dilute sea salt on the germination and growth *Vigna unguiculata* L. Walp (cowpea) in a deepwater hydroponic system was studied. Data on germination and growth was entered in MS Excel, cleaned and exported in Gensart 12, analyzed, means, standard deviation, coefficient of variation were generated. Analysis of variance (ANOVA) was calculated and significantly mean values were compared using Duncan multiple range test at 5% significance level. Plants in nutrient solution with nitrates and free nitrogen ions in sea salt showed better results of germination and growth than crops grown in nutrient solution without sea salt and the worst results were present by nutrient solution with ammonia as a form of nitrogen in sea salt. These results indicate that addition of sea salt (10% dilution) in nutrient solutions and using nitrogen forms nitrate and free ions affect positively the germination and growth of cowpea.

DECLARATION

I, **Lillian Muzaki**, declare that I am the author of this dissertation and it has never been submitted to any other university or institution of higher education. Any assistance I received in its preparation is fully acknowledged and disclosed in the document. I have cited all the relevant sources from which I generated ideas either quoted directly or paraphrased. I therefore submit this research dissertation in partial fulfillment for the award of a Degree in Bachelor of Agricultural Science and Entrepreneurship at Uganda Christian University.

Signature:

Name:

Date:

APPROVAL

This is to certify that this research dissertation has been submitted for examination with my approval as the University Supervisor as a requirement for the award of a Bachelor of Agricultural Science and Entrepreneurship.

Signature: 

Name: **Nanyanzi Mary**

Date: **7th April, 2024**

DEDICATION

I dedicate this work to the Lord Almighty who is the Author of my salvation, In him I move live and find my being, and to my parents Mr. and Mrs. Gidudu for their constant support and provision.

ACKNOWLEDGEMENTS

I greatly acknowledge the hand of God because he gave me grace to finish well, my parents and family for their support, my academic supervisor madam Mary Nyanzi and other people that have taught and inspired me like professor Elizabeth Kizito and generally all my lecturers at Uganda Christian university Mukono

TABLE OF CONTENTS

ABSTRACT.....	i
DECLARATION	ii
APPROVAL	iii
DEDICATION.....	iv
ACKNOWLEDGEMENTS	v
TABLE OF CONTENTS.....	vi
LIST OF TABLES.....	viii
LIST OF FIGURES	ix
LIST OF ABBREVIATIONS	x
CHAPTER ONE	1
1.0. Introduction	1
1.1. Background of study	1
1.2. Hydroponics system	4
1.3. Solutions used in hydroponic systems	7
1.4. Problem statement.....	9
1.5. Objectives	11
1.5.1. Main Objective.....	11
1.5.2. Specific objectives	12
1.6. Hypothesis.....	12
1.7. Justification and significance of study	12
1.8. Conceptual frame work	13

CHAPTER TWO	14
2.0. General Literature Review	14
2.1. Origin, Distribution, Taxonomy and Morphological Description of the Crop 17	
2.2. Effects of nutrient solution with different forms of nitrogen in sea salt on the germination and growth of <i>Vigna unguiculata L. Walp</i>	21
3.0. Study Site	28
3.1. Materials and methods	28
3.1.1. Plant Materials.....	28
CHAPTER FOUR.....	34
4.0. Results and discussion	34
4.1. Effects of nutrient solution with different forms of nitrogen in sea salt on the germination of <i>Vigna unguiculata L. Walp</i>	34
4.1.1. Effects of nutrient solution with different forms of nitrogen in sea salt on the growth of <i>Vigna unguiculata L. Walp</i>	36
CHAPTER FIVE.....	44
5.0. Conclusion and Recommendations	44
5.2. Recommendation.....	44
REFERENCES	45
ANNEX 1: TIME FRAME	54
ANNEX 2: BUDGET.....	55
ANNEX 3:DATA COLLECTION SHEET	56
ANNEX 4: PICTURES	58

LIST OF TABLES

Table 1: Mean effect of nutrient solution with different forms of nitrogen in sea salt on germination of cow pea.	35
Table 2: Mean effect of nutrient solution with different forms of nitrogen in sea salt on number of leaves.....	36
Table 3: Mean effect of nutrient solution with different forms of nitrogen in sea salt on number of branches	37
Table 4: Mean effect of nutrient solution with different forms of nitrogen in sea salt on plant height.....	37
Table 5; Mean effect of nutrient solution with different forms of nitrogen in sea salt on stem diameter.....	38
Table 6; Mean effect of nutrient solution with different forms of nitrogen in sea salt on leaf length.....	38
Table 7; Mean effect of nutrient solution with different forms of nitrogen in sea salt on leaf width	39
Table 8; Mean effect of nutrient solution with different forms of nitrogen in sea salt on growth of cow pea in week 3	40

LIST OF FIGURES

Figure 1 Experimental design	31
Figure 2 Experimental set up	31
Figure 3: Graph showing growth parameter of cow pea in different solutions	40
Figure 4. Treatment 3	58
Figure 5, Treatment 5	58
Figure 6, Treatment 2	59
Figure 7. Treatment 6	59
Figure 8. Treatment 4	60
Figure 9. Treatment 1	60

LIST OF ABBREVIATIONS

FAO	Food and Agriculture Organization
NO ₃	Nitrate
NH ₄	Ammonia
NFT	Nutrient Film Technique
FGP	Final Germination Percentage
MGT	Mean Germination Time
GI	Germination Index
SO ₄ ²⁻	Sulphate
SD	Standard Deviation

CHAPTER ONE

1.0. Introduction

1.1. Background of study

The world population is predicted to increase by over 9 billion people by 2050 and food demand by around 85% (FAO, 2017). This suggests that increasing agricultural production is an urgent issue (Godfray *et al.*, 2010; Diouf, 2011), mainly with increasing concern about the global food security caused by the impacts of abiotic stress on crop plants (Godoy *et al.*, 2021.) (Silva and Santos, 2023). Cowpea (*Vigna unguiculata (L.) Walp*) is a very important crop with high nutritional value (Akibode and Maredia, 2012).

Cowpea is known as “Bbo”, “Gobe”, “likotee” with wide global importance and distribution, mainly in tropical regions (Cavalcante *et al.*, 2016). Nigeria is a leading producer of cowpea in the world (Herniter *et al.*, 2020), while Brazil is the third largest producer (Freitas *et al.*, 2022). This grain legume is considered an essential component of the basic basket in Africa, and in the north and northeast of Brazil (Honaiser *et al.*, 2022). This crop also plays a fundamental role because of its high tolerance to abiotic stress, such as water deficit and low demand for agricultural inputs (Melo *et al.*, 2022). Other studies have also stood out cowpea as a rustic crop, which can grow in poor soils and with low organic matter content, and also is quite tolerant to drought and heat conditions (Melo *et al.*, 1996; Correa *et al.*, 2012). Despite its relevance to agriculture in the developing world and its resilience to stress, studies on cowpea are relatively scarce (Carvalho *et al.*, 2017).

According to (Epstein and Bloom 2006), the appropriate supply of macro- and micronutrients is essential to ensure the successful growth and development of cultivated plants. In controlled experiments, the hydroponic technique has been largely used as a scientific tool for understanding the role of the concentration of these nutrients and their effects on plant growth and physiology. For instance, low concentrations can result in reduced growth and nutritional deficiency, whilst very high concentrations can lead to physiological disturbance, such as stress by water loss i.e. wilting and leaf burn (Cometti *et al.*, 2008).

It is pointed out that excess nutrients decrease the profitability of agricultural activity due to chemical fertilizer high-costs. Moreover, there is a growing concern about the environmental impacts of such chemical amounts resulting from agricultural practices, especially N and P (Hobbie *et al.*, 2017), which also increases the need for optimizing crop input use efficiency. Because of this, there is a great demand for crop plants with low demand for agricultural inputs and with high resilience to abiotic stress (Nieves-cordones *et al.*, 2020).

Cowpea (*Vigna unguiculata L. Walp*) is a warm seasonal annual herbaceous legume belonging to the family Fabaceae and sub family Papilionaceae (Davis *et al.*, 1991). It serves as a cheap source of protein for most people in many developing countries where per capital income and intake of animal protein are both very low (Okigbo, 1976). Cowpea contains 200 – 300g crude protein and 600g of carbohydrate per kilogram (kg) seed. The chemical composition is influenced by environmental and genetic factors (Singh, *et al.*, 2006).

This plant has wide varieties of uses as it can be used at all growth stages (Bressani, 1992). Despite cowpea's great importance, the seed yield of cowpea is low, around 300kg/ha due to the environments, where it is produced which is characterized by various abiotic and biotic stresses.

A cost and time effective screening protocol for cowpea will enhance and expedite research on cowpea by breeders thereby enhancing the production of good quality cowpea which in turn contributes to its availability in meeting demand. In this context, hydroponics is a major scientific modelling tool, facilitating precise control over the treatment and consistent observations of treatment effects. In order to perform such assays whilst providing a flexible experimental platform for manipulation of both the shoot and root environment, the use of hydroponics for research purposes has become common (Gregorio *et al.*, 1997).

Importantly, hydroponics enables observations to be made of intra- and inter-specific genetic variation in plant responses. Hydroponics, the 'water culture' of plants, has been used in both research and commercial contexts since the 18th century. Although now used successfully on a large scale by commercial growers of fast-growing horticultural crops such as lettuce, strawberries, tomatoes, and carnations. Hydroponics was initially developed as a part of early research into plant nutrition.

The use of hydroponics enabled plant scientists to identify which elements were essential to plants, in what ionic forms, and what the optimal concentrations of these elements were. It allowed them to easily observe the effects of elemental deficiencies and toxicities and to study other aspects of plant development under more controlled (temperature- and light-controlled glasshouses) conditions (Yuri *et al.*, 2012).

Hydroponics has been instrumental in establishing the essentiality of most of the mineral nutrients required by plants (Jones, 1982; Reed, 1942), from the early development of nutrient solution recipes in the 1860's by the German scientists Sachs and Knop (Hershey, 1994), through to when nickel was confirmed as an essential micronutrient for higher plants (Brown *et al.*, 1987).

It is particularly useful in identifying visual symptoms or critical deficiency concentrations for diagnostic purposes, characterizing physiological functions of mineral nutrients, determining their uptake kinetics, studying root exudates and gene expression changes and also changes in root morphological traits in response to nutrient deficiencies. It is also commonly used to identify germplasm with enhanced nutrient use efficiency (that is, an ability to produce greater biomass at limited nutrient supply) for breeding programs.

1.2. Hydroponics system

Hydroponic growth systems are a convenient platform for studying whole plant physiology. Major yield loss in cowpea (*Vigna unguiculata*) can be attributed to biotic and abiotic stresses. A cost effective and time saving

screening protocol for cowpea abiotic stresses will enhance and expedite research on cowpea by breeders thereby enhancing its production and availability to meet increasing demand and population rise (Aliyu, 2016)

Hydroponics is a versatile technique that may be used for everything from small-scale village production systems to high-tech space stations. Hydroponic technology has the potential to be a cost-effective means of producing food from harsh natural habitats such as deserts, hilly regions, and polar populations. Hydroponics can produce locally grown high-value crops such as green vegetables and cut flowers in densely inhabited areas.

Hydroponics' prospects may increase if governments develop public policies that encourage subsidies for such production systems. Aside from economic benefits, hydroponics implies water conservation, energy cogeneration, income-generating jobs, lowering the impact on welfare rolls, and enhancing quality of life. (Trejo-Téllez and Gómez-Merino 2012).

A nutrient solution for hydroponic systems is an aqueous solution comprising primarily inorganic ions from soluble salts of necessary elements for higher plants. (Steiner, 1968). An essential element serves a specific physiological function, and its absence disrupts the entire plant life cycle (Taiz and Zeiger, 1998). Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, Sulphur, iron, copper, zinc, manganese, molybdenum, boron, chlorine, and nickel are currently considered essential for most plants. (Salisbury and Ross, 1994).

The essential components are received from the growth media, with the exception of carbon (C) and oxygen (O), which are provided from the atmosphere. Other elements considered beneficial include sodium, silicon, vanadium, selenium, cobalt, aluminum, and iodine, among others, because some of them can stimulate growth, compensate for the toxic effects of other elements, or replace essential nutrients in a less specific role (Trejo-Téllez *et al.*, 2007). The most fundamental nutrient solutions contain simply nitrogen, phosphorus, potassium, calcium, magnesium, and Sulphur, and are supplemented with micronutrients.

The nutrient solution is the basic component of a hydroponic system.

The ability to adjust nutrient solution concentration, also known as electrical conductivity or osmotic pressure, enables the cultivation of a wide range of species. Furthermore, the fundamental advantage of soilless culture is the precise regulation of nutrient input to the plant. Furthermore, controlling pH and root temperature, among other things, leads to increased production and quality.

From literature sea water contains 35g/L of salt therefore when we mix 35g of sea salt in a liter of water we come up with sea water. And several literatures show that sea water is salty because of the salt at the bottom of the ocean (MacIntyre, 1970). Sea water/sea salt contains calcium, potassium, magnesium, chloride, sodium, sulphates and other many trace elements. (Millero, 1974).

1.3. Solutions used in hydroponic systems

Crop production systems should reduce nitrogen application costs and assure that the appropriate form of nitrogen is used. Nitrogen is a constituent of many plant cell components, including amino acids and nucleic acids. Therefore, nitrogen deficiency restricts the growth of the vegetative organs (Barker and Breyson, 2006). It is available in various inorganic forms such as nitrate, ammonium, and nitrogen molecules, and organic forms such as urea and amino acids, which can be changed to forms available for absorption by the plant (Marschner, 1995). Ammonium (NH_4^+) and nitrate (NO_3^-) are used as nitrogen source for the plant, although the plant response to a specific form of nitrogen varies from species to species (Britto and Krounzucker, 2002). At high concentrations, NH_4^+ toxicity can often be occurred for different species (Britto and Krounzucker, 2002; Roosta *et al.*, 2009)

Most plants can make use of either ammonium or nitrate ions. The uptake of these two forms of nitrogen (N) is controlled by genotype, plant development and physiological status, and also by soil properties such as texture, structure, water content and pH (Lea and Morot-Gaudry, 2001, Loulakakis and Roubelakis-Angelakis, 2001). Plant growth and development have long been known to benefit from the presence of NO_3^- . However, despite the fact that NO_3^- assimilation consumes more energy than NH_4^+ assimilation, only few species perform well when NH_4^+ is the sole source (Marschner, 1995). Indeed, many plant species develop symptoms of toxicity when subjected to high concentrations of NH_4^+ , which are not detected when plants are grown with

the same concentration of NO_3^- or in mixed N nutrition (Britto *et al.*, 2001a, Britto *et al.*, 2001b, Britto and Kronzucker, 2002). Although NH_4^+ is an important intermediate in many metabolic reactions, it has been reported that high concentrations of NH_4^+ in the soil or the nutrient solution may lead to leaf chlorosis, net photosynthesis decrease, lower plant yield, lower cation content, changes of several metabolite levels such as amino acids or organic acids and acidification of the rhizosphere (Britto and Kronzucker, 2002)

Nitrogen is a key mineral ingredient that influences plant growth and agricultural productivity. Its benefits are linked to increased leaf area and photosynthetic rate (Pinheiro and Marcellis, 2000; Pons and Westbeek, 2004). Several species have shown linear associations between canopy nitrogen concentration (in g m^{-2}) and leaf area index (LAI) in early developing stages (Yin *et al.*, 2003).

Nutrient solutions with high N concentrations and low electrical conductivity were utilised as a strategy to maximise leaf growth and crop output in hydroponically horticultural production.

Because of its toxicity, plants can only take a limited amount of nitrogen from NH_4^+ (Salsac *et al.*, 1987). Nonetheless, in hydroponically horticultural crop production, a portion of the total N is supplied as NH_4^+ to better manage the pH of the nutrient solution.

Plant tolerance to NH_4^+ varies according to species, environmental conditions, and plant stage development (Castro, 1999; Kotsiras *et al.*, 2002).

From literature sea water contains 35g/L of salt therefore when we mix 35g of sea salt in a liter of water we come up with sea water. And several literatures show that sea water is salty because of the salt at the bottom of the ocean (MacIntyre, 1970). Sea water/sea salt contains calcium, potassium, magnesium, chloride, sodium, sulphates and other many trace elements. (Millero, 1974).

Therefore, the development of research on cowpea growth is important in contributing to optimizing nutrient-use efficiency and increasing food production and nutritional security. In this context, this study aims to evaluate the germination, growth performance of cow pea in different nutrient solutions.

1.4. Problem statement

So many studies have been made about *Vigna unguiculata L. Walp* but the problem of low yield is still persistent and its mostly associated with abiotic and biotic factors which contribute to most of the low yield. According to FAO STAT (2016), about 6,991,174 tones of dry cowpea grains are produced annually worldwide on about 12,316,878 ha. Despite the importance of cowpea, its productivity in typical Sub Sahara Africa farmers' fields is very low, at less than 600 kg/ha compared with a potential grain yield of over 2000 kg/ha (Boukar *et al.*, 2016).

This is partly due to the use of unimproved varieties, inadequate application of inputs, and poor agronomic practices during crop production. Furthermore, cowpea production is constrained by many biotic and abiotic factors, including low soil fertility and a wide range of factors such as insects, diseases,

parasitic weeds, and unavailability of improved seeds (Huynh *et al.*, 2016; Bolarinwa *et al.*, 2021; Rugare *et al.*, 2013)

According to (Haggag *et al.*, 2015) drought and soil salinity are major abiotic stress factors affecting crop production and food safety. In addition, drought and high temperatures are identified as key stress factors that the researcher should emphasize more about the effects of climate change on plants

Cowpea is a low-cost source of protein and energy for many poor people in the tropical world. Its high protein and carbohydrate content, combined with its low-fat content, complement amino acid requirements (Jayathilake *et al.* 2018) Due to the increasing population (FAO, 2017). More studies have to be done to come up with better ways to increase production to meet the demand of the increasing population. Due to the changing climate and resource scarcity like water, more advanced technologies and forms of farming like hydroponic are a solution to the abiotic factors and water scarcity problems affecting soil grown *Vigna unguiculata L. Walp.*

Very little research has been made in this area and more studies about hydroponic solutions that support proper growth of *Vigna unguiculata L. Walp* are needed to maximize production.

Since different plants have different preferences when it comes to nitrogen form, it's critical to identify the best form of nitrogen for each plant in order to minimize the cost of nitrogen fertilizer and to identify the form that will maximize cowpea germination and growth.

Cowpeas require a variety of macro and micronutrients, including K and P, Mg, Ca, Sulphur, Na, Fe, Zn, Cu, Mn, and B, in addition to nitrogen.

All of these trace elements are present in most typical hydroponic solutions. However, these hydroponic solutions are not accessible to all people mostly in developing countries. The majority of inorganic fertilisers do not contain all of these micronutrients in one and are not readily available on the market. Because sea salt contains several of these essential macronutrients, it is reasonably priced, and some studies like (Sakamoto *et al.*, 2014) indicates that the fresh weight of lettuce grown in culture with NaCl was dramatically reduced when compared to those grown in standard culture or culture with seawater. The lettuces grown in the culture with NaCl or seawater contained higher amounts of sugar and anthocyanin, and the lettuce plants grown in the culture with seawater accumulated highest levels of photosynthetic pigments, chlorophylls and carotenoids, its important to study if it can be a useful replacement for some micro and micro nutrients that are not easily available on the market.

The aim of this study was to find out the best form of nitrogen for hydroponically grown cowpea and also if sea salt can replace some macro and micro nutrients in a hydroponic system without having salinity effect on the plant.

1.5. Objectives

1.5.1. Main Objective

To evaluate the performance of cowpea (*Vigna unguiculata L. Walp*) in a nutrient solution with different forms of nitrogen in dilute sea salt

1.5.2. Specific objectives

- I. To determine effects of in a nutrient solution with different forms of nitrogen in dilute sea on the germination of *Vigna unguiculata L. Walp*
- II. To determine effects of in a nutrient solution with different forms of nitrogen in dilute sea salt on the growth of *Vigna unguiculata L. Walp*

1.6. Hypothesis.

- I. Hydroponic solutions with different forms of nitrogen in dilute sea salt affect the rate of germination of *Vigna unguiculata L. Walp*
- II. Hydroponic solutions with different forms of nitrogen in dilute sea salt affect the growth of *Vigna unguiculata L. Walp*

1.7. Justification and significance of study

However much a lot has been done about improving production of *Vigna unguiculata L. Walp*, it's yield is still low yet it has a potential importance. With this increasing demand for food due to the increasing population, a few studies have been done about growing *Vigna unguiculata L. Walp* in a hydroponic system by (Aliyu, 2016) but there is still a gap and need of study to find out the right combination of nutrients for the best results and alternative sources for some micro and macro nutrients like magnesium, zinc, Iron, boron that are not readily available on the market mostly in developing countries

As the climate is changing and water becoming scarce, more people are adapting to growing in hydroponic systems, this study is important in providing an alternative source of macro and micro nutrients and also present the best combination of nutrients for growth of cowpea.

Growing cow pea in hydroponics is associated with advantages like

Use very little water than soil-based farming, making it critical in areas prone to water scarcity hence saving up to 90% water

Reduced risks of soil-borne pests and diseases by eliminating soil.

They can be designed for vertical farming and small, urban spaces, maximizing land use.

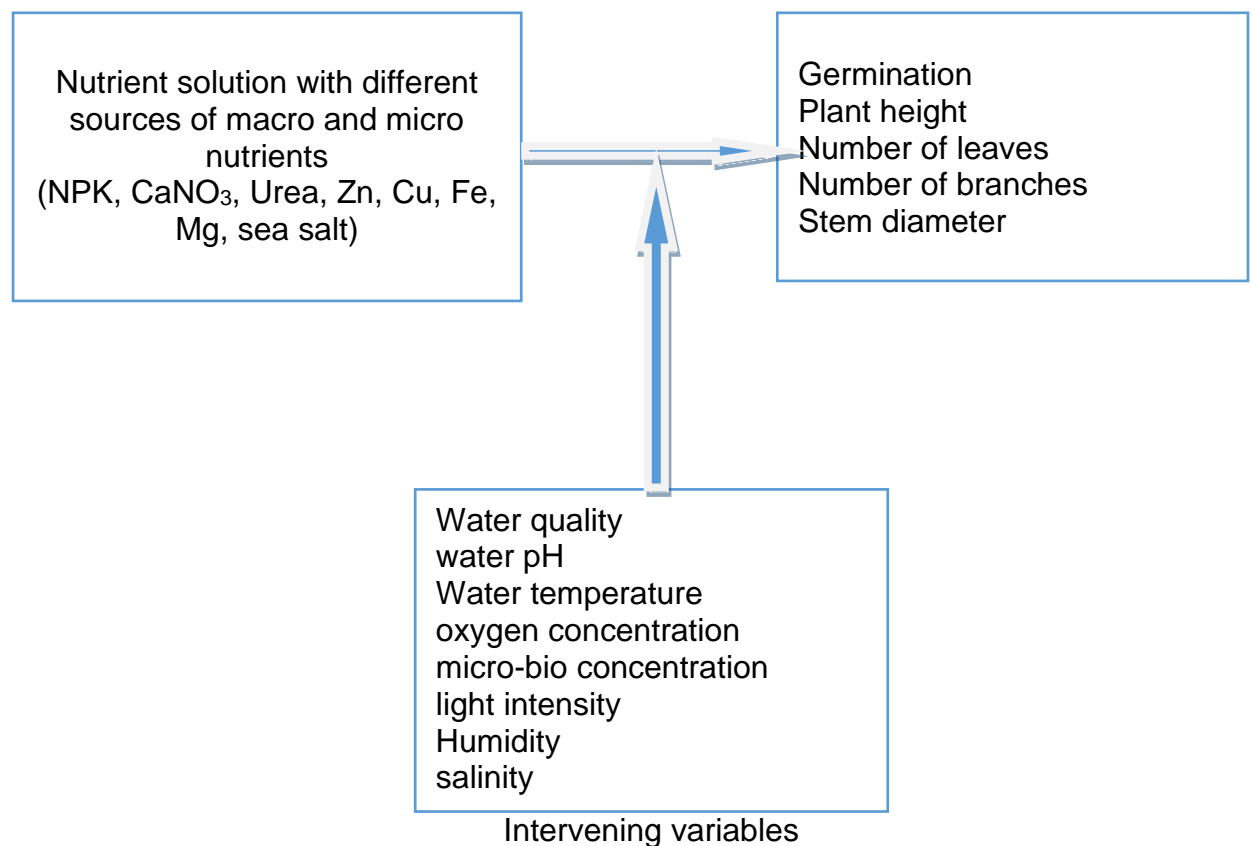
They can operate all year and are less dependent on weather conditions.

They ensure fast growth of vegetables of the same size and quality.

1.8. Conceptual frame work

Independent variables

Dependent variables



CHAPTER TWO

2.0. General Literature Review

Soil is usually the most available growing medium for plants. It provides anchorage, nutrients, air, water etc. for plant growth (Ellis *et al.*, 1974).

However, soils do pose serious limitations for plant growth too, at times.

Some of them are presence of disease-causing organisms and nematodes, unsuitable soil reaction, unfavorable soil compaction, poor drainage, degradation due to erosion etc. (Beibel, 1960). In addition, Open Field agriculture is difficult as it involves large space, lot of labor and large volume of water (Beibel, 1960). In most urban and industrial areas, soil is less available for crop growing, or in some areas, there is scarcity of fertile cultivable arable lands due to their unfavorable geographical or topographical conditions (Beibel, 1960). Other serious problem experienced is to hire labor at regular times for conventional open field agriculture (Butler and Oebker, 2006).

Under such circumstances, soil-less culture can be introduced successfully (Butler and Oebker, 2006). Soilless culture is the technique of growing plants in soil-less condition with their roots immersed in nutrient solution (Maharana and Koul, 2004). Soilless culture systems of cultivation can be classified according to the techniques employed. It supplies fresh vegetables in countries with limited arable land as well as in small countries with large populations. It could be useful to provide sufficient fresh vegetables for the indigenous population as well as for tourists in countries where tourism plays a vital role in their economy. Typical examples of such regions are the West

Indies and Hawaii, which each have a large tourist industry and very little farmland for vegetable production (Resh, 1993).

In soilless culture some cultural practices like soil cultivation and weed control are avoided, and land not suitable for soil cultivation can be used (Polycarpou *et al.*, 2005). Plants grown by hydroponics had consistently superior quality, high yield, rapid harvest, and high nutrient content

Today's climate change and scarcity of good quality water are becoming increasingly severe worldwide (DeWrachien and Goli, 2015). Hydroponic farming is currently gaining popularity around the world because to effective resource management and high-quality food production. Soil-based agriculture is being confronted with a number of issues, including urbanization, natural disasters, climate change, and the indiscriminate use of herbicides and pesticides, which is reducing land fertility.

Soilless culture could be applied to growing some popular local crops with the application of food safety standards and at a reasonable price (Paul, 2000). This system will also help to face the challenges of climate change and also helps in production system management for efficient utilization of natural resources and mitigating malnutrition (Butler and Oebker, 2006).

Soilless culture can provide important requirements for plant growth with equal growth and yield results compared to field soil. Terrestrial plants may be grown with their roots in the mineral nutrient solution only or in an inert medium. When the mineral nutrients in the soil dissolve in water, plant roots are able to absorb them.

When the required mineral nutrients are introduced into a plant's water supply artificially, soil is no longer required for the plant to thrive. The simplest and oldest method for soilless culture is a vessel of water in which inorganic chemicals are dissolved to supply the nutrients that plants require. Various modifications of pure-solution culture have occurred in the past. The retention of nutrients and water can be further improved through the use of sphagnum peat, vermiculite, or bark chips. These are the most commonly used materials, but others such as rice hulls, bagasse (sugarcane refuse), sedge peat, and sawdust are used sometimes as constituents in soilless mixes. Straw bales have been used as growing medium in England and Canada and rockwool (porous stone fiber) is used in Europe.

There are several types of hydroponic structures, including wick, ebb and flow, drip, deep water culture, and the Nutrient Film Technique (NFT) method. Several advantages of this technology include shorter crop growing times than conventional growing, year-round output, low disease and pest incidence, and the elimination of weeding, spraying, and watering.

The Netherlands, Australia, France, England, Israel, Canada, and the United States are the world leaders in hydroponic technology. It is critical to develop low-cost techniques for the successful adoption of commercial hydroponic technology. (Sharma *et al.*, 2018)

2.1. Origin, Distribution, Taxonomy and Morphological Description of the Crop

Cowpea (*Vigna unguiculata* L. Walp.; $2n = 2x = 22$) is an annual self-pollinated diploid and has been classified as the most economically significant indigenous African legume crop. (Moussa *et al.*, 2011) According to (Boukar *et al.*, 2018) cowpea is grown predominantly in the dry savannahs to the Sahel in the fringes of the Sahara Desert, where the annual rainfall is around 300 mm or less annually. Cowpea can grow under harsh environmental conditions where other major crops fail to grow (Pereira *et al.*, 2020). In addition, one of the significant importance to the ecology is the ability to fix atmospheric nitrogen in marginal soils where farmers have no access to agricultural inputs such as fertilizers or manure (Rivas *et al.*, 2016; Timko *et al.*, 2008)

According to FAO STAT (2016), about 6,991,174 tones of dry cowpea grains are produced annually worldwide on about 12,316,878 ha. Despite the importance of cowpea, its productivity in typical Sub Sahara Africa farmers' fields is very low, at less than 600 kg/ha compared with a potential grain yield of over 2000 kg/ha (Boukar *et al.*, 2016).

This is partly due to the use of unimproved varieties, inadequate application of inputs, and poor agronomic practices during crop production. Furthermore, cowpea production is constrained by many biotic and abiotic factors, including low soil fertility and a wide range of factors such as insects, diseases, parasitic weeds, and unavailability of improved seeds (Huynh *et al.*, 2016; Bolarinwa *et al.*, 2021; Rugare *et al.*, 2013)

According to (Haggag *et al.*, 2015) drought and soil salinity are major abiotic stress factors affecting crop production and food safety. In addition, drought and high temperatures are identified as key stress factors that the researcher should emphasize more about the effects of climate change on plants. Plant breeders and biotechnologists have been studying and trying to acquire knowledge and tools, to tackle challenges posed by climate change. The challenge in many is to produce sufficient food for the escalating population growth with limited water supplies and breeding for drought tolerance and water use efficiency (Huynh *et al.*, 2016; Horn *et al.*, 2015)

Water scarcity causes a significant reduction in agricultural productivity and can lead to total crop failure or reduce yield below 360 kg·ha⁻¹. In addition, water deficit reduces leaf area index, chlorophyll content, number of pods per plant, and seed yield in cowpea (Bailey *et al.*, 1990). Even though cowpea is regarded as a drought-tolerant crop and can grow under harsh climatic conditions with limited water, it is also affected by various climatic factors and often lead to low yields (Larweh *et al.*, 2019).

According to (Carvalho *et al.*, 2017), cowpea's growth period can range between 90 to 240 days, but this varies from variety to variety and climatic conditions. (Bastos *et al.*, 2011) reported that well-watered cowpea plants could produce more than 1000 kg grain ha⁻¹, while in Ghana, an average yield of 1.25 metric tons per hectare was observed in farmers' fields (Larweh *et al.*, 2019)

Insect pests are the most important yield-reducing biotic factors in cowpea production worldwide (Sindhu *et al.*, 2019; Togol *et al.*, 2020). The major insect pests of cowpea include aphids (*Aphis craccivora* Koch), flower bud thrips (*Megalourethras* spotted Trybom), pod borer (*Maruca vitrata* Fabricius), and pod sucking bugs (especially *Clavigra llatomentoscollis* Stal, *Riptortus* identifies Fabricius, *Anoplocnemis curvipes* Fabricius, and *Nezara viridula* Linnaeus) (Boukar *et al.*, 2018).

Most of the insect pests affect the crop in the field except storage pests such as weevils that destroy seeds in storage facilities, although infestation may occur while the crop is in the field (Souleymane *et al.*, 2013).

Significant losses due to *Striga gesnerioides* have been reported to range between 83% and 100%, especially in Sub-Saharan Africa (Omoigui *et al.*, 2012). In some parts of Sub-Saharan Africa, such as the northern Guinea savanna of Nigeria and northern Namibia, 100% yield losses on farmer's fields were recorded mainly when susceptible local varieties were used (Horn *et al.*, 2015; Omoigui *et al.*, 2012).

Cowpea contains 200 – 300g crude protein and 600g of carbohydrate per kilogram (kg) seed. The chemical composition is influenced by environmental and genetic factors (Singh, *et al.*, 2006). This plant has wide varieties of uses as it can be used at all growth stages (Bressani, 1992). Despite cowpea's great importance, the seed yield of cowpea is low, around 300kg/ha (Cardoso *et al.*, 1995; Leite *et al.*, 1997) due to the environments, where it is produced which is characterized by various abiotic and biotic stresses. A cost and time

effective screening protocol for cowpea will enhance and expedite research on cowpea by breeders thereby enhancing the production of good quality cowpea which in turn contributes to its availability in meeting demand. In this context, hydroponics is a major scientific modelling tool, facilitating precise control over the treatment and consistent observations of treatment effects. In order to perform such assays whilst providing a flexible experimental platform for manipulation of both the shoot and root environment, the use of hydroponics for research purposes has become common (Gregorio *et al.*, 1997).

Importantly, hydroponics enables observations to be made of intra- and inter-specific genetic variation in plant responses. Hydroponics, the 'water culture' of plants, has been used in both research and commercial contexts since the 18th century. Although now used successfully on a large scale by commercial growers of fast-growing horticultural crops such as lettuce, strawberries, tomatoes, and carnations. Hydroponics was initially developed as a part of early research into plant nutrition.

Growing plants in nutrient solutions (water including fertilizers) with or without the use of an inert medium (sand, gravel, vermiculite, rock wool, perlite, peat moss, coir, or sawdust) to offer mechanical support is referred to as a hydroponic system (Sharma *et al.*, 2018).

A nutrient solution for hydroponic systems is an aqueous solution containing mainly inorganics ions from soluble salts of essential elements for higher plants. Eventually, some organic compounds such as iron chelates may be

present (Steiner, 1968). An essential element has a clear physiological role and its absence prevents the complete plant life cycle (Taiz and Zeiger, 1998). hydroponics is a major scientific modelling tool, facilitating precise control over the treatment and consistent observations of treatment effects. In order to perform such assays whilst providing a flexible experimental platform for manipulation of both the shoot and root environment, the use of hydroponics for research purposes has become common (Gregorio *et al.*, 1997).

The use of hydroponics enabled plant scientists to identify which elements were essential to plants, in what ionic forms, and what the optimal concentrations of these elements were. It allowed them to easily observe the effects of elemental deficiencies and toxicities and to study other aspects of plant development under more controlled (temperature- and light-controlled glasshouses) conditions (Yuri *et al.*, 2012).

2.2. Effects of nutrient solution with different forms of nitrogen in sea salt on the germination and growth of *Vigna unguiculata* L. Walp

A study was done by (Sakamoto *et al.*, 2014) and the effects of salinity and nutrients on the growth of red leaf lettuce (*Lactuca sativa* L. cv. Mother-red)

A closed plant factory with hydroponic cultures supplemented with sodium salt (NaCl) or seawater was employed for cultivation of lettuce. The fresh weight of lettuce grown in culture with NaCl was dramatically reduced when compared to those grown in standard culture or culture with seawater. The lettuces grown in the culture with NaCl or seawater contained higher amounts

of sugar and anthocyanin, and the lettuce plants grown in the culture with seawater accumulated highest levels of photosynthetic pigments, chlorophylls and carotenoids.

These results indicated that the addition of some solutes (e.g. NaCl) to the culture medium affect the size of plant as well as the levels of sugars and pigments in the plant, and suggest that the addition of seawater (20%) to the medium is effective to produce lettuces with higher quality and nutritional value.

(Silva *et al.*, 2013) study shows, using urea in hydroponic systems leads to hydrolysis which, depending on pH conditions, can result in toxic NH_3 liberation in solution. This is one of the reasons why urea is considered to be inappropriate as the sole source of nitrogen in hydroponic cultivation in comparison to a nitrate source (Tan *et al.*, 2000). However, the results obtained in the present study for biomass production and N content show that urea, in the concentration used, besides not inducing nutritional toxicity symptoms, stimulated vegetative growth and potato plant root growth. (Osaki *et al.*, 1995) reported that moderate NH_4^+ concentrations with a controlled-pH nutritive solution prevented solution acidification by proton liberation during N uptake and so, consequently, plant vegetative growth was not affected.

(Ogata, 1963) related that oat plants utilized N- NH_4^+ better than N- NO_3^- in the initial vegetative stage. However, during grain filling, the nitric source becomes more assimilated, suggesting that the effect of N on plant growth varies according to physiological stages. This occurs because, to be

assimilated, nitrate must be reduced in an energy-dependent process after uptake (Mack and Shjoerring 2002).

Of all of the essential mineral nutrients, plants require N in the greatest amounts. Nitrogen is largely taken up by plants in either of two forms: nitrate (NO_3^-) or ammonium (NH_4^+). Small amounts of the free base NH_3 may also move into cells by passive diffusion in parallel with NH_4^+ transport, but at physiological pH the protonated form, NH_4^+ , predominates. Although NO_3^- is normally the most abundant species of inorganic nitrogen in soil, plants can acquire N from the two sources simultaneously using different transport systems. When both forms of N are available in similar quantities, there is often a preference for uptake of NH_4^+ over NO_3^- (Kronzucker et al., 1997; Garnett and Smethurst, 1999; Rocco and Mengel, 2000). This may reflect the lower energy requirement for assimilation of NH_4^+ .

Nitrogen can also be taken up directly in reduced forms, such as amino acids, peptides, purines, or urea (Williams and Miller, 2001). Organic N may be an important source of N in tundra, forests, and other environments where there is a limited supply of inorganic N. Despite its potential importance, very little is presently known about either the mechanism or the control of uptake of organic N. Recently, an active transporter for urea was cloned from *Arabidopsis* (Liu *et al.*, 2003).

From literature sea water contains 35g/L of salt therefore when we mix 35g of sea salt in a liter of water we come up with sea water. And several literatures show that sea water is salty because of the salt at the bottom of the ocean

(MacIntyre., 1970). Sea water/sea salt contains calcium, potassium, magnesium, chloride, sodium, sulphates and other many trace elements.

Some studies of using sea water and salt bittern as a fertilizer to grow solanum are available, there is an issue of salinity when used at a very high concentration but for some varieties of solanum it gives great yield and improved quality of food.

Some studies have shown that salt bitterns gotten after solarization of sea water are used for making commercial fertilizer including Epsom salts. Bittern also has a higher salinity than sea water but it has been used in combination with other fertilizer to grow crops both in soil and in a hydroponic.

Deep sea water (DSW) has the potential characteristics for nutrient supplement in hydroponics cultivation. This experiment was carried out to evaluate the application of DSW as a nutrient supplement for tomato cultivation in hydroponics system by (Chadirin, *et al.*, 2007)

Tomatoes were grown on 4 beds in nutrient film technique (NFT) system circulated with 1.5 ds m⁻¹ (control), 10 ds m⁻¹ 15 ds m⁻¹ and 20 ds m⁻¹ of nutrient solution, respectively. DSW was supplemented into nutrient solution of control to obtain high EC level. Fresh weight of fruits decreased varied from 10-20% by increasing DSW concentration in nutrient solution, but the effect of the treatment was not found on size of 3rd truss fruits. The density of fruits increased as the DSW concentration increased in nutrient solution. Tomato stiffness of treated plants had almost the same value among EC levels although different among 3 trusses. Fruit quality parameters increased by

increasing the DSW concentration in nutrient solution. Treated plants circulated with EC 20 ds m⁻¹ supplemented nutrient solution for 2 weeks produced tomatoes with highest soluble solids, 8.0% Brix or increased 30% of control (1 set truss). However, there were no significant effect on fruits of 2nd and 3rd trusses. DSW could be used as nutrient supplement for hydroponics cultivation of tomato.

A study was done by (Abahri, 2015) on effect of nutrients and salinity on Yields, Growth, and Nutrients distribution of Faba Beans grown in Hydroponics systems.

The objective of this research was to evaluate the effect of two salinity levels (4.68ds/m⁻¹ and 7.8 ds/m⁻¹ NaCl) and three levels of Cooper nutrients solution (100% .25%. 300%) on the growth, yield and nutrient distribution in three Faba Beans cultivars (Baladi, Artasi, and Isbani), were grown in a hydroponics system, the experiment was divided into six group, two group had two salinity levels (4.68ds/m¹ and 7.8 ds/m⁻¹ NaCl), three group had three levels of Cooper nutrients solution (100% .25%. 300%), and the last one contain water only each group contain three lines, in each line one cultivars nutrients solution were supplied to the three cultivars freshly twice a day.

Plants parts were desiccation and burning then turn it to solution in order to use it in analysis instrument. The results indicated that Increasing Cooper concentration increase plant height, leaves area, number of leaves, and number of pods, but decreased root length in the three cultivars .It was found that there is no significant different between (25% and 100%) cooper solution in vegetative growth, while in 300% cooper solution ,there is a significant decrease in vegetative growth in the three cultivars ,but the three cultivars

didn't produce pods, because plants died before reaching the flowering stage. Results show that application of Sodium chloride (4.68ds/m^{-1}) causes reductions in plant height, number of leaves, leaves area, and number of pods, but increasing the root length. While application (7.8 ds/m^{-1}) NaCl cause death in the flowering stage so that plants didn't produce pods. However, there is a decrease in plant height, number of leaves, leaves area, but significantly decrease root length.

There is no significant difference found between (4.68ds/m^{-1} and 7.8 ds/m^{-1} NaCl) in vegetative growth except no of pods and roots length. The result indicates that increased significantly in fresh and dry weight of vegetative growth in the three cultivars, compared to the control, when handled with cooper solutions, where there is no significant difference between 25% and 100% cooper solution. Application 4.68ds/m^{-1} NaCl increased both fresh and dry weights of the shoot, roots, leaves and pods compared to the control, but this increases not significantly

A study was done by (Aliyu, 2016) on Establishing Nutrient Efficient Hydroponic Protocol for Cowpea (*Vigna unguiculata* L. Walp) Evaluations at Seedling Stage. Two nutrient formulations (NFZ1 and NFZ2) and a control were evaluated upon considerations of cowpea (16 varieties) growth requirement on soil. These treatments consisted of variations of the combinations of N-P-K fertilizers, FeSO_4 and ZnSO_4 . Seedling biometrics after 30 days in hydroponics indicated that NFZ2 induced greater seedling performance than NFZ1. This increase in growth rate ranged from 12.83% to 65.24% adopting the NFZ2 protocol in slow and fast-growing varieties,

respectively with an average growth rate of 46.35%. Therefore, this protocol is recommended where fast screening for cowpea is desired in evaluations for breeding purposes

The hydroponic set up was based on Gregorio et al., (1997) recommendations for rice hydroponic protocol with modifications. The equipment (plastic tanks, Styrofoam sheets, wire mesh) were dark colored (except the plastic tanks had an outside dimension of 35 x 29 x 14 cm and contain approximately 8.6 liters of water (Plate 1). The size of tank can be changed to suit local conditions. The support platforms used was a wire mesh of mesh size 0.3cm, glued to fit the bottom of the Styrofoam sheet with a glue gun (plate 2). The Styrofoam sheet (contain 15 circular compartments (4 x 4cm) cut at regular intervals with a spacing of 3cm) can accommodate 15 seed (one seedling per hole) and overlaps the plastic tank.

All nutrient solutions used for hydroponics culture of plants are essentially formulated based on plant growth requirement. The growth solution consisted of the following essential macro-elements: nitrogen (N), potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg) and Sulphur (S); and micro-elements: a soluble form of iron (Fe), zinc (Zn) and chlorine (Cl). Final concentration of elements per liter of distilled water were as follows: (i) 1.5g/L of N-P-K (15-15-15) fertilizer + 0.2g/L of FeSO₄+0.05g/L MgCL₂+0.2g/L ZnSO₄ - (NFZ1), (ii) 1.5g/L of N-P-K (20-10-10) fertilizer + 0.2g/L of FeSO₄ + 0.05g/L MgCL₂+0.2g/L ZnSO₄ - (NFZ2) and (iii) 0.2g/L of FeSO₄ + 1.5g/L Peters 20-20-20 water soluble fertilizer(Control).

CHAPTER THREE

3.0. Study Site

This research was conducted in a greenhouse at Uganda Christian university Mukono (Latitude: 0°21'17.64" Longitude: 32°44'26.52") from 15th Feb 2024 to 15th march 2024.

Mukono, Uganda lies within the Victoria Nile Basin characterized by a variety of fertile soils, Ferralic Cambisols, Chromic Luvisols, Gleysols, Vertisols and are moderately acidic soils with a reddish- or yellowish-brown color. Throughout the year, temperatures remain fairly constant with an average daily maximum temperature ranging from 28°C (82°F) to 30°C (86°F) and an average daily minimum temperature of 18°C (64°F)

Mukono experiences a tropical savanna climate with distinct wet and dry seasons. The wet season lasts from March to May and from September to November. It is characterized by frequent heavy rainfall; The dry season occurs from December to February and June to August. It receives little to no rainfall.

3.1. Materials and methods

3.1.1. Plant Materials

The variety that was used is Ebelat and this was chosen basing on the study conducted in eastern Uganda, assessed consumer and market vendors preferences for different cowpea varieties grown in Uganda. Both consumers and market vendors preferred large white seeded grains which is the Ebelat variety and its readily available on the market. (Mundua *et al.*, 2010)

3.1.2. Hydroponic Setup

The hydroponic setup was based, with modifications, on the suggestions for the rice hydroponic methodology published by Gregorio et al. in 1997. The tools (plastic bucket, wood shavings, plastic mesh): the plastic bucket is 30 x 30 x 50 cm on the exterior and holds around 8 liters of water. The bucket's top is covered with 0.2 cm-sized plastic mesh. Six (4 x 4 cm) compartments cut at regular intervals with 3 cm between each can hold six seeds (one seedling per hole) in the plastic mesh. Aliyu 2016

The purpose of the plastic mesh and wood shavings in the bucket was to retain the seed and seedling.

The seeds were planted directly in each compartment, three in each compartment after germination, some seedlings were thinned out to remain with 6 seedlings. Farouk and Amany, (2012)

The experiment had six treatments prepared on the same day and each treatment has represents a different nutrient solution

3.1.3. Nutrient solution preparation

Solution A containing (different percentages of nitrogen from different sources and same percentages potassium and phosphorous) i.e.

Solution A¹(N, P, K) Nitrogen present in form of nitrogen ions in solution with a major source as NPK fertilizer, (1.5g/L of NPK)

Solution A² (CaNO₃), Nitrogen in solution present in form of nitrate ions and the main source being calcium nitrate (1.5g/L CaNO₃ and 1.5g/L NPK)

Solution A³ (CO(NH₂)₂), Nitrogen in solution present in form of ammonia ions and free nitrogen ions the main source being Urea fertilizer (1.5g/L Urea and 1.5g/L NPK).

Solution B (37%Fe, 20.19%Mg, 36.5%Zn) from Iron(ii)sulphate as a source of iron, magnesium sulphate and magnesium chloride as a source of magnesium ions, Zinc(ii)sulphate as a source zinc ion (0.2g/LFeSO₄ +0.05g/L MgSO₄ +0.2g/L ZnSO₄)

Solution C (sodium chloride 77.76%, magnesium chloride 10.88%, Calcium Carbonate 0.3%, magnesium sulfate 4.74 %, calcium sulfate 3.60 %, potassium chloride 2.46%, magnesium bromide 0.22%) the major source is sea salt (Phibunwatthanawong and Riddech, 2019)

Therefore, each treatment has a different combination of nutrient solutions: T1 (Solution A² + Solution B), T2 (Solution A³ + Solution B). T3 (Solution A² + Solution C), T 4(Solution A³ + Solution C), T5(Solution A¹+ Solution C), T 6(Solution A¹+ Solution B) (Aliyu, 2016) T 6 is the control experiment.

3.2. Experimental set up

The experiment was set up in a completely randomized design with each treatment having three replications each and each treatment represents a different nutrient solution as shown below.

Treatment 1	Treatment 3	Treatment 2
Treatment 2	Treatment 4	Treatment 3
Treatment 3	Treatment 6	Treatment 5
Treatment 4	Treatment 5	Treatment 6

Treatment 5	Treatment 1	Treatment 4
Treatment 6	Treatment 2	Treatment 1

Figure 1 Experimental design



Figure 2 Experimental set up

For each treatment different parameters were studied on each plant which was randomly selected and the parameters included germination parameters and growth parameters

3.3. Data collection

3.3.1. Sample size and sampling method.

Data was collected on six plants per replication and the plants were randomly selected and data was collected on each plant.

3.3.2. Data collection schedule

Seeds are considered germinated when they exhibited radicle extension of > 3 mm. Every 24 hours after soaking, germinated seeds were counted daily in each treatment during the course of four days to determine following germination parameters. (Mfeka, Mulidzi, and Lewu. 2019)

Where the number of germinated seeds was recorded 6 days after planting

Growth parameter was recorded after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

3.3.3. Germination parameters

Final Germination Percentage (FGP) according to ISIA 1993 and ISIA 1999

where $FGP = Ng / Nt \times 100$,

Ng = Total number of germinated seeds,

Nt = Total number of seeds evaluated.

Mean Germination Time (MGT).

Mean germination time (MGT) is calculated by using the equation:

$$MGT = \sum (n \times d) / N,$$

where n = number of seeds germinated on each day,

d = number of days from the beginning of the test, and

N = total number of seeds germinated at the termination of the experiment (Ellis and Roberts, 1981).

The Germination Index (GI) was calculated as described in the Association of Official Seeds Analysts (AOSA) 1983 by following formula:

$GI = \text{no. of germinated seed} / \text{Days of first count} + \dots + \text{no. of germinated seed} / \text{Days of final count}.$

3.3.4. Growth Parameters

During all the experiments the following were measured; the plant height, the number of leaves of the cow pea plant, stem diameter, the leaf length and width.

Plant height. For plant height a ruler was used and height was measured in cm after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

Stem diameter. The diameter of the plant was measured using a thread and a meter rule and recorded in cm after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

Leaf number. Number of leaves was counted after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

Number of branches. Number of branches was counted after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

Leaf length and width. Leaf length and width was measured using a ruler in cm after two weeks of germination for each replication of every treatment and repeated after every one week for three weeks.

3.4. Data analysis

Data was entered in MS Excel, cleaned and exported in Gensart 12, analyzed, means, standard deviation, coefficient of variation were generated

Analysis of variance (ANOVA) was calculated and significant mean values were compared using Duncan multiple range test at 5% significance level.

CHAPTER FOUR

4.0. Results and discussion

4.1. Effects of nutrient solution with different forms of nitrogen in sea salt on the germination of *Vigna unguiculata* L. Walp

The effect of the different nutrient solutions was evaluated through performance of agronomic and yield traits such as germination, stem girth, height, number of leaves, number of branches, leaf area. The results obtained in this study are presented and discussed in detail in the following subsections. Table 1 shows the results for Mean effect of different nutrient solutions on germination of cow pea after four days of germination. The results of the study showed that different treatments affect the germination of cow pea. Plants in T2, T3 and T5 recorded higher value of Germination Index (GI), Final Germination Percentage (FGP), Number of germinated seed and a lower Mean Germination Time (MGT) than the control (T6). Plants in T1 and T4 recorded lower value of Germination Index (GI), Final Germination Percentage (FGP), Number of germinated seed and a higher Mean Germination Time (MGT) than the control (T6)

The highest Germination Index (GI) of 12.95 ± 0.603 was recorded for T3 followed by 10.96 ± 0.262 for T5, followed by 10.8 ± 0.558 for T2. The least Germination Index (GI) was noticed more at 9.522 ± 0.296 for T1 and the lowest at 8.972 ± 0.962 for T4.

The highest Final Germination Percentage (FGP) of 98.15 ± 3.208 was recorded for T3 followed by 88.89 ± 5.556 for T5 and T2. The least Final Germination Percentage (FGP) was noticed more at 68.52 ± 3.208 for T1 and the lowest at 64.81 ± 11.56 for T4.

The lowest Mean Germination Time (MGT) of 15.04 ± 0.260 was recorded for treatment 5 followed by 15.15 ± 0.233 for T2, followed by 15.85 ± 0.234 for T3.

The highest Mean Germination Time (MGT) was noticed more at 16.37 ± 0.725 for T1 and the highest at 16.46 ± 0.991 for T4.

The Highest Number of germinated seed of 17.67 ± 0.577 was recorded for T3 followed by 16 ± 1 for T2, followed by 16 ± 0 for T5. The lower Number of germinated seed was noticed more at 12.33 ± 0.577 for T1 and the lowest at 11.67 ± 2.082 for T4.

These results can be explained by the presence of sea salt as an alternative for some macro and micro nutrients (chloride (Cl^-), sodium (Na^+), sulfate (SO_4^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}), and potassium (K^+) that are favorable for germination and the increased electrical conductivity of the nutrient solution due to presence of sea salt containing several ions

Table 1: Mean effect of nutrient solution with different forms of nitrogen in sea salt on germination of cow pea.

Treatments	Germination Index (GI) Mean \pm SD	Final Germination Percentage (FGP) Mean \pm SD	Mean Germination Time (MGT) Mean \pm SD	Number of germinated seed Mean \pm SD
T1(Soln A ² +SolnB)	9.52 ± 0.296	68.52 ± 3.208^a	16.37 ± 0.725	12.33 ± 0.577
T2(Soln A ³ + Soln B)	10.80 ± 0.558	88.89 ± 5.556^{bc}	15.15 ± 0.233	16.00 ± 1.000
T3(Soln A ² +Soln C)	12.95 ± 0.603	98.15 ± 3.208^c	15.85 ± 0.234	17.67 ± 0.577
T4(Soln A ³ + Soln C)	8.97 ± 0.962	64.81 ± 11.560^a	16.46 ± 0.991	11.67 ± 2.082
T5(Soln A ¹ + Soln C)	10.96 ± 0.262	88.89 ± 5.556^{bc}	15.04 ± 0.260	16.00 ± 0.000
Control	9.90 ± 1.723	75.93 ± 17.860^{ab}	15.83 ± 0.503	13.67 ± 3.215
Mean	10.52	80.86	15.79	14.56
s.e.d	7.251	7.251	7.251	7.251
F.pr	0.006	0.006	0.006	0.006
l.s.d ($\alpha=0.05$)	16.157	16.157	16.157	16.157
c.v %	11.0	11.0	11.0	11.0

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

4.1.1. Effects of nutrient solution with different forms of nitrogen in sea salt on the growth of *Vigna unguiculata* L. Walp

Tables showing the results for Mean effect of different nutrient solutions on growth of cow pea in from week 1 to week 3. The results of the study showed that different treatments affect the number of leaves, number of branches, plant height, stem diameter, leaf length and width of cow pea.

Table 2: Mean effect of nutrient solution with different forms of nitrogen in sea salt on number of leaves

Treatment	Number of leaves week 1	Number of leaves Week 2	Number of leaves Week 3
T1(Soln A ² +SolnB)	3.67±1.219 ^c	5.33±0.478 ^c	9.50±1.521 ^d
T2(Soln A ³ + Soln B)	3.50±1.134 ^c	5.17±0.378 ^c	6.44± 0.843 ^b
T3(Soln A ² +Soln C)	5.28±0.944 ^d	8.00± 0.000 ^d	12.00± 1.434 ^e
T4(Soln A ³ + Soln C)	2.00±0.000 ^a	2.00± 0.000 ^a	2.00 ±0.000 ^a
T5(Soln A ¹ + Soln C)	5.39±0.494 ^d	8.00± 0.000 ^d	12.00± 1.434 ^e
Control	2.83±1.028 ^b	3.89±1.545 ^b	8.50± 2.091 ^c
Mean	3.778	5.398	8.407
s.e.d	0.2125	0.1598	0.3121
F.pr	<.001	<.001	<.001
l.s.d (α=0.05)	0.4188	0.3151	0.6151
c.v %	23.9	12.6	15.7

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

In week 1, the highest mean number leaves of 5.389±0.494 was recorded for T5 followed by 5.278±0.944 for T3, followed by 3.667±1.219 for T1, then 3.5±1.134 for T2, The lowest mean number of leaves recorded of 2±0 for T4 which was lower than T6 (control experiment)

Table 3: Mean effect of nutrient solution with different forms of nitrogen in sea salt on number of branches

Treatment	Number of branches week 1	of Number of branches Week 2	of Number of branches Week 3
T1(Soln A ² +SolnB)	0.06±0.232 ^b	1.28 ± 0.454 ^c	2.39 ±0.688 ^d
T2(Soln A ³ + Soln B)	0.00± 0.000 ^a	1.17± 0.378 ^c	1.56 ±0.607 ^b
T3(Soln A ² +Soln C)	1.00± 0.000 ^c	2.00 ±0.000 ^d	3.33± 0.478 ^e
T4(Soln A ³ + Soln C)	0.00± 0.000 ^a	0.00 ±0.000 ^a	0.00± 0.000 ^a
T5(Soln A ¹ + Soln C)	1.00 ±0.000 ^c	2.00± 0.000 ^d	3.33± 0.478 ^e
Control	0.00 ±0.00 ^a	0.61± 0.688 ^b	2.06 ± 0.791 ^c
Mean	0.3426	1.176	2.111
s.e.d	0.02224	0.0869	0.1216
F.pr	<.001	<.001	<.001
l.s.d (α=0.05)	0.04384	0.1714	0.2397
c.v %	27.5	31.4	24.4

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

The highest mean number branches of 1 ± 0 was recorded for T3 and treatment 5 followed by 0.0556 ± 0.232 for T1 and for mean number of branches of 0 ± 0 was the same for T2, T4 and the control experiment.

Table 4: Mean effect of nutrient solution with different forms of nitrogen in sea salt on plant height

Treatment	Plant height week 1	Plant height Week 2	Plant height Week 3
T1(Soln A ² +SolnB)	8.71±0.715 ^b	10.58±0.589 ^b	15.44 ± 2.583 ^d
T2(SolnA ³ +SolnB)	9.17±0.746 ^c	11.13±1.066 ^c	12.13± 1.159 ^b
T3(SolnA ² +SolnC)	11.28±1.163 ^d	16.77±1.166 ^d	21.25± 1.565 ^f
T4(SolnA ³ +SolnC)	7.29±0.856 ^a	7.63±0.931 ^a	7.68±0.950 ^a
T5(SolnA ¹ +SolnC)	11.24±0.887 ^d	17.03±1.127 ^d	19.79± 1.505 ^e
Control	9.039±0.827 ^{bc}	10.71±1.301 ^{bc}	14.26 ±2.365 ^c
Mean	9.455	12.309	15.09
s.e.d	0.2079	0.2496	0.418
F.pr	<.001	<.001	<.001
l.s.d (α=0.05)	0.4098	0.4921	0.824
c.v %	9.3	8.6	11.7

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

The highest mean plant height of 21.25 ± 1.565^f was recorded for T3 followed by 19.79 ± 1.505^e for T5, followed by 15.44 ± 2.583^d for T1, The lowest mean plant height recorded of 7.68 ± 0.950^a for T4.

Table 5; Mean effect of nutrient solution with different forms of nitrogen in sea salt on stem diameter

Treatment	Stem diameter week 1	Stem diameter Week 2	Stem diameter Week 3
T1(Soln A ² +SolnB)	0.50±0.059 ^a	1.11± 0.109 ^b	1.41 ± 0.277 ^b
T2(Soln A ³ + Soln B)	0.81±0.151 ^b	1.25± 0.192 ^c	1.44± 0.189 ^b
T3(Soln A ² +Soln C)	1.19±0.119 ^d	1.75± 0.128 ^d	1.99 ±0.106 ^c
T4(Soln A ³ + Soln C)	0.49±0.0715 ^a	0.54±0.077 ^a	0.54± 0.069 ^a
T5(Soln A ¹ + Soln C)	2.00 ±0.135 ^e	2.12± 0.124 ^e	2.27± 0.117 ^d
Control	0.91±0.253 ^c	1.22± 0.171 ^c	1.43± 0.172 ^b
Mean	0.9852	1.3324	1.511
s.e.d	0.03454	0.03282	0.0387
F.pr	<.001	<.001	<.001
l.s.d (α=0.05)	0.06810	0.06470	0.0764
c.v %	14.9	10.5	10.9

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

The highest mean stem diameter of 2.27 ± 0.117^d was recorded for treatment 5 followed by 1.99 ± 0.106^c for T3. The lowest stem diameter recorded of 0.54 ± 0.069^a for T4. Generally, the steam diameter for T4 was almost constant from week 1 to week 3.

Table 6; Mean effect of nutrient solution with different forms of nitrogen in sea salt on leaf length

Treatment	Leaf length week 1	Leaf length Week 2	Leaf length Week 3
T1(Soln A ² +SolnB)	4.94±0.712 ^b	5.60± 0.589 ^b	6.29 ± 0.698 ^c
T2(Soln A ³ + Soln B)	5.44±0.606 ^c	5.79± 0.531 ^b	5.98± 0.514 ^b
T3(Soln A ² +Soln C)	5.96±0.583 ^d	6.51 ± 0.571 ^c	7.13 ±0.582 ^d
T4(Soln A ³ + Soln C)	3.30±0.302 ^a	3.33± 0.310 ^a	3.52 ±0.567 ^a
T5(Soln A ¹ + Soln C)	5.97±0.676 ^d	6.80 ±0.462 ^d	7.32 ±0.567 ^d
Control	5.18±0.485 ^b	5.58± 0.561 ^b	6.22± 0.621 ^{bc}
Mean	5.131	5.601	6.044
s.e.d	0.1246	0.1128	0.1291
F.pr	<.001	<.001	<.001
l.s.d (α=0.05)	0.2456	0.2223	0.2545

c.v %	10.3	8.5	9.1
-------	------	-----	-----

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

Table 7; Mean effect of nutrient solution with different forms of nitrogen in sea salt on leaf width

Treatment	Leaf width week 1	Leaf width Week 2	Leaf width Week 3
T1(Soln A ² +SolnB)	3.78± 0.590 ^b	4.25±0.646 ^b	5.30± 0.477 ^e
T2(Soln A ³ + Soln B)	4.06 ±0.496 ^c	4.17±0.452 ^b	2.40± 0.314 ^a
T3(Soln A ² +Soln C)	4.38± 0.385 ^d	4.95±0.428 ^c	5.32± 0.421 ^e
T4(Soln A ³ + Soln C)	2.33± 0.291 ^a	2.42±0.309 ^a	2.48 ± 0.659 ^b
T5(Soln A ¹ + Soln C)	4.56± 0.401 ^d	5.14±0.585 ^c	4.95 ± 0.765 ^d
Control	3.89± 0.549 ^{bc}	4.233±0.695 ^b	4.62± 0.581 ^c
Mean	3.832	4.194	4.472
s.e.d	0.0949	0.1141	0.1215
F.pr	<.001	<.001	<.001
l.s.d ($\alpha=0.05$)	0.1871	0.2250	0.2394
c.v %	10.5	11.5	11.5

Means with similar letters are not significantly different at $p \leq 0.05$ based on the Duncan's Multiple Range Test

From week 1 to week 3, T2, T3, and T5 have a higher mean length and width than the control experiment with length of 7.32 ±0.567^d and width of 4.95 ± 0.765^d for T5 being the highest followed by length of 7.13 +0.582d and width of 5.32± 0.421^e for T 3, then length of 5.98+ 0.514^b and width of 2.40+ 0.314^a for T2. T1 and T4 have a lower leaf length and width than the control with the length of 6.29 ± 0.698^c and width of 5.30± 0.477^e for T1 then the lowest which is length of 3.52±0.302 and width of 2.48 + 0.659b for T4.

Table 8; Mean effect of nutrient solution with different forms of nitrogen in sea salt on growth of cow pea in week 3

Treatment	Number of leaves	Number of branches	Plant height (cm)	Stem diameter (cm)	Leaf length (cm)	Leaf width (cm)
T1(SolnA ² +SolnB)	9.50±1.521 ^d	2.39 ±0.688 ^d	15.44 ± 2.583 ^d	1.41 ± 0.277 ^b	6.29 ± 0.698 ^c	5.30± 0.477 ^e
T2(SolnA ³ +SolnB)	6.44± 0.843 ^b	1.56 ±0.607 ^b	12.13± 1.159 ^b	1.44± 0.189 ^b	5.98± 0.514 ^b	2.40± 0.314 ^a
T3(SolnA ² +SolnC)	12.00± 1.434 ^e	3.33± 0.478 ^e	21.25± 1.565 ^f	1.99 ±0.106 ^c	7.13 ±0.582 ^d	5.32± 0.421 ^e
T4(SolnA ³ +SolnC)	2.00 ±0.000 ^a	0.00± 0.000 ^a	7.68±0.950 ^a	0.54± 0.069 ^a	7.32 ±0.567 ^a	4.24± 0.659 ^b
T5(SolnA ¹ +SolnC)	12.00± 1.434 ^e	3.33± 0.478 ^e	19.79± 1.505 ^e	2.27± 0.117 ^d	7.32 ±0.567 ^d	4.95 ± 0.765 ^d
Control	8.50± 2.091 ^c	2.06 ± 0.791 ^c	14.26 ±2.365 ^c	1.43± 0.172 ^b	6.22± 0.621 ^{bc}	4.62± 0.581 ^c
Mean	8.407	2.111	15.09	1.511	6.044	4.472
s.e.d	0.3121	0.1216	0.418	0.0387	0.1291	0.1215
F.pr	<.001	<.001	<.001	<.001	<.001	<.001
l.s.d (α=0.05)	0.6151	0.2397	0.824	0.0764	0.2545	0.2394
c.v %	15.7	24.4	11.7	10.9	9.1	11.5

Means with similar letters are not significantly different at $p \leq 0.05$ based

on the Duncan's Multiple Range Test

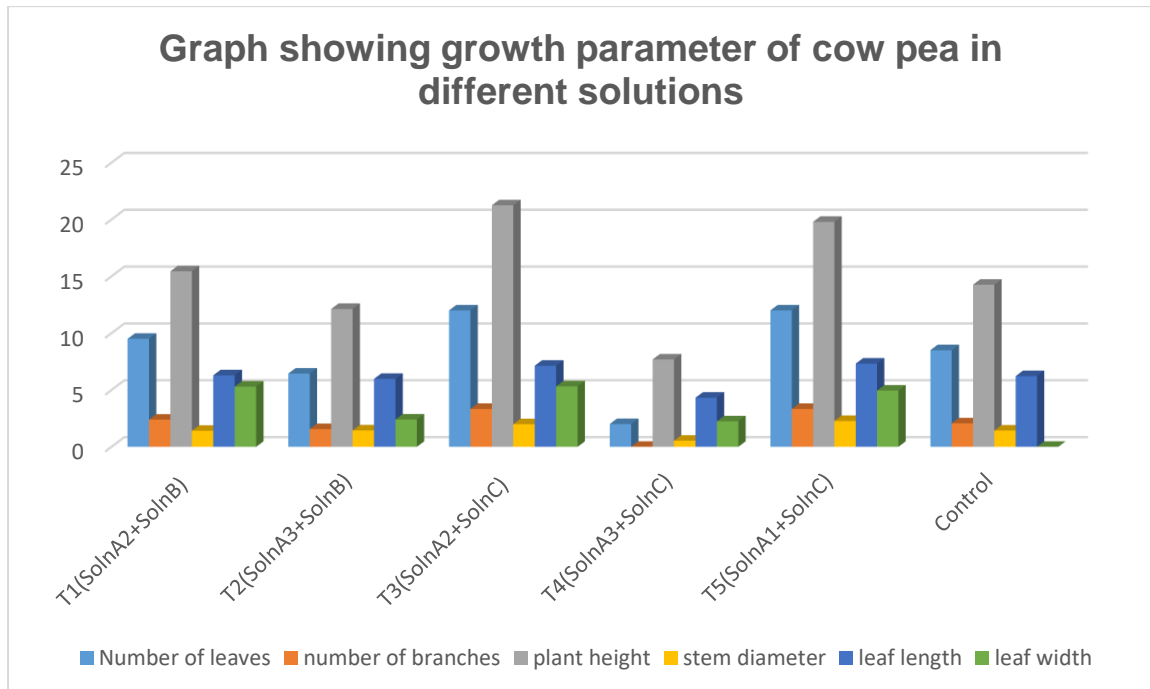


Figure 3: Graph showing growth parameter of cow pea in different solutions

The highest number of leaves (12.00 ± 1.434), number of branches (3.33 ± 0.478), plant height (21.25 ± 1.565), length (7.13 ± 0.582), width (5.32 ± 0.421) was record for T3, followed by number of leaves (12.00 ± 1.434), number of branches (3.33 ± 0.478), plant height (19.79 ± 1.505), length (7.32 ± 0.567), width (4.95 ± 0.765) for T5. Then the lowest number of leaves (2.00 ± 0.000), number of branches (0.00 ± 0.000), plant height (7.68 ± 0.950), length (7.32 ± 0.567), width (4.24 ± 0.659) was recorded for T4, Stuntedness was observed in T4 as seen in the results from week 1 to week 3, The plant height was almost constant, it increased from 7.29 ± 0.856 to 7.63 ± 0.931 to 7.68 ± 0.950 and the number of leaves, number of branches was constant.

These results can be explained by the fact that high ammonia concentrations can disrupt critical metabolic pathways within the seed or seedling. This affects the generation of essential enzymes and inhibits protein synthesis, eventually affecting germination and early growth.

Ammonia can damage the structure and function of cell membranes in seeds and seedlings. These membranes regulate the flow of necessary nutrients and waste products into and out of the cells. Damage to these membranes can cause cell death and delayed development

Ammonia can inhibit cellular respiration, which is required for energy synthesis in seeds and seedlings. This diminished energy availability impairs the developing plant and can result in germination failure or poor hence stunted growth.

(Silva *et al.*, 2013) study shows, using urea in hydroponic systems leads to hydrolysis which, depending on pH conditions, can result in toxic NH_3 liberation in solution. This is one of the reasons why urea is considered to be

inappropriate as the sole source of nitrogen in hydroponic cultivation in comparison to a nitrate source (Tan *et al.*, 2000), this explains the lowest results from treatment 2 and treatment 4,

Although T2 and T4 have the same form of nitrogen which is ammonia ions, T2 has better results than T4 and this is because treatment 4 contains sea salt (NaCl) and in saline environments, plants prefer nitrate (NO₃⁻) and the individual components of NPK (Nitrogen, Phosphorus, Potassium) over ammonium (NH₄⁺) ions because absorbing nitrate needs less energy. They use particular transporters to carry NO₃⁻ into their cells, and there are no additional actions required to transform it into a useful form. Ammonium uptake requires an energy input. Plants need to transform NH₄⁺ into organic nitrogen molecules using a process known as nitrogen absorption. This requires an additional metabolic step when compared to utilising nitrate directly.

In saline environments, high amounts of sodium (Na⁺) ions compete with ammonium (NH₄⁺) for uptake by plant roots. This competition may reduce the supply of ammonium for the plant. This therefore explains the results in T4 being the lowest because it contains ammonia ions as the major source of nitrogen.

T3 and T5 having the highest and best results in all experiments because nitrates in T3 don't require energy to be taken up and in T5 has NPK that is easily taken up by the plants in a nutrient solution and also the sea salt in T3 and T5 boasts growth because of the trace elements present (sodium chloride 77.76%, magnesium chloride 10.88%, Calcium Carbonate 0.3%, magnesium sulfate 4.74%, calcium sulfate 3.60%, potassium chloride 2.46%, magnesium

bromide 0.22%) that boast germination and growth. The results in T3 and T5 can also be attributed to the good root health and proper root development.

These results are contrary to the results gotten from a similar experiment which was carried out on lettuce done by (Sakamoto *et al.*, 2014) and the effects of salinity and nutrients on the growth of red leaf lettuce (*Lactuca sativa* L. cv. Mother-red)

A closed plant factory with hydroponic cultures supplemented with sodium salt (NaCl) or seawater was employed for cultivation of lettuce. The fresh weight of lettuce grown in culture with NaCl was dramatically reduced when compared to those grown in standard culture or culture with seawater. The lettuces grown in the culture with NaCl or seawater contained higher amounts of sugar and anthocyanin, and the lettuce plants grown in the culture with seawater accumulated highest levels of photosynthetic pigments, chlorophylls and carotenoids.

With cowpea the best results of growth were observed in T3 and T5 both containing sea salt that is 77% NaCl hence we can conclude that sea salt improved growth of cowpea with comparison to the normal standard protocol solution used in the study of (Aliyu, 2016) with comparison to the control and T1 and T2, whereas lettuce presented a decrease in growth in media with sea water, this could be because the two crops are from different families and the percentage dilution used in the study of (Sakamoto *et al.*, 2014) which is 20% dilution was higher than the 10% dilution used in the T5 and T3, or also we can conclude that cowpea is more tolerant to NaCl and it produces better results of germination on growth when grown in nutrient solution with nitrates and free nitrogen ions in dilute sea salt.

CHAPTER FIVE

5.0. Conclusion and Recommendations

5.1. Conclusion

Basing on the results gotten in my study it indicates that different forms of nitrogen in sea salt affect the germination of *Vigna unguiculata L. Walp* therefore I accept the hypothesis that different forms of nitrogen in sea salt affect the germination of *Vigna unguiculata L. Walp*

Basing on the results gotten in my study it indicates that different forms of nitrogen in sea salt affect the growth of *Vigna unguiculata L. Walp* therefore I accept the hypothesis that different forms of nitrogen in sea salt affect the growth of *Vigna unguiculata L. Walp*

5.2. Recommendation.

Following the results of this study it is therefore recommended that further studies should be made on the yield and quality of *Vigna unguiculata L. Walp* grown in treatment 5 and treatment 3.

It is also recommended to vary the concentration of sea salt to investigate its effect on the on the growth and germination of *Vigna unguiculata L. Walp*

REFERENCES

Aliyu, R. Establishing Nutrient Efficient Hydroponic Protocol for Cowpea (*Vigna unguiculata* L. Walp) Evaluations at Seedling Stage. 2016

Moussa, B., Lowenberg-DeBoer, J., Fulton, J., & Boys, K. (2011). The economic impact of cowpea research in West and Central Africa: A regional impact assessment of improved cowpea storage technologies. *Journal of Stored Products Research*, 47(3), 147-156.

Jayathilake, C., Visvanathan, R., Deen, A., Bangamuwage, R., Jayawardana, B. C., Nammi, S., & Liyanage, R. (2018). Cowpea: an overview on its nutritional facts and health benefits. *Journal of the Science of Food and Agriculture*, 98(13), 4793-4806.

Farouk, S., & Amany, A. R. (2012). Improving growth and yield of cowpea by foliar application of chitosan under water stress. *Egyptian Journal of Biology*, 14, 14-16.

Rivas, R., Falcão, H.M., Ribeiro, R.V., Machado, E.C., Pimentel, C. and Santos, M.G. (2016) Drought Tolerance in Cowpea Species Is Driven by Less Sensitivity of Leaf Gas Exchange to Water Deficit and Rapid Recovery of Photosynthesis after Rehydration. *South African Journal of Botany*, 103, 101-107.

Pereira, S., Singh, S., Oliveira, R.S., Ferreira, L., Rosa, E. and Marques, G. (2020) Co-Inoculation with Rhizobia and Mycorrhizal Fungi Increases Yield and Crude Protein Content of Cowpea (*Vigna unguiculata* (L.) Walp.) under Drought Stress. *Landbauforschung- Journal of Sustainable and Organic Agricultural Systems*, 70, 56-65.

Timko, M.P. and Singh, B.B. (2008) Cowpea, a Multifunctional Legume. In: Moore P.H. and Ming, R., Eds., *Genomics of Tropical Crop Plants*, Springer, New York, 227-258.

Mfeka, N., Mulidzi, R. A., & Lewu, F. B. (2019). Growth and yield parameters of three cowpea (*Vigna unguiculata* L. Walp) lines as affected by planting date and zinc application rate. *South African Journal of Science*, 115(1-2), 1-9.

Sharma, N., Acharya, S., Kumar, K., Singh, N., & Chaurasia, O. P. (2018). Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation*, 17(4), 364-371.

Aurdal, S. M., Foereid, B., Sogn, T., Børresen, T., Hvoslef-Eide, T., & Fagertun Remberg, S. (2022). Growth, yield and fruit quality of tomato *Solanum lycopersicum* L grown in sewage-based compost in a semi-hydroponic cultivation system. *Acta Agriculturae Scandinavica, Section B— Soil & Plant Science*, 72(1), 902-912

Trejo-Téllez, L. I., & Gómez-Merino, F. C. (2012). Nutrient solutions for hydroponic systems. *Hydroponics-a standard methodology for plant biological researches*, 1-22.

Andriolo, J. L.; Godoi, R. S.; Cogo, C. M.; Bortolotto, O. C.; Luz, G. L. & Madaloz, J. C. (2006).

Growth and Development of Lettuce Plants at High NH₄⁺: NO₃⁻ Ratios in the Nutrient Solution. *Horticulture Brasileira*, Vol.24, No.3, (Jul-Set 2006), pp. 352-355, ISSN 0102-0811

Hardwick rc. 1987. The nitrogen content of plants and the self-thinning rule of plant ecology: a test of the core-skin hypothesis. *Annals of Botany* 60: 439-446.

Liu, W.K.; Zhang, Y.B.; Zha, L.Y.; Liu, Y.F. Effects of Continuous Light Before Harvest on Nutrient Element Contents of Hydroponic

Lettuce Cultivated Supplied with Three Nitrogen Levels and Two LED Red and Blue Light Qualities. *Spectrosc. Spectr. Anal.* 2020, 40, 3884–3889.

(Aurdal, S. M., Foereid, B., Sogn, T., Børresen, T., Hvoslef-Eide, T., & Fagertun Remberg, S. (2022).

Reid, R., & Hayes, J. (2003). Mechanisms and control of nutrient uptake in plants. *International review of cytology*, 229(3), 73-114.

Liu, W.K.; Zhang, Y.B.; Zha, L.Y. Effect of LED Red and Blue Continuous Lighting before Harvest on Growth and Nutrient Absorption of Hydroponic Lettuce Cultivated under Different Nitrogen Forms and Light Qualities LED. *Spectrosc. Spectr. Anal.* 2020, 40, 2215–2221

Kotsiras a; olympios cm; drosopoulos j; passam hc. 2002. Effects of nitrogen form and concentration on the distribution of ions within cucumber fruits. *Scientia Horticulturae* 95: 175_183.

Pinheiro-henriques ar; marcelis fm. 2000. Regulation of growth at steady-state nitrogen nutrition in lettuce (*Lactuca sativa* L.): interactive effects of nitrogen and irradiance. *Annals of Botany* 86: 1073-1080.

Pons tl; westbeek mhm. 2004. Analysis of differences in photosynthetic nitrogen-use efficiency between four contrasting species. *Physiologia Plantarum* 122: 68-78.

Schenk mk. 1996. Regulation of nitrogen uptake on the whole plant level. *Plant and Soil* 181: 131-137.

ADAMS, P., 2002: Nutritional control in Hydroponics. In: Savvas, D., Passam, H.C. (eds.), *Hydroponic production of vegetables and ornamentals*, 211-261. Embryo Publications - Athens.

Sapkota, S., Sapkota, S., & Liu, Z. (2019). Effects of nutrient composition and lettuce cultivar on crop production in hydroponic culture. *Horticulturae*, 5(4). <https://doi.org/10.3390/horticulturae5040072>

ALAN, R., Z ÜLKADIR, A., P ADEM, H., 1994: The influence of growing media on growth, yield and quality of tomato grown under greenhouse conditions. *Acta Hort.* 366, 429-436

BÆVRE, O.A., 1985: A comparison of the fruit quality of tomatoes grown in soil and in a nutrient solution (NFT). *Scientific Reports of the Agricultural University of Norway* 64, 1-10

Cornish, P.S., 1992: Use of high electrical conductivity of nutrient solution to improve the quality of salad tomatoes (*Lycopersicon esculentum*) grown in hydroponic culture. *Austral. J. Exp. Agri.* 32, 513-520

Conesa, E.; Niñirola, D.; Vicente, M.J.; Ochoa, J.; Bañón, S.; Fernández, J.A. The influence of nitrate/ammonium ratio on yield quality and nitrate, oxalate and vitamin C content of baby leaf spinach and bladder campion plants grown in a floating system. In *International Symposium on Soilless Culture and Hydroponics*; International Society for Horticultural Science: Leuven, Belgium, 2008; Volume 843, pp. 269–274.

Mahlangu, R.I.S.; Maboko, M.M.; Sivakumar, D.; Soundy, P.; Jifon, J. Lettuce (*Lactuca sativa*L.) growth, yield and quality response to nitrogen fertilization in a non-circulating hydroponic system. *J. Plant Nutr.*2016, 39, 1766–1775.

Abahri, A. S. T. (2015). *Effects of nutrients and salinity on yields, growth, and nutrients distribution of faba beans grown in hydroponics system* (Doctoral dissertation).

Haggag, W.M., Abouzienna, H., Abd-El-Kreem, F. and El Habbasha, S. (2015) Agriculture Biotechnology for Management of Multiple Biotic and Abiotic Environmental Stress in Crops. *Journal of Chemistry and Pharmaceutical Research*, 7,882-889.

Sakamoto, K., Kogi, m., & Yanagisawa, T. (2014). Effects of salinity and nutrients in seawater on hydroponic culture of red leaf lettuce. *Environmental Control in Biology*, 52(3), 189-195.

Bailey, J.A., Nash, C., O'Connell, R.J. and Skipp, R.A. (1990) Infection Process and Host Specificity of a *Colletotrichum* Species Causing Anthracnose Disease of Cowpea, *Vigna unguiculata*. *Mycological Research*, 94, 810-814

Souleymane, A., Aken'Ova, M.E., Fatokun, C. and Alabi, O. (2013) Screening for Resistance to Cowpea Aphids (*Aphis Craccivora* KOCH) in Wild and

Cultivated Cowpea (*Vigna unguiculata* L. Walp) Accessions. International Journal of Science, Environment and Technology, 2, 611-621.

Togola, A., Boukar, O., Servent, A., Chamarthi, S., Tamò, M. and Fatokun, C. (2020) Identification of Sources of Resistance in Cowpea Mini Core Accessions to *Aphis craccivora* Koch (Homoptera: Aphididae) and Their Biochemical Characterization. Euphytica, 216, Article No. 88.

Bolarinwa, K.A., Ogunkanmi, L.A., Ogundipe, O.T., Agboola, O.O. and Amusa, O.D. (2021) An Investigation of Cowpea Production Constraints and Preferences among Smallholder Farmers in Nigeria. GeoJournal

Larweh, V., Akromah, R., Amoah, S., Asibuo, J.Y., Kusi, F. and Prempeh, R. (2019) Effect of *Striga gesnerioides* on Cowpea (*Vigna unguiculata* L. Walp) Yield Components. Research Square

Rugare, J.T., Mabasa, S. and Tsekenedza, S. (2013) Response of Cowpea (*Vigna unguiculata* L.) Genotypes to Witch Weed (*Alectra vogelii* Benth) Infection. Asian Journal of Agriculture and Rural Development, 3, 667-673.

Huynh, B.L., Matthews, W.C., Ehlers, J.D., Lucas, M.R., Santos, J.R., Ndeve, A. Close, T.J. and Roberts, P.A. (2016) A Major QTL Corresponding to the Rk Locus for Resistance to Root-Knot Nematodes in Cowpea (*Vigna unguiculata* L. Walp) Theoretical and Applied Genetics, 129, 87-95.

Boukar, O., Belko, N., Chamarthi, S., Togola, A., Batiemo, J., Owusu, E., Haruna, M., Diallo, S., Umar, M.L., Olufajo, O. and Fatokun, C. (2018) Cowpea (*Vigna unguiculata*): Genetics, Genomics and Breeding. *Plant Breeding*, 138, 415-424.

Carvalho, M., Muñoz-Amatriaín, M., Castro, I., Lino-Neto, T., Matos, M., Egea-Cortines, M., et al. (2017) Genetic Diversity and Structure of Iberian Peninsula Cowpeas Compared to World-Wide Cowpea Accessions Using High Density SNP Markers. *BMC Genomics*, 18, Article No. 891.

Bastos, E.A., Nascimento, S.P., Silva, E.M., Freire Filho, F.R. and Gomide, R.L. (2011) Identification of Cowpea Genotypes for Drought Tolerance¹ [Identificação de genótipos de feijão-caupitolerantes à seca]. *Revista Ciência Agronômica*, 42, 100-107.

Rambo, L.; Ma, B.L.; Xiong, Y.; Regis Ferreira da Silveira, P. Leaf and canopy optical characteristics as crop-N-status indicators for field nitrogen management in corn. *J. Plant Nutr. Soil Sci.* 2010, 173, 434–443.

Bohn, T.; Walczyk, T.; Leisibach, S.; Hurrell, R.F. Chlorophyll-bound Magnesium in Commonly Consumed Vegetables and Fruits: Relevance to Magnesium Nutrition. *J. Food Sci.* 2004, 69, 347–350.

Ašimović, Z.; Ćengić, L.; Hodžić, J.; Murtić, S. Spectrophotometric determination of total chlorophyll content in fresh vegetables. *Godina LXI Broj* 2016, 66, 104–107

Savvas, D.; Passam, H.C.; Olympios, C.; Nasi, E.; Moustaka, E.; Mantzos, N.; Barouchas, P. Effects of ammonium nitrogen on lettuce grown on pumice in a closed hydroponic system. *HortScience* 2006, 41, 1667–1673.

Kowalczyk, K.; Mirgos, M.; Błaczek, K.; Niedzińska, M.; Gajewski, M. Effect of different growing media in hydroponic culture on the yield and biological quality of lettuce (*Lactuca sativa* var. *capitata*). *Acta Hort.* 2014, 1142, 105–110.

MASSANTINI, F., Favilli, R., Magnani, G., Oggiano, N., 1988: Soilless culture biotechnology for high quality vegetables. *Soilless Culture* 4, 27-40.

Massantini, F.; Favilli, R.; Magnani, G.; Oggiano, N. Soilless culture, biotechnology for high quality vegetables. *Soil. Cult. (Neth.)* 1988, 4, 27–40.

Shao, M.J.; Liu, W.K.; Zhou, C.B.; Wang, Q.; Li, B.S. Effects of High Light Duration and Frequencies on Growth and Nutrient Element Contents of Hydroponic Lettuce Cultivated Under LED Red and Blue Light LED. *Spectrosc. Spectr. Anal.* 2021, 41, 2853–2858

ANNEX 1: TIME FRAME

TIME FRAME					
Activity	Month 1	Month 2	Month 3	Month 4	Month 5
Concept development					
Proposal writing					
Proposal defense					
Data collection					
Data analysis					
Dissertation writing					

ANNEX 2: BUDGET

Item	Quantity	Price	Total price
Buckets	18	5000 each	90,000
Net cups	18	3000 each	54,000
NPK	1kg	3500@ kg	3500
CAN	1kg	3500@ kg	3500
Sea salt	1kg	2800@ kg	2800
Magnesium sulphate	500g	32000@ 1/2kg	32,000
Ferrous sulphate	500g	32000@ 1/2kg	32,000
Litmus paper	1 pack	15000	15,000
Ruler	2	3000	3,000
Total			235,800 shillings

ANNEX 3: DATA COLLECTION SHEET

DATA COLLECTION SHEET								
NAME.....								
WEEK.....								
DATE.....								
LOCATION.....								
Treatment	Replication No.	Plant No.	Number of leaves	Height of plant	Number of branches	Stem diameter	Leaf area	
							length	width
1	1	1						
		2						
		3						
		4						
		5						
		6						
2	1	1						
		2						
		3						
		4						
		5						
		6						
3	1	1						
		2						
		3						
		4						
		5						
		6						
4	1	1						
		2						
		3						
		4						
		5						
		6						
5	1	1						

		2						
		3						
		4						
		5						
		6						
6	1	1						
		2						
		3						
		4						
		5						
		6						

ANNEX 4: PICTURES



Figure 4. Treatment 3



Figure 5, Treatment 5



Figure 6, Treatment 2



Figure 7. Treatment 6



Figure 8. Treatment 4



Figure 9. Treatment 1

