GERMINATION OF COMMON BEANS (*Phaseolus vulgaris*) UNDER STRESS USING SALTS; SODIUM CHLORIDE (NaCl), POTASSIUM CHLORIDE (KCl) AND SODIUM BICARBONATE ($NaHCO_3$)

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This is to certify that this project work, titled "**GERMINATION OF BEANS *(Phaseolus vulgaris*) UNDER STRESS USING SALTS; SODIUM CHLORIDE (NaCl), POTASSIUM CHLORIDE (KCl) AND SODIUM BICARBONATE ($NaHCO_3$)**" was carried out by Yasmina Omone ALIU-ANOFOKHAI with matriculation number LSC2009993 of the Department of Science Laboratory Technology (Biotechnology Techniques), Faculty of Life Sciences, University of Benin City, Edo State, under the supervision of Dr. Alex Orukpe.

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DEDICATION

I dedicate this seminar work to God Almighty, my family and friends who have shown constant support and encouragement throughout this journey.

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ABSTRACT

In this study, the effects of salt stress on the germination of common beans (*Phaseolus vulgaris*), a major source of affordable plant protein and an important staple in Nigeria were examined. The three salts that were applied at concentrations of 100 ppm, 500 ppm and 1000 ppm were sodium chloride (NaCl), potassium chloride (KCl) and sodium bicarbonate ($NaHCO_3$). Distilled water was utilised as the control in this study. To find out how well they responded in terms of germination, growth, and nutritional value, white and brown bean cultivars were evaluated. Priming of 200 healthy seeds in the respective prepared salt solutions was done using a completely randomised design. Growth metrics such biomass, shoot length and root length, germination rate and leaf spread were measured and moisture content was ascertained by the germination. The results indicated that growth and proximate composition were significantly impacted by salinity stress. The most detrimental was Sodium chloride (NaCl), especially at higher concentrations which decreased biomass. While Sodium bicarbonate ($NaHCO_3$) was somewhat less harmful, Potassium chloride (KCl) had moderately detrimental effects and certain treatments were able to maintain proximal balance. Compared to brown beans, white beans showed a higher resistance to moderate salt, particularly during germination and shoot growth. With Sodium chloride (NaCl) being the most damaging and Sodium bicarbonate ($NaHCO_3$) the least, the study finds that salinity stress lowers the growth and nutritional value of common beans. It proposes the introduction of salt-tolerant cultivars, enhanced soil and water management to prevent sodium buildup. Also, an additional study into biochemical and molecular mechanisms of salt tolerance to support sustainable bean production in saline-prone regions.

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF STUDY

Beans has a longstanding position as a staple of the Nigerian diet due the fact that it is an accessible and affordable source of nutrition for a wide range of people as it is the cheapest plant protein in Nigeria and most parts of Africa. Beans is also significant in the Nigerian diet because it has a potent combination of its high nutritional content, historical use as a financial stabilizer and fixed cultural importance. Consuming beans in Nigeria is not a straightforward dietary decision, rather it is a calculated reaction to a complicated interaction between inherited customs, economic realities and public health requirements. Beans has high-quality protein and fiber composition that act as a vital defense against chronic illnesses and also solve the pervasive protein shortage.

Food legumes belonging to the genus Phaseolus, family Leguminosae, subfamily Papilio-nideae, tribe Phaseoleae, and subtribe Phaseolinae are commonly referred to as beans. About 50 wild-growing species of Phaseolus are found only in the Americas; Asian Phaseolus has been reclassified as Vigna. Life histories (annual to perennial), growth patterns (bush to climbing), reproductive systems and adaptations (from cool to warm and dry to wet) are all represented by these species. Common beans (Phaseolus vulgaris L.), lima beans (Phaseolus lunatus L.), runner beans (Phaseolus coccineus L.), tepary beans (P. acutifolius A. Grey), and year beans (P. polyanthus Greenman) are among the five domesticated species in the genus. These species have different adaptations and reproductive systems: mesic and temperate, mostly self-pollinated; warm and humid, cool and humid, outcrossing; cleistogamous; and cool and humid, outcrossing, in that order. The other domesticated species, which form a syngameon and are sibling species, are phylogenetically closer to the lima bean. In terms of science and economics, the common bean is the principal species. Its wild ancestor, P. vulgaris var. mexicanus and var. aborigineus, is widely distributed throughout Latin America, from northern Mexico to northwest Argentina. The USDA in Pullman, Washington, USA, and CIAT in Cali, Colombia, both have sizable germplasm collections of both domesticated and wild types. The National Botanical Garden in Meise, Belgium, is home to the Phaseolinae reference collection. The most significant legume for direct human consumption worldwide is the common bean (Gepts, 2001).

The most significant grain legume for direct human consumption globally is the bean (Phaseolus spp.), especially the common bean P. vulgaris L. Because of their biological nitrogen fixation, effects on the soil, and weed control, they are a major source of highly valuable plant protein and micronutrients, they offer health benefits associated with regular consumption, and they help to improve the environment in a sustainable way when grown in agricultural rotation or with intercropping (Bitocchi *et al*, 2017).

Plate 1.1: An image showing brown beans (*Phaseolus vulgaris*).

Plate 1.2: An image showing white beans (*Phaseolus vulgaris*).

1.2 IMPORTANCE OF BEANS (PULSES) IN FOOD SECURITY AND NUTRITION (WITH EMPHASIS ON NIGERIA)

Nigeria's severe food insecurity has gotten worse, and internal conflicts and the continued consequences of climate change, like drought and floods, have made matters worse. Furthermore, economic difficulties have an impact on food supply, particularly a decline in fiscal and foreign exchange earnings, which has slowed the rate of food imports and raised local costs. Furthermore, it is now increasingly difficult for agricultural and food systems to sustainably supply local food needs due to the tremendous strain that the geometric growth in population, particularly in the last 50 years, has imposed on the finite food supplies. When combined, these indicators constitute a major cause of undernourishment. If well utilized, the abundant local legume resources can help alleviate food insecurity. Nonetheless, the majority of legumes are listed as underutilized crops by the Food and Agriculture Organization of the United Nations. Additionally, Nigerians rely too much on high-calorie foods, which is opposed by dietitians around the world. Legumes provide plant-based protein, which is essential for human health and a healthy metabolism. The advantages of using Nigeria's underutilized and neglected legume resources sustainably are highlighted in this work.

Potential remedies for food insecurity are covered in the book, along with ways to enhance human nutrition and health (Ikhajiagbe *et al*, 2021).

1.3 UNDERSTANDING SALT STRESS IN PLANTS

Salinization is a global environmental issue that is endangering global food security by having a detrimental effect on crop productivity. Understanding how plants tolerate salt and identifying opportunities for the production of salinity-resistant plants are urgently needed given the growing threat posed by salinity. Since various plants have varying tolerances for salt, halophytes and glycophytes have developed modified defense mechanisms against the stress. Thus, the physiological, metabolic, and molecular facets of plants' response to salt stress have been covered. Because of its multigenic feature, traditional breeding methods for creating salt-tolerant plants have not been very successful (Ibrahimova et al, 2021)

One important environmental element affecting plant growth and productivity is salt stress. Researchers will be better able to create strategies to enhance crop performance in challenging environmental circumstances if they have a deeper grasp of the mechanisms underlying salt resistance. In plants, salt stress can result in secondary stresses, especially oxidative stress, ionic stress, and osmotic stress. Plants therefore depend on signals and pathways that restore cellular ionic, osmotic, and reactive oxygen species (ROS) homeostasis in order to adapt to salt stress (Yang and Guo, 2018) .

1.4 IMPACT OF SALINITY ON AGRICULTURAL PRODUCTIVITY GLOBALLY AND IN NIGERIA

Although it is challenging to quantify, agricultural losses resulting from salinity are thought to be significant and are predicted to rise over time. Particularly common is secondary salinization of agricultural fields in arid and semiarid regions where irrigation systems are necessary for crop production. Salt affects at least 20% of all irrigated lands, and other estimates put that number as high as 50%. The amount of land under irrigation seems to have stabilized, despite the fact that the world's population is still growing. Therefore, increases in yield per land area are required to meet the demand for greater food production. Crop plant genetic engineering for increased salt tolerance will be a crucial strategy to achieve this goal. Moderately salt-tolerant crops can be irrigated with brackish water in arid areas where fresh water becomes scarce. Certain agricultural species have produced transgenic lines that, in controlled conditions, can grow and develop at quite high saline levels. The yield potential of these transgenics needs to be further examined in field settings (Pitman and Läuchli, 2002).

1.5 SCOPE OF STUDY

This study evaluated the effects of stress using salts; sodium chloride (NaCl), potassium chloride (KCl) and sodium bicarbonate ($NaHCO_3$) on the germination of white and brown beans *(Phaseolus vulgaris).*

1.6 PROBLEM STATEMENT

Despite beans' nutritional and economic importance in Nigeria, its productivity is often limited by poor seed germination. Uneven or delayed germination results in non-uniform plant stands, poor resource use efficiency, and lower yields. Although seed priming and the application of growth regulators have shown promise in improving germination and early growth, there is insufficient data comparing their effects on different beans seed types (white and brown). This gap in knowledge makes it difficult to recommend effective germination-enhancing strategies for farmers and seed producers. Specifically, the differential responses of white and brown beans seeds to various concentrations of salts; Sodium Chloride (NaCl), Potassium Chloride (KCl) and Sodium Bicarbonate ($NaHCO_3$) remain largely unexplored, hindering the development of targeted and effective seed treatment protocols for improved beans production in diverse agricultural settings.

1.7 AIM AND OBJECTIVES OF STUDY

Aim

The aim is the germination of common beans (*Phaseolus vulgaris*) under stress using salts; Sodium Chloride (NaCl), Potassium Chloride (KCl) and Sodium Bicarbonate ($NaHCO_3$).

Also, Investigating and comparing the effects of different salts (Sodium Chloride (NaCl), Potassium Chloride (KCl) and Sodium Bicarbonate ($NaHCO_3$)) on the germination and early seedling growth of white and brown beans *(Phaseolus vulgaris)* seeds.

Objectives of study

1. To determine the germination time of white and brown beans *(Phaseolus vulgaris)* treated with various salts; Sodium Chloride (NaCl), Potassium Chloride (KCl) and Sodium Bicarbonate ($NaHCO_3$).

2. To determine the germination parameters of white and brown beans *(Phaseolus vulgaris)*.

3. To determine the productivity rate of the white and brown beans *(Phaseolus vulgaris)* when treated with various salts.

1.8 SIGNIFICANCE AND LIMITATION OF STUDY

1.8.1 SIGNIFICANCE

Beyond the laboratory, this discovery has important ramifications that will benefit numerous stakeholders in Nigeria's public health and agriculture sectors. In addition to improving germination, the study offers farmers insights into how seed priming with various salts might improve the nutritional value of their harvests, potentially raising market value and household dietary quality. More nutrient-dense bean-based products will be developed and made available to consumers and food processors, addressing malnutrition. The creation and distribution of optimal priming methods customized for various bean varieties will be supported by the practical knowledge that seed producers and agricultural extension agents will acquire. By examining the effects of KCL, NaCl and $NaHCO_3$ on germination, the study closes a significant knowledge gap in academia, advancing future research on biofortification and advancing our understanding of seed physiology. Furthermore, the study improves the nutritional environment for disadvantaged populations and helps food security policy by encouraging nutrient-rich common beans. In the end, increasing the nutritional profile of a staple that is so extensively consumed also benefits Nigeria's agricultural economy by raising the standard of crops and the incomes of smallholder farmers.

1.8.2 LIMITATION

Despite some of the limitations being regulated, laboratory circumstances might not accurately represent environmental factors found in the real world such as soil type, pests, or climate stress, which could have an impact on field applicability. Only two bean varieties are included in the study, leaving out a larger range of cultivars that might react differently. Additionally, it exclusively examines three particular salts at particular concentrations, alternative salts are not investigated. Furthermore, only germination components are included in the analysis like leaf spread, moisture content and biomass. Lastly, by concentrating only on the final nutritional results, the study ignores the underlying biochemical mechanisms such as gene expression or enzyme activity that are accountable for the observed changes.

1.9 DEFINITION OF TERMS

The following crucial concepts are defined operationally to guarantee clarity and accuracy throughout this investigation:

- **Beans (*Phaseolus vulgaris*):** A widely cultivated leguminous crop in tropical and subtropical regions, known for its edible seeds rich in protein.
- **Salts:** Salts are ionic compounds formed when the hydrogen ion (H^+) of an acid is replaced by a metal ion or another positive ion (cation). They are typically the products of a neutralization reaction between an acid and a base.
- **Sodium Chloride(NaCl):** Sodium chloride (NaCl) is a neutral ionic compound formed when hydrochloric acid (HCl) reacts with sodium hydroxide (NaOH) during a neutralization reaction.
- **Potassium Chloride (KCl):** Potassium chloride (KCl) is an inorganic salt formed when potassium (K) reacts with chlorine (Cl_2) or when potassium hydroxide (KOH) reacts with hydrochloric acid (HCl) in a neutralization reaction.
- **Sodium bicarbonate ($NaHCO_3$)**: Sodium bicarbonate ($NaHCO_3$) is a mildly alkaline salt composed of sodium ions (Na^+) and bicarbonate ions (HCO_3^-). It is a white crystalline solid that is soluble in water and commonly used in cooking, medicine, and cleaning.
- **Germination:** The process by which a plant grows from a seed. Operationally, it refers to the emergence of the radical (embryonic root) through the seed coat.

- **Seedling Emergence:** The process where a germinated seedling breaks through the soil surface and becomes visible.
- **Seed Priming:** A pre-sowing seed treatment involving controlled hydration that allows metabolic processes to begin without radical emergence, often leading to faster and more uniform germination when planted.
- **Radical Length:** The measured length of the primary root of a seedling, typically from the base of the seed to the tip of the root.
- **Plumule Length:** The measured length of the embryonic shoot of a seedling, typically from the point of attachment to the cotyledons to the tip of the first true leaves.
- **Seedling Vigor Index:** A composite measure that combines germination percentage and seedling growth parameters (e.g., radical and plumule length) to indicate the overall strength and health of the seedlings. It is often calculated as: (Germination % × Seedling Length) / 100.
- **Dormancy:** A state in which seeds are prevented from germinating even under environmental conditions normally favorable for germination.

CHAPTER TWO

LITERATURE REVIEW

Legumes, commonly called pulses, belong to the Leguminosae or Fabaceae family, which includes around 690 genera and 18,000 species. The term "legume" comes from the Latin word *legere*, meaning "to gather," while "pulse" traces back to the Latin *puls*, referring to a porridge-like bean dish enjoyed by the ancient Romans. Within the family, there are three main subfamilies Papilionoideae, Caesalpinioideae, and Mimosoideae distinguished largely by their flower structure. Most edible legumes, including soybeans, chickpeas, beans, and peas, fall under Papilionoideae, while lesser-known members include clover, lentils, licorice, and peanuts, the latter of which are botanically legumes but not always treated as such in culinary contexts (Allaire and Brady, 2010).

A defining feature of Fabaceae plants is their unique flowers and fruit. These flowers are hermaphroditic, containing both stamens and pistils, which makes them self-fertile but also capable of cross-pollination. This duality often blurs distinctions among subspecies. The flowers typically have five petals arranged in a butterfly-like, or papilionaceous, shape: a large protective "banner," two lateral "wings," and two fused petals forming the "keel," which encloses the reproductive organs. After pollination, the flower withers to reveal the ovary, which matures into the characteristic pod of the legume plant (Allaire and Brady, 2010).

Beans

There are numerous common names for beans in various languages. Various bean classes, seed kinds, growth behaviours and, of course, particular varieties are distinguished by descriptive and common names, as are Phaseolus vulgaris L. and other edible seed legume species. The numerous agronomic, physical, and consumer traits of beans are also used to categorise them. Certain bean classes have relatively limited production and acceptability, which varies by nation and location.

In the English language, the generic term" beans" is often used not only for P. vulgaris but also for other species, such as P. coccineus, and it may even refer to other genera, such as Vigna. For this reason, descriptive adjectives, such as the following, are often used to distinguish P. vulgaris from other grain legumes: French beans, dry beans, food beans, field beans, beans, common beans, kidney beans, haricot beans, Phaseolus beans, and dry edible beans. Common bean or haricot bean are perhaps the most common species descriptors in English, but they are not of universal usage. These and other descriptors may be employed as a species description in one country and be used to describe a specific class of beans in another.

Beans usually refers to food legumes of the genus Phaseolus, family Leguminosae, subfamily Papilionoideae, tribe Phaseoleae, subtribe Phaseolinae. The genus Phaseoluscontains some 50 wild-growing species distributed only in the Americas (Asian Phaseolus have been reclassified as Vigna). These species represent a wide range of life histories (annual to perennial), growth habits (bush to climbing), reproductive systems, and adaptations (from cool to warm and dry to wet). The genus also contains five domesticated species: in decreasing order of importance, common bean (Phaseolusvulgaris L.), lima bean (P. lunatus L.), runner bean (Phaseoluscoccineus L.), tepary bean (P. acutifolius A. Gray), and year bean (P. polyanthus Greenman).

2.1.1 OVERVIEW OF BEANS AND SALT STRESS

Beans rank among the world's most important and widely farmed legume crops, due to being a staple for hundreds of millions of people around the in world because of its nutrition, versatility, and low price. The family Fabaceae, or Leguminosae, covers a great variety of species, each with unique and particular attributes (Smith, 2020).

The term "**beans**" broadly refers to the seeds of various genera and species within the **Fabaceae family**, encompassing a wide range of common and economically significant types. These include the **Common Bean** (*Phaseolus vulgaris*), which is the most widely cultivated and includes varieties like kidney, pinto, navy, black, cannellini, and green by beans. Other notable types are the **Lima Bean** (*Phaseolus lunatus*), also known as butter beans; the **Fava Bean** (*Vicia faba*), or broad beans; and botanically distinct but commonly grouped legumes such as the **Chickpea** (*Cicer arietinum*) and **Lentil**(*Lens culinaris*). Additionally, the **Soybean** (*Glycine max*) stands out for its extensive industrial uses and high protein content, while the **Mung Bean** (*Vigna radiata*) is popular in Asian cuisine, and the **Cowpea** (*Vigna unguiculata*), including black-eyed peas, is widely grown in Africa and Asia. This diverse array of species underscores the broad genetic base within the "bean" category (Jones and Davis, 2021).

KCl as a Salt Stress Agent in Common Bean (*Phaseolus vulgaris* L.)

Potassium chloride (KCl) plays a dual role in plant physiology: while potassium (K^+) is an essential macronutrient, excessive KCl under saline conditions can impose stress on bean plants.

Ion Balance and K^+/Na^+ Discrimination

Bean plants (*Phaseolus vulgaris*) have been demonstrated to possess **low discrimination between K^+ and Na^+ ions** under high salinity conditions. At moderate concentrations, KCl can elevate internal K^+ levels; but this can lead to uncontrolled K^+ loading and ionic imbalance similarly harmful as Na^+ toxicity (Epstein and Zhu, as cited in Lourens and

Ludlow). When Na^+ is abundant, bean roots struggle to differentiate and regulate uptake effectively, exacerbating ionic stress rather than alleviating it (Tester and Davenport, 2003KI, 1994)

2.1.2 BOTANICAL DESCRIPTION AND CLASSIFICATION OF BROWN AND WHITE BEANS

Most brown and white beans fall under the species ***Phaseolus vulgaris* L.**, commonly known as the **common bean**. This species is highly diverse, with numerous cultivars exhibiting a wide array of seed colors, shapes, and sizes, including various shades of brown and white. Some white beans can also be varieties of *Phaseolus lunatus* or *Vigna unguiculata*.

Common Bean (*Phaseolus vulgaris* L.)

Classification:

- •**Kingdom:** Plantae (Plants)
- **Clade:** Tracheophytes (Vascular plants)
- **Clade:** Angiosperms (Flowering plants)
- **Clade:** Eudicots
- **Clade:** Rosids
- **Order:** Fabale
- **Family:** Fabaceae (Leguminosae) – the pea or legume family
- **Subfamily:** Faboideae
- **Genus:** *Phaseolus* L.
- **Species:** *Phaseolus vulgaris* L.

2.1.3 NUTRITION COMPOSITIONS OF COMMON BEANS

Beans are often praised as a good source of plant protein across different countries and its Far from being a mere supplements to other protein sources The common bean offers a robust profile of macronutrients and a remarkable array of essential micronutrients, making them incredibly beneficial for overall human health. Their availability and affordability across the country also make common beans an important component for global food security, especially in providing plant-based protein to a growing population (Parodi *et al*., 2018; Nadeem *et al*., 2021).

Common beans are recognized as an excellent source of plant-based protein, containing approximately 20–25% protein by dry weight. While, certain varieties, such as the African locust bean, can contain protein levels as high as 34% (Progressive Academic Publishing, 2016). Although traditionally classified as "incomplete" proteins due to limiting levels of sulfur-containing amino acids like methionine, beans are rich in lysine. This amino acid profile makes them complementary when consumed with grains such as rice, which are typically low in lysine but high in methionine—resulting in a complete protein source (A Legume a Day, 2023). This attribute is particularly beneficial in vegetarian and vegan diets that depend on plant-based sources to meet protein requirements (Health.com, 2024).

The primary caloric contribution of common beans comes from complex carbohydrates, mainly starch (43–45%) and dietary fiber (18–20%) (The Bean Institute, 2023). These carbohydrates are digested and absorbed slowly, promoting a sustained energy release and supporting glycemic control. Therefore, beans are considered a low-glycemic index food, making them especially valuable in dietary management for conditions like diabetes mellitus (North Dakota State University Extension, 2023). Additionally, common beans are naturally low in fat, with most varieties containing less than 1% total fat. This low-fat composition adds to their cardioprotective benefits and supports balanced nutrition free of excessive saturated fats (The Bean Institute, 2023).

2.2 SOCIOECONOMIC IMPORTANCE OF BEANS

Beans (*Phaseolus vulgaris* L.) are not only a dietary staple but also a critical component in sustainable agriculture and rural livelihoods. Their nutritional profile is impressive, containing 20–30% crude protein, 40–60% carbohydrates, 5–15% dietary fiber, 1–2% fat, and an abundance of essential minerals such as calcium (Ca), magnesium (Mg), iron (Fe), and zinc (Zn) (Nwadike *et al*., 2018). These characteristics underscore their importance in combating malnutrition and micronutrient deficiencies, particularly in low-income populations.

In many African countries, especially Nigeria, beans serve a dual role as a food security crop and a source of income. They are widely cultivated by smallholder farmers across diverse agro-ecological zones, including the savanna, rainforest, and middle belt regions, due to their adaptability and relatively short growing cycle (Aremu *et al*., 2016). The crop provides a reliable source of income, particularly for women, who dominate much of the production, processing, and marketing activities (Agunuwa *et al*., 2021). The economic value of beans increases during the dry season when food scarcity becomes more pronounced, and the market price of legumes tends to rise, enhancing household income security.

Beyond direct income, beans contribute to broader agricultural sustainability through their symbiotic nitrogen-fixing capability, which enriches soil fertility and reduces the dependence on synthetic nitrogen fertilizers (Adesemoye *et al*., 2009). This ecological benefit lowers input costs for farmers and improves the productivity of intercropped cereals such as maize and millet, which often accompany legumes in traditional farming systems (Okeleye *et al*., 2014). Consequently, beans support both ecological balance and economic stability in smallholder farming systems.

Moreover, the high demand for beans across West Africa supports regional trade. Nigeria is not only the largest producer but also a major exporter of cowpeas and common beans to neighboring countries such as Niger, Benin, and Cameroon (Kamai *et al*., 2020). This cross-border trade enhances foreign exchange earnings and contributes to national GDP.

In summary, beans represent more than a nutritional asset—they are pivotal to the socioeconomic structure of farming communities, especially in Nigeria. Their production, consumption, and trade directly influence rural livelihoods, food security, soil health, and the broader agricultural economy

2.3 MECHANISMS OF SALT STRESS IN PLANTS

2.3.1 Osmotic Stress

Salt stress imposes an immediate **osmotic challenge** to plants by decreasing soil water potential, thereby limiting water availability for root uptake. This leads to reduced cell turgor, stomatal closure, and reduced leaf expansion, collectively resulting in stunted growth and wilting (van Zelm *et al*., 2023). Studies on wheat and barley have demonstrated that water-deficit symptoms appear within hours of exposure to saline conditions, underscoring the rapidity of osmotic effects (Zhu *et al*., 2023).

2.3.2 Ion Toxicity

With continued exposure, Na^+ and Cl^- accumulate in plant tissues, disrupting the balance of essential ions like K^+, Ca^{2+}, and Mg^{2+}. This ion imbalance impairs key cellular functions—such as enzyme activity, membrane stability, and photosynthesis—and may generate nutrient deficiencies (Ma *et al*., 2022). Excess sodium in the cytoplasm can also depolarize membranes and interfere with signal transduction pathways (Ma *et al*., 2022; Yang and Guo, 2024).

2.3.3 Oxidative Stress

Salt-induced osmotic and ionic stress often trigger the overproduction of **reactive oxygen species (ROS)**—such as superoxide (O_2^-), hydrogen peroxide (H_2O_2), and hydroxyl radicals (·OH)—which damage lipids, proteins, and nucleic acids (Jiang et al., 2020; Ullah et al., 2023). Excess ROS levels overwhelm detoxification mechanisms, leading to cellular injury (Ullah et al., 2023). Plants counteract this via **antioxidant defenses**. Enzymes such as superoxide dismutase (SOD), catalase (CAT), and peroxidases (POD, APX) convert ROS into less harmful molecules (Xiao *et al*., 2022). These antioxidants are critical for maintaining redox homeostasis, and higher activities of SOD, CAT, and APX have been observed in salt-tolerant plants (Xiao *et al*., 2022; Ullah *et al*., 2023).

2.4 PLANT RESPONSES TO SALT STRESS

Plants have evolved several adaptive responses to survive in salt-stressed environments. These responses are often categorized into **morphological, physiological, and biochemical mechanisms**, which collectively help the plant maintain cellular homeostasis and minimize damage from stress conditions.

2.4.1 Morphological Adaptations

Under salt stress, plants often exhibit reduced shoot length, smaller leaves, shorter internodes, and inhibited root development. In legumes such as beans, salt stress induces morphological changes like **thicker leaf cuticles**, **increased root-to-shoot ratios**, and **reduced nodule formation**, all of which help in conserving water and enhancing stress tolerance (Rai *et al*., 2021). Morphological traits like root hair elongation or proliferation may improve water uptake from saline soils.

2.4.2 Physiological Adaptations

Salt stress affects **stomatal conductance**, **transpiration rate**, and **photosynthetic efficiency**. To conserve water, plants reduce stomatal opening, limiting gas exchange, but consequently also reducing photosynthesis (Munns and Tester, 2008). Salt-affected plants may also accumulate compatible solutes like **proline** and **glycine betaine**, which maintain osmotic balance and stabilize proteins and membranes (Ashraf and Foolad, 2007).

Leguminous crops like beans may also alter water potential through osmotic adjustment. The accumulation of ions like **K^+ and Ca^{2+}** helps in preserving cell turgor and maintaining enzyme function despite ion toxicity caused by Na^+ and Cl^- intrusion (Farooq *et al*., 2015).

2.4.3 Biochemical Adaptations

Biochemical responses include the upregulation of **antioxidant enzymes** such as **superoxide dismutase (SOD)**, **catalase (CAT)**, and **peroxidases (POD)**, which detoxify reactive oxygen species (ROS) generated under salt stress (Mittler, 2002). Furthermore, the production of **osmolytes** like **sugars**, **polyols**, and **proline** help stabilize proteins and membranes and protect against dehydration (Parida and Das, 2005).

2.5 IMPACT OF SALT STRESS ON CROP GROWTH AND YIELD

Salt stress significantly reduces **crop biomass**, **flowering**, **fruit set**, and **yield**. In beans, high salinity affects **germination rates**, **pod development**, and **seed quality**. Salinity inhibits nutrient uptake (particularly nitrogen and phosphorus), causing metabolic imbalances and disrupting hormonal signals involved in flowering and seed development (Khan *et al*., 2021). Studies have shown that sodium chloride (NaCl) stress can reduce seed yield by up to 50% in common beans (Benidire *et al*., 2019).

Additionally, high salt concentrations alter root architecture and decrease root length, limiting water and nutrient absorption (Zhu, 2001). This stress also disturbs ion homeostasis by increasing Na^+ and Cl^- concentrations in tissues, which can inhibit cell division and elongation (Munns and Tester, 2008).

2.6 EFFECTS OF SALT STRESS

Salt stress affects not only the physical but also the chemical composition of legumes, thereby influencing **nutritional value**, **storage quality**, and **marketability**.

2.6.1 Effects on Moisture Content

Salinity can reduce water absorption, resulting in lower moisture content in seeds (Gadallah, 1999). This can affect seed viability and storage longevity.

2.6.2 Effects on Crude Protein Content

Protein synthesis is sensitive to salt-induced nitrogen metabolism disruption. Beans grown under NaCl stress typically exhibit reduced crude protein levels due to impaired uptake and assimilation of nitrate and ammonium ions (Ashraf and Harris, 2004). Studies indicated a 10–20% decline in protein content under high salt conditions.

2.6.3 Effects on Crude Fat Content

Salt stress tends to lower lipid synthesis by inhibiting acetyl-CoA carboxylase activity, thus reducing crude fat levels in legumes (Hussein and El-Masry, 2012). This reduction could affect caloric content and storage.

2.6.4 Effects on Ash Content (Mineral Composition)

Ash content often increases under salt stress due to ion accumulation (particularly Na^+ and Cl^-) in plant tissues, but this can be at the expense of essential micronutrients like **Mg^{2+}**, **Ca^{2+}**, and **Fe^{2+}**, leading to hidden nutritional deficiencies (Fageria *et al*., 2011).

2.6.5 Effects on Crude Fiber Content

Studies suggest a potential increase in fiber content due to increased lignification of cell walls under osmotic stress, which can enhance physical barriers against further damage (Abd El-Samad *et al*., 2010).

2.6.6 Effects on Carbohydrate Content

Carbohydrates may either increase due to stress-induced accumulation of soluble sugars or decrease if photosynthesis is severely impaired. These changes are cultivar-dependent and influenced by stress duration and severity (Farooq *et al*., 2015).

2.7 OVERVIEW OF THE GERMINATION PARAMETER TECHNIQUES

Germination parameter are the quantifiable metrics used to describe the speed, extent and uniformity of the germination process. It also helps to determine the major nutritional components of food, including moisture, ash, crude protein, crude fat, crude fiber, and carbohydrate content. These metrics help assess the nutritional quality of beans grown under salt stress.

2.7.1 Moisture Determination

Done via oven-drying method at 105°C until constant weight is achieved (AOAC, 2019). Moisture affects storage and shelf life.

2.7.2 Ash Determination

Involves incinerating the sample at 550°C to quantify total mineral content.

2.7.3 Crude Protein Determination (Kjeldahl Method)

This method estimates nitrogen content, multiplied by a factor (usually 6.25) to estimate crude protein.

2.7.4 Crude Fat Determination (Soxhlet Extraction)

Uses petroleum ether or other organic solvents to extract fats.

2.7.5 Crude Fiber Determination

Involves digestion with acid and alkali to estimate indigestible cell wall materials.

2.7.6 Carbohydrate Determination (By Difference)

Calculated by subtracting the sum of other components from 100%.

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

This project work was carried out in the laboratory at the National Space Research Laboratory at the early stages of germination and while it was in the nursery. It was later transferred outside to a nearby empty field where it grew to maturity.

During the early stages, it was kept in an incubation room where it received adequate aeration, sunlight, humidity and water mixed with the different salt concentrations (salt solutions) were added to the appropriate Petri dish containing the beans to be grown.

3.2 EXPERIMENTAL GROUPS AND DESIGN

3.2.1 EXPERIMENTAL GROUPS

1. Control Group: This group contained only water and was used as a baseline for the experiment.
2. NaCl Treatment Groups: This group consisted of different concentrations of NaCl which were 100ppm, 500ppm and 1000ppm respectively.
3. KCl Treatment Groups: This group consisted of different concentrations of KCl; which were 100ppm, 500ppm and 1000ppm respectively.
4. $NaHCO_3$ Treatment Groups: This group consisted of different concentrations of $NaHCO_3$ which were 100ppm and 100ppm, 1000ppm respectively.

3.2.2 EXPERIMENTAL DESIGN

The experimental design was completely randomized. Seeds were treated with different concentrations of growth stimulators (100 ppm, 500 ppm, and 1000 ppm) and distilled water as control.

Number of seeds used: 200 (20 seeds per treatment). The beans seeds was carefully selected and separated accordingly for each stimulator.

Priming method: Each batch of seeds was primed in 20ml of the respective prepared concentration for 1 hour before sowing.

The solutions were prepared.

Each growth stimulator was separately weighed and dissolved in 1000 ml of distilled water, prepared into 100 ppm, 500 ppm, and 1000 ppm concentrations, and labelled accordingly.

Planting: Cotton wool was placed at the base of sterilized petri dishes, and primed seeds were planted on them.

Replicates: Each treatment was replicated in 3 petri dishes, while distilled water treatment (control) was maintained in 1 petri dish.

3.3 MATERIALS, EQUIPMENT AND REAGENTS

3.3.1 Materials

100 healthy white beans

100 healthy brown beans

10 clean cans of bottle water

Beakers

Volumetric cylinder

10 Petri dishes

Razor blade

Cotton wool

Disposable hand gloves

Face mask

Loamy soil

Masking tape

Marker

Forceps

3.3.2 Equipment

Weighing balance

3.3.3 Reagents

Sodium chloride (NaCl)

Potassium chloride (KCl)

Sodium bicarbonate ($NaHCO_3$)

Distilled water

3.4 SAMPLE COLLECTION

The sample was purchased on the 6th of July from Ring-road in Benin City, Edo State. Nigeria. The reagents where provided by the laboratory.

3.5 METHODOLOGY

3.5.1 CULTIVATION: SEED PREPARATION AND POT PREPARATION

Healthy, viable and undamaged beans were selected. It was then soaked in the respective solutions of salt concentrations for an hour, after which it was sowed in the respective Petri dish containing cotton wool and little amount of the prepared salt solution was added to the Petri dish.

The seedlings were transferred to the nursery after five days(120 hours). The pot used for the nursery were clean plastic pots which were gotten from cut up water bottles. These plastics were cleaned and loamy soil was add to fill these cut up plastics pots. Water was then added to loosen the soil up a bit before transferring the seedlings.

3.6 MAINTENANCE AND THE APPROPRIATE GROWTH CONDITIONS

The plastic pots containing the growing seedlings were placed in an incubation room under controlled conditions. Maintaining appropriate temperature, humidity and photoperiod (about 12hours of sunlight daily).

Watering or irrigation was done using the prepared salt solutions and watering was done every two days (every 48hours) until the seedlings were transferred to the field.

3.7 REAGENT PREPARATION

To prepare 100ppm of each salt solution

100mg (0.1g) of each salt is dissolved in 1000ml of distilled water

So the required milligram or gram (mg/g) of salt to be dissolved in 250ml of distilled water will be,

0.1g = 1000ml

x = 250ml

Cross multiply

x = $\frac{25}{1000}$

x = 0.025g

To prepare 500ppm of each salt solution

500mg (0.5g) of each salt is dissolved in 1000ml of distilled water

So the required milligram or gram (mg/g) of salt to be dissolved in 250ml of distilled water will be,

0.5g = 1000ml

x = 250ml

Cross multiply

x = $\frac{125}{1000}$

x = 0.125g

To prepare 1000ppm of each salt solution

1000mg (1g) of each salt is dissolved in 1000ml of distilled water

So the required milligram or gram (mg/g) of salt to be dissolved in 250ml of distilled water will be,

1g = 1000ml

x = 250ml

Cross multiply

$$x = \frac{250}{1000}$$

$x = 0.25g$

3.8 SEED PRIMING

1. A total of Ten (10) beakers where prepared and labelled
2. (KCl 100ppm, 500ppm , 1000ppm , NaCl 100ppm, 500ppm and 1000ppm, and $NaHCO_3$ 100ppm, 500ppm and 1000ppm and Water (H_2O)).
3. A total of 200 viable seeds, (100 of brown and 100 of white beans) where picked and set apart and 20 seeds(10 of each variety), where placed in each beaker.
4. 20ml of each concentration(100ppm, 500ppm, 1000ppm) of the Reagents (KCl, NaCl and $NaHCO_3$) where poured into the beaker containing the seeds, and the seeds were left to prime for 30 minutes.
5. While the seeds where priming Ten (10) Petri dishes where prepared and labelled with each growth regulator and concentration respectively. Afterwards an appropriate amount of cottonwool was spread in each Petri dish to act as the base for the plant and a source of Carbon.
6. At the 30mins mark the seeds where implanted into the
7. Petri dished containing the cotton wool and the variety was separated in the Petri dishes.
8. Afterwards the growth was observed for a total of 120 hours.

Plate 1.3: An image showing the growing seedlings on a Petri dish at 48 hours.

Plate 1.4: An image showing the growing seedlings on a Petri dish at 72 hours.

Plate 1.5: An image showing the growing seedlings on a Petri dish at 120 hours.

3.9 TRANSPLANTING INTO NURSERY

Growing crops in a nursery is crucial because it offers a regulated setting where young plants may be closely tended to during their formative years. In the nursery, seedlings are given enough nutrients and water to support healthy growth while being shielded from inclement weather, pests, and illnesses. In addition to lowering the initial land and resource requirements, this approach guarantees consistent and robust seedlings and allows farmers to choose just the healthiest plants for field planting. In order to produce consistent and healthy bean seedlings for this experiment, a nursery was necessary. This allowed for a more precise evaluation of the effects of various growth regulators on germination and early growth.

1.A total of Ten (10) plastic bottles were cut in half and filled with sand to act as the nursery.

2. Water was used to soak the sand in the Nursery to prevent dryness and to aid the growth of the plant

3. Two seedlings each from each of the Concentration where transplanted into the nursery and allowed to grow for a total of 4 days before transferring into the Field.

Plate 2.1: An image showing the growing seedlings on the nursery material (cut plastic bottle).

3.9.1 FIELD PREPARATION AND TRANSPLANTING

Transplanting seedlings from the nursery to the main field is crucial because it allows plants to grow in wider spaces with adequate access to soil nutrients, water, and sunlight. This step ensures proper plant population, reduces competition among crops, and encourages stronger root establishment. By transplanting only healthy and well-developed seedlings, farmers increase the chances of better crop survival, higher yields, and improved overall productivity in the field. For this project, transplanting to the field was necessary to observe how the bean seedlings responded to natural conditions after initial nursery growth, and to evaluate the overall effect of the applied growth regulators on their survival, establishment, and performance under field conditions.

1. The field was first prepared by clearing and tilling the soil,
2. Each of the nursery bottle were watered before uprooting to soften the soil and reduce root damage.
3. Holes were dug and prepared in the field, and the seedlings were placed into the holes and soil was added to cover the roots and make ridges to prevent water logging.
4. Regular aftercare practices such as irrigation, weeding, and pest control were carried out to ensure proper growth and development.

Plate 2.2: An image showing recently transplanted seedlings in the field.

Plate 2.3: An image showing the beans spread after 50 days of transplanting.

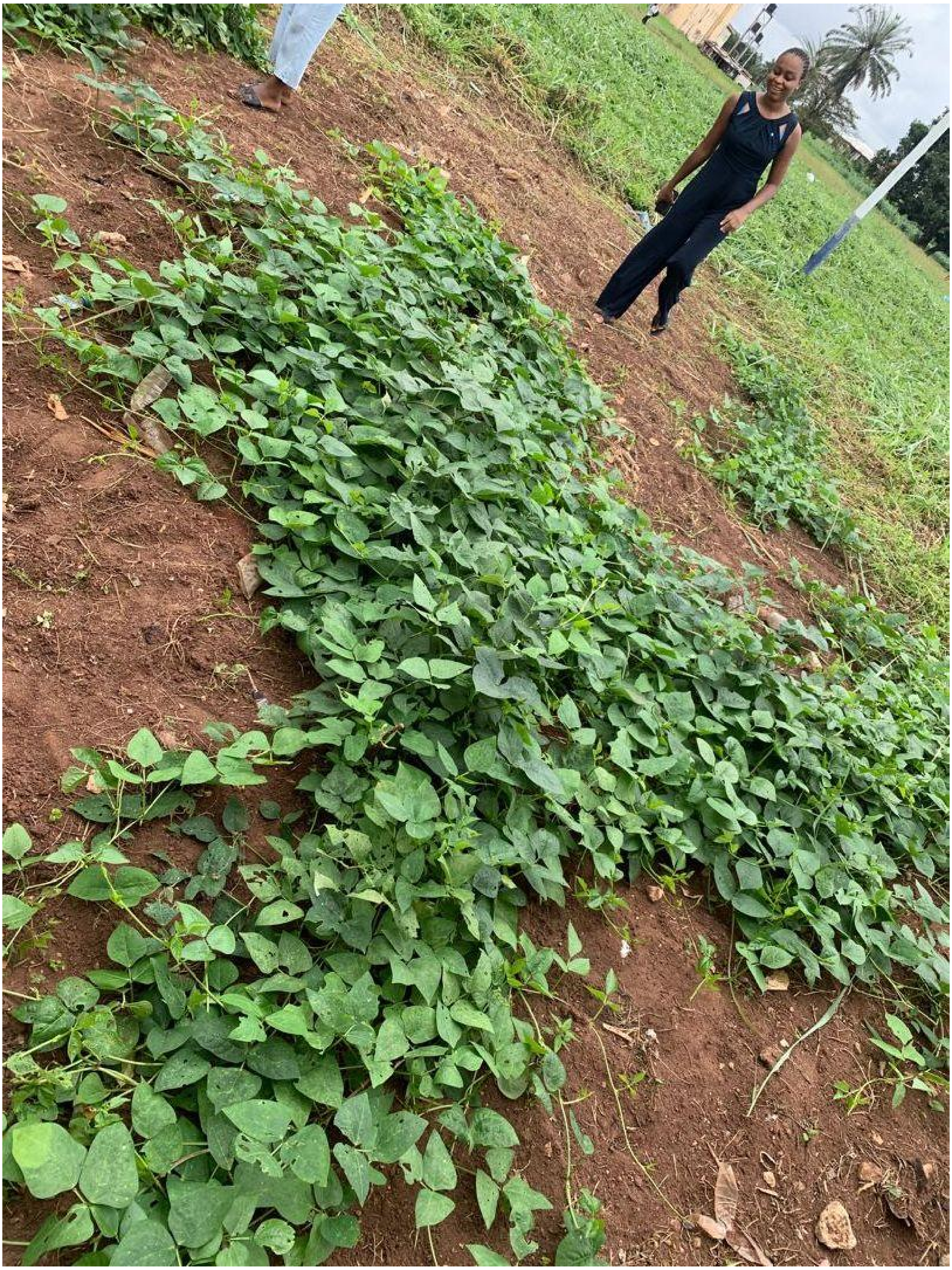

Plate 2.4: An image showing the beans spread after 2 months in the field.

Plate 2.5: An image showing the beans spread after 3 months in the field.

Plate 2.6: An image showing a flower blooming from the beans after 4 months in the field.

CHAPTER FOUR

RESULTS

4.1 **BRIEF OVERVIEW**

This chapter presents the results of the germination of common beans (Phaseolus vulgaris) stressed by several salt treatments; sodium bicarbonate ($NaHCO_3$), potassium chloride (KCl), and sodium chloride (NaCl). The results are arranged to show how each salt affects the nutritional makeup of the beans, as well as how much of each salt is present. For clarity, the results are displayed in tables and figures, together with statistical analysis to assess the importance of the discrepancies that were noticed. In contrast to the control group, the impacts on moisture content, biomass, root length, shoot length and more are described in depth in the sections that follow.

4.2 **GERMINATION RATE RESULTS**

Table 1.1 A table showing the germination rate results

Samples	No of germinated seeds	Shoot length(cm)	Root length(cm)	No of roots	Wet weight(g)	Biomass(g)	Moisture content
Water(CTR)bb	7	4.3	2.2	18	2.15	0.52	1.63
Water(CTR)wb	8	6	5.6	13	2.93	0.53	2.4
Kcl100ppm bb	10	6.1	6.8	13	2.8	0.69	2.11
Kcl100ppm wb	10	6	6.1	14	0.9	0.15	0.75
NaCl100ppm bb	10	7	2.3	13	1.31	0.37	0.94
NaCl100ppm wb	9	7.8	2.5	12	1.35	0.38	0.97
$NaHCO_3$100ppm	10	4.3	4.2	21	2.03	0.78	1.25

bb							
$NaHCO_3$100ppm wb	10	9.1	2.24	1	1.55	0.2	1.35
KCl500ppm bb	9	5.5	2.5	14	2.37	0.8	1.57
KCl500ppm wb	10	4.2	3	14	2.16	0.43	1.73
NaCl500ppm bb	8	6.4	3.3	25	1.46	0.47	0.99
NaCl500ppm wb	10	6	6.3	9	0.54	0.06	0.48
$NaHCO_3$500ppm bb	10	4.3	5	14	0.89	0.18	0.71
$NaHCO_3$500ppm wb	10	9.1	4.8	10	1.37	0.3	1.07
KCl1000ppm bb	10	3.4	1.7	15	1.13	0.23	0.9
KCl1000ppm wb	10	6.6	3.9	14	0.96	0.3	0.66
Nacl1000ppm bb	9	6.1	2.5	18	1.53	0.5	1.03
NaCl 1000ppm wb	9	6.8	4.4	9	0.61	0.19	0.42
$NaHCO_3$1000ppm bb	10	3.3	1.4	14	0.52	0.14	0.38
$NaHCO_3$1000ppm wb	9	4.2	3.2	11	2.23	0.05	2.18

KEY WORDS :

CTR= Water

KCl= Potassium chloride

NaCl= Sodium chloride

$NaHCO_3$= Sodium bicarbonate

bb = Brown beans

wb =White beans

NOTE: To get moisture content:

Wet weight – Biomass = Moisture content

For example;

In Kcl100ppm bb, the moisture content will be

2.8 – 0.69 = 2.11

Thus, 2.11 is the moisture content in Kcl100ppm bb

Also,

Biomass = Shoot dry weight + Root dry weight

OBSERVATIONS

1. At the 30 hours mark, 100ppm of KCl, 100ppm of NaCl, 100ppm of $NaHCO_3$ and 1000ppm of KCl showed significant increase in growth compared to the other seedlings.
2. At the 48 hours mark, leaves were visible in across all salt solutions and even water but the seedlings in Kcl had the most leaves. In KCl 6 seedlings sprouted and had leaves(5 white and 1 brown).
3. At the 120 hours mark, leaves were observed across all the salt concentrations except in 1000ppm of NaCl.

4.3 FIELD OBSERVATION RESULT

Table 1.2 A table showing the parameters gotten from the field observation

Samples	No of leaves	No of branches	Length of spread(cm)	Wet weight of spread	Dry weight of spread	Moisture content
Water	88	3	217	20.1	9.3	10.8
KCl	125	4	215.2	29.86	10.26	19.6
NaCl	36	1	126	16.92	4.68	12.24
$NaHCO_3$	66	3	196	14.94	2.78	12.16

KEY WORDS :
CTR= Water
KCl= Potassium chloride
NaCl= Sodium chloride
$NaHCO_3$= Sodium bicarbonate

Table 1.3 A table showing the number of pods produced from each sample of common beans

Samples	No of Pods
Water(CTR)	2
Kcl 100ppm	0
KCl 500ppm	1
KCl 1000ppm	1
NaCl 100ppm	0
NaCl 500ppm	1
NaCl 1000ppm	0
$NaHCO_3$ 100ppm	1
$NaHCO_3$ 500ppm	1
$NaHCO_3$1000ppm	1

KEY WORDS :
CTR= Water
KCl= Potassium chloride
NaCl= Sodium chloride
$NaHCO_3$= Sodium bicarbonate
bb = Brown beans
wb =White beans

Plate 3.1 An image showing the spread of the plant grown with NaCl concentration.

Plate 3.2 An image showing the spread of the plant grown with KCl concentration.

Plate 3.3 An image showing the spread of the plant grown with $NaHCO_3$ concentration.

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 DISCUSSION OF FINDINGS

This study investigated the effect of three different salt stressors on the germination of common beans (Phaseolus vulgaris): sodium bicarbonate ($NaHCO_3$), potassium chloride (KCl), and sodium chloride (NaCl). The principal aim was to ascertain and contrast the effects of these distinct salts, in differing concentrations, on the nutritional content of beans. Wide-ranging effects on food security and agriculture in saline-prone areas may result from the findings of this study, which provide important insight into how soil salinity (a major abiotic stressor) may alter the nutritional content of this staple crop.

To give a thorough grasp of the observed occurrences, the results in this discussion section are carefully reviewed and compared with the corpus of existing scientific literature. The fundamental processes by which these salts affect plant metabolism by combining the biochemical data on plant growth (shoot and root length, germination rate, and biomass) with the physiological data on plant germination (crude protein, crude fat, etc.) can be determined. The comparative effects of each salt will be carefully highlighted in the discussion, indicating whether osmotic stress, specific ion toxicity, or a mix of the two are principally responsible for the detrimental effects on nutritional quality. This section will conclude whether each goal was accomplished and offer a solid foundation for further research by interpreting the results in light of the study's initial aims and objectives.

5.1.1 INTERPRETATIONS OF RESULT

1. Seed Germination: In all treatments, both brown and white beans sprouted with 9–10 seeds sprouting in the majority of treatments. Although salts did not significantly hinder

germination in certain instances, greater doses (such as NaCl1000 ppm Wb = 9) marginally decreased germination.

2. Shoot Length: For the control (water), the shoot lengths were moderate (Bb = 4.3 cm; Wb = 6 cm). In fact, several treatments (such as NaCl100 ppm Wb = 7.8 cm and NaCl1000 ppm Wb = 6.6 cm) lengthened the shoots in comparison to the control. On the other hand, shoot length decreased in several high-salt environments (such as KCl1000 ppm Bb = 3.4 cm). The Conclusion is dependent on the type of salt and bean variety, the effects of salt stress vary. At moderate stress levels, white beans appear to be more resilient.

3. Root Length: With the exception of a few instances (e.g., NaCl1000 ppm Wb = 3.9 cm, higher than some lower levels), root development generally declined as salt concentration increased. This shows that salt stress inhibits root extension; controls had greater root lengths (2.2–5.6 cm) than several stressed samples.

4. Number of Roots: The number of roots, which ranged from 11 to 25 among treatments, was not significantly impacted. Extreme values, however, imply variation based on bean type and salt.

5. Wet and Dry Weight: The biomass of the control plants was higher (wet weight: 2.15-2.93 g). Biomass was often decreased by high salt stress, particularly dry weight (e.g., $NaHCO_3$ ppm Wb = 0.05g). Wet weight ($NaHCO_3$1000 ppm Bb = 0.52 g) was maintained or slightly increased by some treatments, indicating potential stress adaption.

NOTE:

Wb = White Beans

Bb = Brown Beans

Overall conclusion of result

Beans under salt stress have decreased biomass and root and shoot growth. Although white beans (wb) lose biomass under high stress but exhibit somewhat improved tolerance in terms of shoot length and germination under moderate stress. Under higher salt levels, brown beans (bb) are more susceptible, particularly in terms of shoot/root elongation. The effects of various salts vary:

- Dry weight was more significantly decreased by NaCl stress.
- Shoot length was significantly decreased by KCl stress at high concentrations.
- The effects of $NaHCO_3$ stress were less severe, and some biomass was preserved. This implies that under the measured conditions, $NaHCO_3$ is comparatively less toxic, whereas NaCl is the most hazardous salt.

5.2 CONCLUSION

This study examined how common beans (*Phaseolus vulgaris*) responded to salt stress caused by sodium chloride (NaCl), potassium chloride (KCl), and sodium bicarbonate ($NaHCO_3$) in terms of germination, growth and proximate composition. The results showed that the effects of salinity stress on seed germination, shoot and root development, biomass accumulation, and nutritional content were quantifiable. The most harmful stress was discovered to be NaCl, particularly at higher doses, which resulted in notable declines in biomass and proximate quality. Even while KCl stress was not as bad as NaCl stress, it nevertheless had a deleterious effect on shoot and root elongation at high concentrations. On the other hand, some treatments seemed to preserve biomass and proximate balance better than NaCl and KCl, suggesting that $NaHCO_3$ had somewhat weaker impacts. Differences across the varieties were also noted that white beans, especially in terms of germination and shoot growth, showed a comparatively higher tolerance to moderate salt concentrations than brown beans. This implies that managing bean cultivation in saline environments may be significantly influenced by varietal selection. In conclusion the conditions examined, salt stress has a detrimental effect on common bean productivity and nutritional quality, with NaCl being the most detrimental, KCl being somewhat detrimental, and $NaHCO_3$ being the least detrimental.

5.3 RECOMMENDATIONS

1. Varietal Selection: Although white bean varieties have demonstrated a comparatively higher tolerance to salt stress than brown bean types, farmers in saline-prone locations should give priority to growing them.

2. Soil and Water Management: Since sodium chloride was one of the most hazardous salt, steps should be made to prevent sodium buildup in soils. Some of them include diluting irrigation water to minimise salinity levels, adding gypsum as a soil amendment and ensuring correct drainage.

3. Seed Priming: Since moderate salt concentrations seemed to preserve or even enhance some growth factors, seed priming with lower concentrations of salts especially $NaHCO_3$ may be investigated as a management tactic.

4. Futher Research: To gain a better knowledge of the mechanisms underlying beans ability to withstand salt, future research should go beyond the germination factors to include micronutrients, anti-nutritional factors and biochemical reactions (e.g., enzyme activity, gene expression).

5. Policy and Extension Services: To maintain productivity, agricultural extension programs should inform farmers about the dangers of salinised soil and encourage adaptable techniques such crop rotation using salt-tolerant species and soil amendment techniques.

6. Scaling Up: Before widespread adoption, field-based experiments in Nigeria's various agro-ecological zones are advised to confirm these results in actual farming settings.

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