KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

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DEPARTMENT OF CROP AND SOIL SCIENCES

EFFECT OF SALINITY ON GROWTH AND YIELD OF SEVEN RICE (*ORIZA SATIVA L*) VARIETIES.

BY

BABA DRAMMEH

JULY, 2015

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI.

COLLEGE OFAGRICULTURE AND NATURAL RESOURCES

FACULTY OF AGRICULTURE

DEPARTMENT OF CROP AND SOIL SCIENCES

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A Thesis submitted to the Department of Crop and Soil Sciences,

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partial fulfillment of the requirement for the award of

Masters of Philosophy Degree in Agronomy

BY

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BSc. Hons. Agronomy Engineering (Havana University)

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DECLARATION

I certify that this dissertation, Effect of Salinity on Growth and Yield of Seven Rice Varieties (Oryza sativa L), is my own work and it has not been partly or wholly presented for any degree. All helps and references are duly acknowledged.

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ABSTRACT

A pot experiment was conducted at Crops Research Institute (CRI), Fumesua Kumasi, Ghana to evaluate the response of seven rice varieties (Sikamo, Gbewa Jasmine 85, Nerica L19, Tox 3377, Amankwatia, IR841 and Nerica/4) to different salt concentrations. Each pot was filled with 10kg of sterilized top-soil (of a ferric acrisol) obtained from the research field of the institute. The levels of salinity studied were: 0, 2, 4, and 6dS/m. The set up was a factorial experiment with treatments arranged in Completely Randomized Design. Each treatment was replicated four times. Ten seeds were sown per pot and seedlings were thinned to two per hill at two weeks after emergence. Saline treatments were imposed by irrigating each with water containing different concentrations of sodium chloride. The result showed that plant height and tiller production were significantly affected by soil salinity. Root biomass , however , was not affected by salinity. Rice grain yield and its components were all negatively affected by salinity. Under the conditions of this study, the rice varieties could tolerate up to salt concentration of 2dS/m.

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DEDICATION

This work is dedicated to my mother (Mama Samateh) and my lovely wife, (Aminata Samateh), who waited for me and took good care of my family during my study.

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CHAPTER ONE

1.0 INTRODUCTION

Rice is one of the main staple cereal food crops in most parts of Africa, and it accounts for 20 to 50% of total caloric consumption of many countries in the world. Rice is consumed by nearly one-half of the entire world population. It is a staple food especially in East, South East Asia, the Middle East and West Indies and it is becoming increasingly popular in Africa. Rice is one of the few foods in the world which is entirely non-allergenic and gluten-free (http://www.hungrymonster.com/foodfacts.cfm). Throughout history, rice has been one of man's most important food.

In Ghana Rice is cultivated as a sole crop and the ultimate objective of the farmer is to cultivate and feed the family (Nutsugha *et al.,* 2004).

Rice production in the Gambia is affected by various problems including weeds, pests and diseases. The high and increasing population growth rate in Africa has led to the high demand for rice in Sub Saharan Africa and its consumption is growing faster than that of any other staple food in Africa (WARDA, 2008). Between 2005 and 2008, the price of milled rice increased four-fold from US$250 to almost US$1000 per metric tonnes. Four out of the eleven largest rice importing countries in the world are within

Sub Saharan Africa with Nigeria as the world's largest importer (WARDA, 2007). In 2003, Ghana imported 415,150 metric tonnes representing 60% of the country's total rice consumption (LRAN, 2008). The Gambia also imports 175,000 tons annually representing 70% of total rice consumption (WOW, 2008).

This unique grain helps sustain two-thirds of the world's population. Rice is life for thousands of millions of people. It is deeply embedded in the cultural heritage of societies.

About 80% of the world's rice is produced by small-scale farmers which is consumed locally. Ninety five percent of the world's rice is grown by less developed countries, mostly in Asia (IRRI, 1995). Rice cultivation is the principal activity and source of income for about 100 million households in Asia and Africa (Sanint *et al.*,1998; IRRI, 2009).

Rice is naturally fat, cholesterol and sodium free. It is a complex carbohydrate containing only 103 calories per one-half-cup serving. It provides more than 50 percent of the daily calories ingested by more than half of the world population. It is so important in Asia that it influenced local language and beliefs. In classical Chinese, the same term refers to both rice and agriculture. Indeed, the words rice and food are sometimes one and the same in eastern semantics (UNCTAD, 2010).

Rice is grown on about 150 million hectares, more than 10% arable land of the world. Total world production exceeds 500 million tonnes of paddy (Chang, 2004). Food security, which is the condition of having enough food to provide adequate nutrition for a healthy life, is a critical issue in the developing world. About 3 billion people, nearly half of the world population, depend on rice for survival. In Asia as a whole, much of the population consume rice in every meal. In many countries, rice accounts for more than 70% of human caloric intake.

The percentage of total calorie intake contributed by rice varies widely between different regions. Just over 30% of all calories in Asia come from rice (http://www.patentlens.net>patentlens).

Beyond providing sustenance, rice plays an important cultural role in many countries. Products of the rice plant are used for a number of different purposes, such as fuel, thatching, industrial starch, and art works (http://www.patentlens.net/daisy/Rice genome/3649.html). The Asian varieties are high yielding and are used for medicinal purposes as well as food. According to Hartwell (1967), the seeds of the rice plant are used in folk medicine for breast cancers, tumors, warts, and stomach indurations. The flowers are dried as cosmetic and dentifrice in China; awns are used for treatment of jaundice in China (Duke and Ayensu, 1984). The stem is used for different conditions;: ash for discharges and wounds, sapraemia in Malaya; infusion of straw for dysentery, gout, and rheumatism. The husk is used for dysentery and considered tonic in China. Rice cakes are fried in camel's fat for hemorrhoids in China. Rice water is used for fluxes and ulcers and applied externally for gout with pepper in Malaya. Boiled rice is used for carbuncles in Malaya and poultice onto purulent tumors in the East Indies. The root is considered astringent, anhidrotic, and is decocted for anemia. Sprouts are used for poor appetite, dyspepsia, fullness of abdomen and chest, and weak spleen and stomach in China. The lye of charred stems (merang, Indonesia) is used as a hair wash and used internally as an abortifacient. In the Philippine Islands, an extract (tikitiki), rich in anti neurotic B1 vitamin, made of rice polishing, is used in treatment of infantile beriberi and for malnutrition in adults (Reed,1976).

Because of its importance in food security, income generation and political stability, the Food and Agricultural Organization (FAO) declared the year 2004 as the international year of rice (FAO, 2004).

Salinity is a major problem of rice production in The Gambia and it is affecting the farmers especially those who are on lowland areas. Two most important ions that induce salt stress in plants are $Na^+$and Cl^- Sodium is nonessential but beneficial element, whereas Cl^- is essential phytomicro nutrient (Marschner,1995). However, both are potentially toxic in excessive concentrations, triggering specific disorders and causing substantial damages to crops.

Under excessive Na^+ and Cl^- rhizosphere concentration (activity), there are competitive interactions with other nutrient ions (e.g. K^+, NO_3^-,$H_2PO_4^-$) for binding sites and transport proteins in root cells, and thereafter for (retranslocation, deposition and partitioning within the plant (Grattan and Grieve, 1999; Tester and Davenport, 2003;

White and Broadley, 2001). Significants enhanced uptake and accumulation of Na^+ and Cl^- accompanied with a decrease in K^+ concentration in the same tissues was obtained under moderate (60 mM) Na^+Cl^- salinity conditions, (Ondrasek *et al*., 2009a).

In the same studies, salinity stress reduced all vegetative parameters (e.g. number of strawberry runners by up to 7-fold and length of the longest runner by 3-fold), decreased total fruit yield (in radish by 35%, muskmelon by 50% and strawberry by

60%), accelerated leaf senescence and reduced the strawberry growing period by up to 22 days i.e. induced plant mortality after 65-day treatment with salinised (60 mM Na^+Cl^-) nutrient solution (Ondrasek *et al*., 2009).

Salinity is considered as one of important physical factors influencing rice production. Knowledge of salinity effects on rice seedling growth and yield components, would improve management practices in fields and increase our understanding of salt tolerance

mechanisms in rice. Most of the cultivated rice in the tropics are not tolerant to salinity conditions and greater portion of the cultivated areas are found in the salinity conditions. Salinity is one of the major factors affecting rice production throughout the world and this is primarily caused by salt water intrusion from the sea. The access to salt tolerance varieties is difficult because they are not common. The cost of salinity to agriculture is estimated conservatively to be about $US 12 billion per annum, and is expected to increase as soils are further affected (Ghassemi *et al.,*1995).

In order to increase the area under cultivation, salt tolerant varieties are needed. Farmers are facing difficulty in addressing salinity problem in their own environment. Providing tolerant varieties to salinity would enhance the productivity of the subsistence farmers and to increase their area under cultivation and improve their standard of living.

The main objective of the research was to evaluate and select salt tolerant rice varieties The specific objectives were:

i. to determine the effect of salinity on the growth and development of seven rice varieties.
ii. to determine the yield response of seven rice varieties to salinity.
iii. to establish the degree of salinity tolerance of the seven rice varieties.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of rice

Rice*, Oryza sativa*, is believed to be associated with wet, humid climate, though it is not a tropical plant. It is probably a descendent of wild grass that was most likely cultivated in the foothills of the far Eastern Himalayas . From where it spread to western and Northern India, to Afghanistan and Iran and south to Sri Lanka. The data of (2500 BC) has already been mentioned for Mohenjodarao, while in Sri Lanka rice was a major crop as early as 1000 BC The rice crop may well have been introduced to Greece and neighboring countries of Mediterranean by returning members of Alexander the Great's expedition to India in 324BC However, in all probability rice did not become an established crop in Europe until much later, perhaps, in 15th or 16th century (Dogara and Jumare, 2014). Rice grown in the Mediterranean region are japonicas while the rice grown in the Indian subcontinent are indicas. Rice also travelled from India to Madagascar and East Africa and then to countries of West Africa. Indica rice also spread eastward to Southeast Asia and north to China (Dogara and Jumare , 2014), perhaps (Khush, 1997). The japonica rice was most likely domesticated somewhere in northern parts of South East Asia or South China. It moved north to become a temperate japonica. From China, temperate japonicas were introduced in Korea and from Korea to Japan around the beginning of first century. In the hilly areas of Southeast Asia japonica rice were grown under upland culture as a component of shifting cultivation before the upland tribes moved into the lowlands and introduced the japonicas into lowland culture. From mainland Southeast Asia, both indica and japonica rice were introduced into Malaysia, Philippine, and Indonesia and from Philippines to Taiwan. Migrating Malays from

Indonesia introduced tropical japonicas into Madagascar in 5th or 6th century. Portuguese priests introduced the tropical japonicas from Indonesia into Guinea Bissau from where they spread to other West African countries. Thus, most of upland rice varieties grown in West Africa are tropical japonicas. The Portuguese also introduced tropical japonicas and lowland indicas to Brazil and Spanish people brought them to other Latin American countries. Thus, in Brazil today, most of the upland varieties are tropical japonicas and lowland varieties that belong to indica group **(**Dogara and Jumare , 2014).

2.2 Importance of Rice

Rice (*Oryza sativa* L.) is one of the most important food crops in the world considering the area under cultivation and the number of people depending on it. It is the principal food of nearly half of mankind. It is estimated that, 40% of the world's population use rice as a major source of energy. Globally, rice ranks second only to wheat in terms of area harvested, but in terms of importance as a food crop, rice provides more energy per hectare than any other cereal crop. At average world yields, a hectare of rice could sustain 5.7 persons for a year compared to 5.3 for maize and 4.1 for wheat (De Datta, 1981).

In order to meet the projected demand for rice, it has been estimated that global annual rice production needs to be increased from the present 560 million tons to 850 million tons by 2025 (Khush, 1997). This additional rice production has to come from either an expansion of the area cultivated to rice increasing yields or both. Expanding the area under rice cultivation is not an option for increasing rice production in many areas due to

the pressures of urbanization, industrialization, crop diversification and other economic factors (Tyagi and Mohanty, 2000). In Asia where 90% of the world's rice is produced, land area under rice is actually declining (Papademetriou, 2000). It is only in Africa and Latin America that suitable areas for rice production still remain under utilized. Hence most of the additional rice production has to come from land already under rice cultivation through yield improvement. Thus, increasing the efficiency of rice production systems through the judicious use of agrochemicals, irrigation and cultivars of rice better adapted to their cultivation environments may offer the only possibilities of meeting the forecast demand for rice in the future.

2.3 Production systems of rice and their associated abiotic stresses

Rice is cultivated in a wide range of ecosystems under varying temperatures and moisture regimes. The majority of rice ecotypes are semi-aquatic adapted to saturated soil conditions where it is difficult for other crop species to survive. Four major agroecosystems are generally recognized (Khush, 1997): (1) irrigated lowland rice, (2) rainfed lowland rice, (3) upland rice, and (4) flood-prone rice.

Irrigated lowland rice is grown in lowlands with an assured supply of water and the rice is grown in bonded fields with water control. Rainfed lowland rice, on the other hand, is grown in lowlands characterized by alternate flooding and drying as a result of seasonal rainfall patterns. Most of the rainfed lowlands are underdeveloped and lack proper water management. In contrast to lowland rice, upland rice is grown in free-draining soils where the water table is always below the rooting depth. Moisture comes entirely from rainfall.

Flood-prone rice is grown in low-lying lands close to rivers. In West Africa, flood-prone rice that is produced in coastal tidal swamps where the dominant vegetation is mangrove, is called mangrove swamp rice (WARDA, 1994). Salinity and other soil stresses restrict mangrove swamp rice production to small areas in some West

African countries. The relative importance of each of these production systems (irrigated lowland rice, rainfed lowland rice, upland rice and flood-prone rice) varies from one rice-producing region to the other. All these production systems are associated with different abiotic stresses such as drought, flooding, weed infestation, salinity, soil acidity and poor nutrient supply. More inputs are used in producing irrigated rice than in any of the other systems. As a result of this, the highest rice yields are recorded in irrigated fields. The lowest yields are found in upland rice production systems where high weed infestation, frequent droughts and poor nutrient supplies greatly limit rice yields (Manneh., 2004).

2.4 Constraints in rice production

Farmers lose an estimated average of 37% of their rice crop to pests and diseases every year. Rice pests are any organisms or microbes with the potential to reduce the yield or value of the rice crop (or of rice seeds). Rice pests include weeds, pathogens, insects, nematode, rodents, and birds (Thanh and Singh, 2006). A variety of factors can contribute to pest outbreaks, including climatic factors, improper irrigation, the overuse of insecticides and high rates of nitrogen, fertilizer application (Thanh and Singh, 2006).

Major rice diseases and pests such as sheath blight, blast, stem rot diseases and stem borer were perceived as most serious constraints ranking at number 1 and 2 by 8. and 78 per cent of respondents, respectively. Blast, bacterial sheath blight and stem borer were the major pests and diseases in the traditional Basmati belt. They caused sizable yield losses (Siddiq, 1994).

Salinity is one of the major problems that contribute significantly to yield reduction and restrict the expansion of cultivated area of rice in the sub-region (Siddiq,1994).

On average, 20% of the world's irrigated land is affected by salt, and this figure rises to 43% in countries such as Egypt, Iran and Argentina (Metternicht and Zinck, 2003).

2.5 Effect of salinity on physiological process in plants

Rice plants are relatively susceptible to soil salinity as an abiotic stresses, and NaCl is a major salt that causes this problem (Flowers, 2004; Gao *et al.,* 2007). Salt stress is one of the major obstacles affecting plant growth and crop productivity worldwide. To cope with salt stress, plants undergo a variety of changes from physiological adaptations to gene expression (Chinnusamy *et al.,* 2008).

Salinity affects a broad range of metabolic processes in plants and induces changes in contents and activities of many enzymes (Amirjani, 2012). As a result of ion imbalance and hyperosmotic stresses, which are primary effects of salt stress, secondary stresses such as oxidative damage may occur. Stress environment decreases carbon reduction by the Calvin cycle and decrease in oxidised NADP to serve as an electron acceptor in

photosynthesis. When ferrodoxin is over reduced during photosynthetic electron transfer, electrons may be transferred from photosystem I (PSI) to oxygen to form superoxide radicals (O_2) by the process called Mehler reaction, which triggers chain reactions that generate more aggressive reactive oxygen species (ROS). Any imbalance in the cellular redox homeostasis can be called as an oxidative stress and results in the production of ROS because of the univalent reduction of oxygen.

Salt stress increases the rate of production of ROS such as superoxide radical (O_27), hydrogen peroxide (H_2O_2), hydroxyl radical (OH), alkoxyl radical (RO) and singlet oxygen ($1O_2$) formation via enhanced leakage of electron to oxygen. It is already known that these cytotoxic ROS, which are also generated during metabolic processes in the mitochondria and peroxisomes, can destroy normal metabolism through oxidative damage of lipids, proteins and nucleic acids (Gueta-Dahan *et al*., 1997). Lipid peroxidation, induced by free radicals, is also important in membrane deterioration

(Demiral and Turkan, 2005; Mandhania *et al*., 2006).

Two plant processes that can be affected by salinity are water relations and ionic relations. During initial exposure to salinity, plants experience water stress, which in turn reduces leaf expansion. During long-term exposure to salinity, plants experience ionic stress, which can lead to premature senescence of adult leaves. The problem is compounded by mineral deficiencies (Zn and P) and toxicities (Fe, Al, and organic acids), submergence, (deep water) and drought (Gregorio *et al*., 2002). Thus, the photosynthetic area available to support continued growth is reduced (Cramer and Nowak 1992). Reduced photosynthesis with increasing salinity is attributed to either stomatal closure, leading to a reduction in intracellular CO_2 partial pressure, or nonstomatal factors (Bethke and Drew

1992). There are evidences showing that salinity changes photosynthetic parameters, including osmotic and leaf water potential, transpiration rate, leaf temperature, and leaf relative water content (RWC). Salt also affects photosynthetic components such as enzymes, chlorophylls and carotenoids.

Changes in these parameters depend on the severity and duration of stress (Misra *et al*., 1997) and on plant species (Dubey, 1994).

Photosystem II (PSII) is believed to play a key role in the response of photosynthesis to environmental perturbations (Baker, 1991). The effects of salinity stress on PSII have been studied extensively. However, the data on the effects of salinity stress on PSII photochemistry are conflicting. Some studies have shown that salt stress could inhibit PSII activity (Hasegawa *et al*., 2000; Munns, 2002; Ashraf and Shahbaz, 2003; Ashraf, 2004), while others have indicated that salinity has no effect on this parameter (Abadıa *et al*., 1999).

2.6 Salinization and loss of crop land

Salinity is becoming a serious problem in several parts of the world. The saline area is three times larger than land used for agriculture (Binzel and Reuveni, 1994). It is one of the key environmental factors that limit crop growth and agricultural productivity. Total area under salinity is about 953 million ha covering about 8% of the land surface (Szabolcs, 1979; Singh, 2009). Several physiological pathways, that is photosynthesis, respiration, nitrogen fixation and carbohydrate metabolism have been observed to be affected by high salinity (Chen *et al.,* 2008). The global extent of primary salt-affected

soils is about 955 M ha, while secondary salinization affected some 77 M ha, with 50% of these in irrigated areas (Metternichi and Zinck, 2003).

Salinity is a major problem over a vast area in South and South-East Asia. In India 20.2, Indonesia 13.21, Malaysia 4.58, Bangladesh 2.85 and Thailand 1.46 million ha is affected by salinity (Hakim *et al.,* 2010). On the other hand, in arid and semi-arid regions, limited water and hot-dry climates frequently cause salinity problem that limit or prevent crop production.

There are two types of salinity which can occur example: primary and secondary either naturally or coursing from the human activities.

Salinized soils are generated by both natural and artificial factors. In arid and semi-arid regions, soil salinization is accelerated by capillary transport of salts to the ground surface from the water table, due to an imbalance of water loss through evaporation and water supply through precipitation. Agricultural activities by humans can also cause soil salinization. For example, improper management of irrigation and drainage systems can greatly increase salt accumulation in soils, because irrigation water contains soluble inorganic salts. In addition, cultivation in coastal areas may pose a risk of seawater contamination in irrigation water.

2.6.1 Primary Salinity

Primary salinity is a natural process that affects soils and waters and occurs generally in regions of the world where rainfall is insufficient to leach salts from the soil and evaporation or transpiration is high (McDowell, 2008). In episodes of high evaporation, transpiration and reduced rainfall, salinity becomes a problem as the volume of water

decreases while salt concentrations increase (Bridgman *et al.*, 2008). Approximately 1000 million hectares, which corresponds to seven per cent of the world's total land area, is affected to some extent by salt (Rose 2004). The majority of the globe's saline affected land is influenced by primary salinity resulting from natural soil evolution (Hlsebusch *et al*., 2007). Arid tropical areas, in particular, are subject to potential evaporation that is higher than rainfall, which leads to the rising of water to the topsoil where solutes accumulate and salinity can occur naturally (Hlsebusch *et al*., 2007). Australia's arid and semi-arid areas usually have salt present in the groundwater (Bridgman *et al.*, 2008). For example, the River Darling becomes saline during harsh drought periods and salinity concentrations increase in the Hunter Valley when flow diminishes (Bridgman *et al.*, 2008).

2.6.2 Secondary salinity

Soil and water salinization in the dry season is a problem for crop production in the coastal Secondary salinity is caused by man made changes to the hydrological cycle either through the replacement of native vegetation with shallow-rooted vegetation or through the excessive use or inefficient distribution of water in irrigation for agriculture (Beresford *et al.,* 2001; Rose, 2004). Modern anthropogenic land-use practices are increasing the area of salt-affected land, which is a major environmental issue (Bridgman *et al.*, 2008). Estimates of secondary salinity affecting the globe are suggested at around 74 million hectares, with 43 million hectares of that land occurring on irrigated land and the remaining area on non-irrigated land (Rose, 2004). In

Australia, areas of the Murray Basin and the Mallee region in Victoria (VIC) and New South Wales (NSW) are affected by dry land and irrigation salinity, while irrigation salinity impacts the Riverina Plain in VIC and NSW and the River land Region in South Australia (Beresford *et al*., 2001). Annually, around 1.8 million ha is subject to dry season salinity (Carew-Reid, 2007; MRC, 2010), of which around 1.3 million ha is affected by saline water above 5g/l. During low river flow periods between March and April, saline water intrudes up 40-50 km inland from estuaries through main river systems (White, 2002; Sam, 2006). Rice losses by salinity take place with both highyielding rice (in double or triple rice cropping systems) and traditional rice (in rice - shrimp rotational farming system). The rice damage by salinity becomes more severe in case of a drought in the early or late periods of the rainy season. The Vietnamese

Ministry of Agriculture and Rural Development (MARD, 2011) reported that, out of 650,000 ha of high-yielding rice grown in the lower delta, annually about 100,000 ha of rice is highly risky to dry-season salinity intrusion.

2.7 Effects of Salinity on Soil Physical Properties

Soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates. This process is known as flocculation and is beneficial in terms of soil aeration, root penetration, and root growth. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels, salinity can have negative and potentially lethal effects on plants. As a result, salinity cannot be

increased to maintain soil structure without considering potential impacts on plant health (Krista *et al.*, 2003).

Sodium, however has the opposite effect of salinity on soils. The primary physical processes associated with high sodium concentrations are soil dispersion of clay platelet and aggregate swelling.

2.8 Effect of salinity on the growth and development of rice

Generally rice has a life cycle of 3-7 months, depending on the environmental condition such as the climate (temperature, humidity and precipitation) and variety. Crops are often exposed to salinity immediately after planting in saline soil or in areas inundated by sea water or irrigated with brackish water. The major inhibitory effect of salinity on plant growth and development has been attributed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization. Nutritional imbalance caused by such ions leads to reduction in photosynthetic efficiency and other physiological disorders (Hakim *et al.,* 2010). At low concentrations, salt suppresses plant growth and at higher concentration can cause death (Michael *et al*., 2004). It has also been reported that under saline conditions, germination ability of seeds differ from one crop to another and even a significant variation is observed amongst the different varieties of the same crop (Maas et al Hoffman, 1986). Khan *et al*., (1997) observed that rice varieties showed a great variation in germination due to salinity effect.

2.9 Screening for salinity tolerance varieties

Rice is one of the most suitable crops for saline soils although it is usually considered moderately sensitive to salinity. Saline soil are usually under waterlogged conditions, other crops cannot grow in these areas except rice. Salt tolerance is generally a sustained growth of the plant in the soil environment impregnated with NaCl and other salt combination (Gregorio *et al*.,1997).

Salinity stress, caused by excess accumulation of salts mainly sodium ions (Na^+), can cause reductions in agricultural crop yields because most crops are susceptible to high salt concentrations in soil (Munns and Tester, 2008). Once soil salinity reaches critical thresholds that significantly reduce crop production, such cultivated lands are often abandoned by farmers because desalting soil is costly, and thus not a realistic approach for extensively salinized lands. Owing to the potential agricultural losses resulting from soil salinization, much attention has been paid to improvement of salinity tolerance in crops. Salinity stress affects various cellular processes, as indicated by alterations in the expression profiles of a variety of genes with divergent functions in response to high salinity. Primarily, salinity stress negatively affects plant growth through osmotic stress and ionic stress. Osmotic stress causes dehydration of plant cells because of the lower osmotic potential generated by high salt concentration in soils. Ionic stress induced by excess accumulation of Na^+ disrupts cellular ion homeostasis and metabolism. High Na^+ concentration in soils can also inhibit the absorption of potassium ions (K^+), an essential nutrient, by the roots (Ueda *et al*., 2013).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1. Location of the study

The experiment was conducted in pots at the Crops Research Institute (CRI) Fumesua Kumasi, Ghana. The area is approximately located on latitude 6º41' North and longitude 1º38' West. Rainfall pattern in Kumasi is bimodal with a mean 1484 mm (58.4 in) of rainfall per year, or 123.7 mm (4.9 in) per month, (http://www.kumasi.climatemps.com/)wet season is from March to July while the minor wet season occurs from September to November, the major dry season commence from mid-November to end of February.

There is a short dry season usually in August.

Temperature is uniformly high throughout the year. The lowest mean monthly temperature of about 24.6ºC is usually recorded in August and the highest mean monthly temperature of about 28.8ºC is recorded in February. Relative humidity is uniformly high at 89.00h throughout the year.

The annual evapo-transperation in Kumasi is about 1484mm with monthly value ranging from 107 to 144 mm in the major dry season and 71 to 118 mm in the rainy season (Mensah *et al.,* 2008)

3.2 Experimental Design

The experiment was factorial in Completely Randomized Design (CRD) with 7 varieties and 4 levels of salt concentration replicated 4 times. An area of $36m^2$ was used for the arrangement of the buckets.

3.3 Rice varieties and their characteristics

The following varieties used in the experiment were; Sikamo, Gbewa Jasmine 85, Amankwatia, Nerica L 19, IR841, Nerica/4, Tox 3377.gas shown in the Appendix 1.

All the varieties were obtained from CRI. The plants were grown in pots with dimension of 27cm high and 25cm top diameter. Ten kilograms of sterilized soil was placed in each bucket.

3.4 Soil used

The soil used for the experiment was sandy-clay loam,classified as Ferric Acrisols (Adu, 1992). The soil was collected near arboretum of the Crops Research Institute,

3.5 Soil sampling for laboratory analysis

Before filling the pots, soil sample was collected from the area to determine the physico-chemical properties. The sampling was done through the following procedure.

The area to be sampled was cleared and all surface debris (rocks and twigs) removed. An area of $4m^2$ was demarcated in the sampling place. A spade was used to cut into the soil to a depth of 0-40 cm and collected a column of soil. The samples were collected from three different places and mixed together to serve as composite sample. The sample was

labeled and taken to the laboratory for analysis of the following: pH, Organic Carbon, Organic Matter, Electrical Conductivity,, textural classification, nitrogen, phosphorus, potassium, calcium, magnesium, sodium, Aluminum^{+}, Hydrogen^{+}.

3.6 Soil preparation and pot filling

The soil was brought from the field to the laboratory and placed on white polythene sheet for air drying. The soil was air dried for 8 days and sieved through a 2.5 mm mesh. Ten kilograms (10 kg) of air dry soil was placed in each plastic bucket used for the experiment.

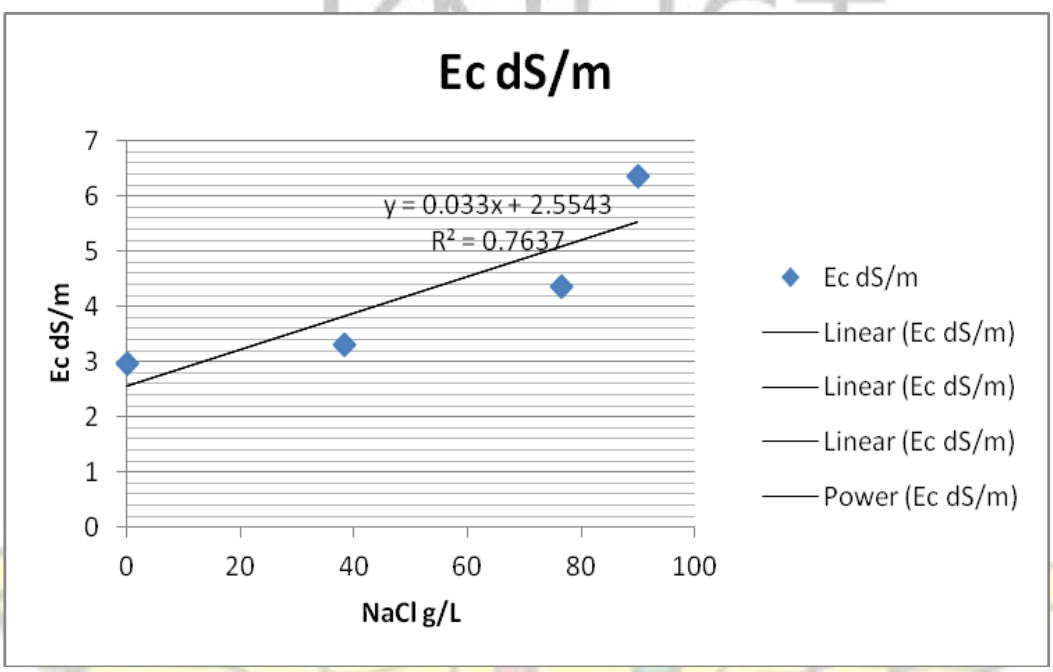
3.7 Nursery and transplanting of seedlings

Seedlings were raised on sterilized soil in pots. Each variety was planted separately in a pot for the period of 14 days. Ten seeds were sown in a pot for each variety. At the nursery, the plantlets were irrigated four times in a week. At 14 days after seeding, 2 seedlings were transplanted in each pot.

3.7.1 Fertilizer application

Urea fertilizer of 46% N was applied at the rate of 4g/pot at two weeks after transplanting. Compound fertilizer (N-P-K) 15-15-15 was applied at the rate of 4g/pot before transplanting. After seedling emergence, cultural practices were continued up to harvest. sodium chloride was applied 14 days after transplanting.

3.7.2 Calibration of Electrical Conductivity (EC) against sodium chloride concentration.



The calibration of sodium chloride NaCl against electrical conductivity EC was done by weighing 20g of soil for each level of salinity ($2dSm^{-1}$, $4dSm^{-1}$ and $6dSm^{-1}$). This was carried out to determine the electrical conductivity (EC) imposed by of the sodium chloride (NaCl) at different treatment concentrations.

A saturated paste was prepared by adding 7mm of water to each 20g of soil and stirred until the soil paste meets the saturation criteria, i.e. the soil paste glistens as it reflects light; flows slightly when the container was tipped; and slides freely and cleanly from a spatula except for those soils with high clay content. The mixture was covered and allowed to stand overnight. The saturation criteria were then rechecked using Eutect instrument. If the mixture fails to meet these criteria, more water or soil was added until

criteria were met. A saturated paste subsample was used to determine the moisture content, i.e., saturation percentage (SP). The temperature of the machine was at 25-26ºC during the process.

3.7.3 Soil pH

Soil pH was determined in 1:1 suspensions of soil and water using a pH meter. Twenty grams soil sample was weight into 100ml polythene bottles. To 20ml distilled water was added and the bottle shaken for two hours. After calibrating the pH meter with buffer solutions of pH 4.0 and 7.0, the pH was read by immersing the glass electrode into the upper part of the suspension.

3.7.4 Electrical Conductivity

Electrical conductivity was determined by using (EUTECH Instrument PC700) at a temperature of 25- 26ºC in saturated paste methods.

3.7.5 Organic Carbon

Organic C was determined by Nelson and Sommers modified Walkley-Black Wet oxidation method as outlined by Nelson and Sommers (1982). Two grams (2.00 g) of soil was weighed into 500 ml conical flask and 10 ml of 0.166 *M* (1.0 *N*) $K_2Cr_2O_7$ solution added, followed by 20 ml concentrated of H_2SO_4 and allowed to cool on an asbestos sheet for 30 minutes. Two hundred millimeters (200 ml) of distilled water was added followed by 10 ml of H_3PO_4 and then 1.0 ml of diphenylamine indicator solution. This mixture was then titrated with 1.0 *N* ferrous sulphate solution until the colour changed from a blue-

black coloration to a permanent greenish colour. A blank determination was carried out in a similar fashion in every batch of samples analysed without soil.

The formula below was used to calculate percent organic carbon:

$$\%C = \frac{N \times (V_{bl} - V_s) \times 0.003 \times 1.33 \times 100}{g}$$

where

N = Normality of $FeSO_4$ solution

V_{bl} = ml of $FeSO_4$ used for blank titration V_s

= ml of $FeSO_4$ used for sample titration g=

mass of soil taken in gram

0.003 = milli-equivalent weight of C in grams (12/4000)

1.33 = correction factor used to convert the Wet combustion C value to the true C value since the Wet combustion method is about 75 % efficient in estimating C value , (i.e. 100/75 = 1.33).

Organic matter content was determined using the formula:

% C X 1.724. (1.724 is the Conventional Van Bemellen factor)

3.7.6 Determination of Total Nitrogen

Total N was determined using the Kjeldahl digestion method. Ten (10) grams soil was weighed into a 500 ml Kjeldahl digestion flask and one spatula full of copper sulphate, sodium sulphate and selenium mixture followed by 30 ml of concentrated H_2SO_4 was added. The mixture was heated strongly to digest the soil to a permanent clear green

colour. The digest was cooled and transferred to a 100 ml volumetric flask and made up to the mark with distilled water. A 10 ml aliquot of the digest was transferred into a Tecator distillation flask and 20 ml of 40 % NaOH solution was added. Steam from a Foss Tecator apparatus was allowed to flow into the flask. The ammonium distilled was collected into a 250 ml flask containing 15 ml of 4 % boric acid with mixed indicator of bromocresol green and methyl red. The distillate was titrated with 0.1 N HCl solution. A blank digestion, distillation and titration were carried out without soil as a check against traces of nitrogen in the reagents and water used (Okelabo *et al*., 1993).

Calculation:

$$\%N = \frac{(a-b) \times 1.4 \times N \times V}{s \times t}$$

Where; a = ml HCl used for sample

titration b = ml HCl used for blank

titration

1.4 = 14 x 10^{-3} x 100 % (14 = atomic weight of N)

N= normality of HCl.

V = total volume of digest

S = mass of air dry soil sample taken for digestion in grams (10.0 g) t

= volume of aliquot taken for distillation (10.0 ml)

3.7.7 Determination of available phosphorous

Available P was determined using the (Bray P-1) method (Bray and Kurtz, 1945). Five

(5) grams of soil was weighed and placed into a 50 ml centrifuge tube. Thirty (30) ml of Bray-1 extracting solution (0.025 N HCl + 0.03N NH_4F) was added. Soil suspension was shaken for five minutes using a mechanical reciprocating shaker. The suspension was allowed to stand for 2 minutes and then centrifuged for 10 minutes at 3000 rpm. Working standards in Bray 1 extractant using 5 clean 250 ml volumetric flasks were prepared. Different concentrations (0, 2, 4, 8, 12, 16 and 20 ml) of stock 250 µg P / ml of KH_2PO_4 (A.R. grade) solution were pipetted into each 250 ml volumetric flask and made up to the 250 ml mark using Bray 1 solution. The working standards contain respectively 0, 1, 2, 4, 6, 8 and 10 µg P/ml in 250 ml volumetric flasks.

One (1.0) ml of the clear supernatant solution (sample), blank and the standard solutions were pipetted into a set of clean 15 ml centrifuge tubes. Six (6) ml of distilled water was added and mixture shaken vigorously followed by the addition of 2.0 ml of molybdateHCl reagent. Finally, 1.0 ml of 1.76 % solution of ascorbic acid (reducing reagent) was added to the mixture and was vigorously shaken. The mixture was allowed to stand undisturbed for 6 minutes for development of the blue coloration after which the percent transmittance values were recorded at 650 nm wavelength on a colorimeter or visible range spectrophotometer.

A graph of absorbance versus concentration (ppm) P was plotted. Read the unknown samples and obtain ppm P by interpolation on the graph plotted.

The P content was determined by comparing the recorded values to a standard curve plotted using standard P solutions after the percent transmittance (% T) was converted to absorbance by the formula:

Absorbance = 2- log T.

Calculation: ppm P (µg P / kg soil) = C* 30/6

Where;

C = concentration derived from the standard curve

30/6= volume of extractant/ dilution factor.

3.7.8 Exchangeable potassium and sodium

Ten (10.0) grams of soil was weighed into a 150 ml extraction bottle and 100 ml of 1.0 *N* NH_4AOc solution (pH=7.0) was added. This was shaken for 1 hour on a mechanical reciprocating shaker. Potassium and Na content were read by means of Jenway PFP 7 Flame Photometer after calibration with prepared K standards.(Moss, 1961)

3.7.9 Exchangeable Calcium and magnesium

Extraction of soil was done by 1.0 *N* Ammonium Acetate (pH=7.0) solution. Calcium titration was done by measuring 10 ml of the filtrate into a 250 mL conical flask, addition of 10 ml of 10 % KOH solution, 1.0 ml of 30 % triethanolamine, 3 drops of 2 % KCN solution and two drops of 0.4 % of calcon-red indicator in 99 % alcohol. The mixture was vigorously shaken and then titrated with 0.02 N EDTA solution to a pure blue endpoint colour.

Calcium and magnesium determination was carried out by measuring 10 ml of the filtrate into a 250 ml conical flask, followed by addition of 5 ml of ammonium chloride – ammonium fluoride buffer solution, 1.0 ml of 30 % triethanolamine, 3 drops of 2 %

KCN and one drop of 0.2 % of EBT (Eriochrome Black T) indicator in 99 % alcohol. Mixture was shaken vigorously and then titrated with 0.02 N EDTA to a pure turquoise blue endpoint colour.

Blank titrations were done in both titrations.

Calculation:

$$\text{Ca + Mg (or Ca) (cmol}_{+}\text{ / kg soil)} = \frac{0.02 \times (Va - Vb) \times 1000}{g}$$

Where

g = mass (g) of air dry soil used in the extraction

Va = ml of 0.02 N EDTA solution used in the sample titration

Vb = ml of 0.02 N EDTA solution used in the blank titration

0.02 = concentration of EDTA

1000 = conversion factor from g to $cmol_{+}$ / kg

3.7.10 Determination of exchangeable acidity (Al + H)

Three (3.0) grams of air-dried soil (siewed to pass a 2 mm mesh) was weighed into a folded filter paper (Whatman No. 42) placed on a funnel and positioned on the Erlenmeyer flask. Fifty (50) ml of 1.0 *N* KCl solution was gently poured through the soil in the filter paper and the leachate collected into the Erlenmeyer flask.

Five (5) drops of 0.1 % phenolphthalein in 99 % alcohol indicator was added to the leachate in the conical flask. This was titrated with 0.05 *N* NaOH to pink end point.

Volume (ml) of NaOH used (V) was recorded.

3.7.11 Exchangeable Aluminum.

Four (4.0) ml of 3.0 *N* NaF was added to the titrated extract in the Erlenmeyer flask. This mixture was shaken on a magnetic stirrer while being titrated with 0.05 *N* HCl to colourless end point and the volume (ml) of HCl used (V) recorded.

Calculations:

Exchangeable acidity (meg/100 g) = $\frac{V*0.05*100}{W} = V*1.67$

Where

V = Titre volume of NaOH used (ml)

Normality of NaOH = 0.05 *N*

W = weight of soil sample used = 3.0 g

Exchangeable aluminum (meg/100 g) = $\frac{V*0.05*100}{W} = V*1.67W$

Where

V = Titre volume of HCl used (ml)

Normality of HCl = 0.05 *N*

W = weight of soil sample used =3.0 g

3.7.12 Determination of Effective cation exchangeable capacity (ECEC*).*

Effective cation exchange capacity was determined by the sum of exchangeable bases (Ca^{2+}, Mg^{2+} K^{+} and Na^{+}) and exchangeable acidity (Al^{3+} and H^{+}).

3.7.13 Determination of Base Saturation

Per cent base saturation was determined by dividing total exchangeable bases **(TEB) by** effective cation exchange capacity **(ECEC**), multiplied by 100.

Calculation:

$$\%\ Base\ saturation = \frac{TEB * 100}{ECEC}$$

3.8 Plant Data Collected

3.8.1 Plant Population

Plant population was selected randomly after two weeks after transplanting each replication and 112 plant survived because by then sodium chloride was not applied to the plants.

3.8.2 Plant height

At 30, 60 and 90 days after transplanting (DAT), plant height was taken by measuring from the surface of the soil to the flag leaf of the plant. However, at 90 days after transplanting, the height was measured from the surface of the soil to last panicle of the plant.

3.8.3 Days to 50% booting.

Days to 50% booting was recorded when fifty percent of the plant booted.

3.8.4 Days to 50% flowering

Days to 50% flowering was recorded when fifty percent of a particular variety flowered

3.8.5 Plant population at harvest

Plant population at harvest was recorded by counting number of plants that survived at harvest.

3.8.6 100 grain weight

One hundred grain weight was recorded by weighing 100 seeds at moisture content of 12 to 13 % for each varieties. This was repeated three times to have mean of 100 grain weight.

3.8.7 Grain yield

The grain yield was observed by weighing the total seeds of each variety and recorded the mean.

3.8.9 Number of panicle/plant

Number of panicle was taken by counting the panicle on each plant. This was observed on all the plants in a particular variety and the mean was calculated.

3.9 Panicle length

Panicle length was measured using ruler from the base panicle to the tip of last grain on the panicle. This was taken at the level of all the replications and mean was calculated.

3.10 Roots biomass

Roots biomass for each treatment was recorded after oven drying the roots sampled at 60ºC for 48 hours. The sampled roots were placed in an envelope before putting in the oven. The sampling was done by random picking from each replication.

3.11 Number of tillers and productive tillers

Number of tillers was recorded at 30, 60 and 90 days after transplanting. This was done for each treatment and the mean was calculated. The productive tillers for each variety was counted at 90 days after transplanting.

3.12. Ranking rice varieties for their tolerance to salinity

This was carried out through visual observation in terms of tolerance of the varieties to salinity levels, notice was taken about their leaves, their heights, the tillers, their early booting and flowering. The tolerant ones maintained their leaves, tillers, flowers, height, and were booted early. The non-tolerant ones showed a reverse characteristics.

3.13 Statistical analysis

Analysis of variance was done and mean values of each attribute was compared using

Least Significant Difference (LSD) at 5% probability. This analysis was done using the Genstat statistical package.(12th edition).

CHAPTER FOUR

4.0 RESULTS

4.1 Initial soil analysis

The initial soil properties are presented in the Tables 4.1 below

Table 4.1a Initial chemical properties of the soil

								TEB	BS(%)	EC
				Exchangeable Cations cmol/kg						
pH	Org C(%)	Org M(%)	Total N(%)	K	Na	Ca	Mg	TEB	BS(%)	µS/cm
6.81	2.45	4.23	0.20	0.72	0.17	5.14	1.32	7.34	0.88	0.62

Table 4.1b continued. Initial chemical properties of soil and texture

Exchangeable Acidity				Soil texture(%)			Textural Class		
Al^+	H^+	ECEC cmol/kg soil	Available P mg/kg soil	Sandy	Silt	Clay			
0.5	0.51	8.35	5.9	57.28	14	28.72	Sandy	Clay	Loam

Table 4.1 (a and **b)** showed the results of the initial soil chemical properties taken from the depth 0-40cm used for the experiment. The tables shows that the initial soil reaction was slightly acidic (pH 6.81) and Calcium, Magnesium and Potassium concentration were low. The percent base saturation of the initial soil properties was 88%. The particle size analysis showed that the texture of the soil was sandy clay loam with initial value of organic carbon and organic matter, 2.45% and 4.23% respectively.

4.2 Final soil Analysis

Final soil properties shown in Tables 4.2a and 4.2b showed there was a reduction in final soil organic carbon, organic matter, soil pH and total nitrogen as compared to the initial soil properties (Table 4.1). The level of potassium increased; however, there was a decrease in calcium and magnesium as salinity increased. An increase in salinity showed an increase in sodium.(Table 4.2b)

Table 4.2a Final chemical properties of the soil

pH	% Organic	%Total	% Organic	Ex.Cation Capacity(cmol/kg)				TEB	Ex Acidity
H_2o	Carbon	Nitrogen	Matter	Ca	Mg	K	Na	cmol/kg	cmol/kg
5.24	1.63	0.14	2.80	4.01	0.80	0.31	0.21	5.33	0.60
5.3	1.70	0.14	2.93	3.96	0.90	0.28	0.20	5.34	0.60
5.28	1.65	0.14	2.84	4.00	0.85	0.31	0.20	5.36	0.60

Table 4.2b Continued. Final chemical properties of soil and texture

		Available (ppm)		Mec Analysis(%)			Texture	EC/dS/m
ECEC(cmol/kg	BS(%)	Bray 1						
		P	K	Sand	Clay	Silt		
5.93	89.88	56.11	118.64	63.88	2.06	34.1	sandy loam	291.6
5.94	89.90	55.98	120.34	62.45	2.13	35.4	Sandy loam	295.02
5.96	89.93	56.21	118.02	61.95	2.54	35.5	Sandy loam	290.78

4.3 Plant Height

Plants height results are presented in Table 4.3. The Nerica/4 variety were the tallest plants on all sampling days. At 30 DAT, its treatment effect was significantly higher than all the varieties but there were no significant difference among the remaining varieties. At 60 DAT, plant height of Nerica/4 was significantly taller ($p<0.05$) than that of the Gbewa Jasmine 85 variety, Amankwatia and IR841. All other varieties were similar in height. At 90 DAT, plants height of Nerica/4 was significantly ($p<0.05$) higher than those IR841, Amankwatia and Gbewa Jasmine 85 varieties. All other

varietal height effects were statistically similar.

For salinity of 2dS/m supported the tallest plants at 30 and 60 DAT sampling, but these effects were similar to the control treatment effect. Both the 2dS/m and control treatment effects were significantly higher than that of the 4dS/m salt concentration on both days. At 90 DAT, treatment effects of the control and 2dS/m salt concentration were similar, and both effects were significantly higher than 4dS/m concentration. Soon after NaCl application, plants in 6dS/m salt concentration could not survive.

Table 4.3 Plant height of rice plants of different varieties at different salinity levels at three sampling period.

	Plant height(cm) at		
Treatment	30 DAT	60DAT	90 DAT
Variety			
Sikamo	30.5	60.1	69.8
Gbewa J.85	32.9	51.6	52.9
Amankwatia	34.1	52.2	52.8
Nerica L19	37.8	58.6	58.6

IR841	34.4	53.2	53.2
Nerica/4	51.1	73.4	74.3
Tox 3377	37.9	63.7	65.2
LSD(0.05)	10.16	17.54	18.34
CV(%)	39.1	42.3	43.2
Salt levels(dS/m)			
0	61.9	89.6	97.9
2	64.3	95.7	96.9
4	21.6	50.6	51.8
6	0.0	0.0	0.0
LSD(0.05)	7.68	13.26	13.87
CV(%)	39.1	42.3	43.2

4.4 Number of tillers

As presented in Table 4.4, the number of tillers/plant at 30days after transplanting ranged from 8. to 12 The greatest number of tiller count was obtained from Nerica L 19 and Amankwatia varieties which effect was significantly higher than that of Tox 3377 variety only. All other treatment differences they were not significant at 5% probability. At 60 DAT, the Amankwatia variety produced the greatest number of tillers (23) and but this was significantly higher ($p<0.05$) than IR 841, Nerica/4 and Tox 3377 varieties only. The Nerica/4 variety produced the least number of tillers, and this was similar to IR 841 and Tox 3377 varietal effects. All other treatment differences were not significant.

Salt concentration affected tiller production on both sampling occasions. At 30 DAT, the control and concentration 2dS/m treatment effects were similar, which were significantly higher than treatment effects of 4dS/m and 6dS/m. Number of tillers supported by the 4dS/m concentration treatment was significantly higher than that of the 6dS/m treatment . At 60 DAT, number of tillers from 2dS/m was significantly higher than all other

treatment effects. The control treatment effect was also higher than those of 4 and 6dS/m treatments, whilst that of 4dS/m was also higher than that of the 6dS/m treatment.

Table 4.4 Effect of variety and salt concentration of rice tillers sampled over 2 periods

	Number of Tillers at	
Variety	30 DAT	60DAT
Treatment		
Sikamo	11	19
Gbewa J.85	11	20
Amankwatia	12	23
Nerica L19	12	20
IR841	9	15
Nerica/4	9	10
Tox 3377	8	11
LSD(0.05)	3.65	6.48
CV(%)	51.7	54.5
Salt levels(dS/m)		
0	18	24
2	18	30
4	4	12
6	0.0	0.0
LSD(0.05)	3	5
CV(%)	51.7	54.5

4.5 Plant population

Plant population at 2 WAT was not significantly ($p>0.05$) affected by rice variety or salt concentration (Table 4.5). However, plant population at harvest was significantly affected by both variety and salt concentration. Nerica L 19 variety had the greatest effect, which was significantly higher than those of Gbewa Jasmine 85 and Amankwatia varieties only. For salt concentration, the control treatment effect was the greatest, and

this was significantly higher than all other treatment effects, treatment effect of the 2dS/m concentration was also greater than that of the 4dS/m concentration.

Table 4.5 Plant population at two weeks after transplanting and at harvest

	Plant population per pot at	
Treatment	2 WAT	Harvest
Variety		
Sikamo	2	1
Gbewa J.85	2	1
Amankwatia	2	1
Nerica L19	2	1
IR841	2	1
Nerica/4	2	1
Tox 3377	2	1
LSD(0.05)	NS	0.25
CV(%)	0	45
Salt levels(dS/m)		
0	2	1.82
2	2	0.96
4	2	0.36
6	2	0.07
LSD(0.05)	NS	0.19
CV(%)	0	45

4.6 Yield Components Table 4.6 shows the yield and yield component of the seven rice varieties under

different salinity concentrations.

The number of panicle per plant was greatest in the Amankwatia variety, but this was significantly higher ($p<0.05$) than the treatment effect of IR841, Nerica/4 and TOX3377 varieties only. Furthermore, the treatment effect of Tox 3377 which was the lowest, was significantly lower than those of the Sikamo and Gbewa Jasmine 85 varieties. All other treatments effects were similar. Salinity level of 2dS/m and the control treatments

supported similar number of panicles per plant and both effects were significantly higher than those of 4 and 6dS/m salt concentrations. Treatment effects of 4 and 6dS/m salts concentrations were not significantly different.

The Nerica L19 produced the longest panicles, 17.96cm,(Table 4.6) and this was significantly higher than all other treatment effects. All other treatment effect were similar. Panicle length of the 2dS/m treatment was the longest and this was significantly higher than all other treatment effects. The control treatment effect was also significantly higher than that of the 6dS/m salt concentration.

The Nerica L19 variety recorded the greatest mean seed weight and this was significantly higher than all the treatment effects, except those of Nerica/4 and Tox3377 varieties (Table 4.6). The effect of the IR841 variety, which was lowest, was significantly lower than that of Nerica/4 variety. All other treatment differences were not significant. For salinity, treatment effects of the control and 2dS/m were similar and both effects were significantly higher ($p<0.05$) than those of 4 and 6dS/m treatments.

Additionally, the treatment effect of 4dS/m was also significantly higher than that of the 6dS/m concentration treatment.

In terms of grain yield there is no significant differences among the varieties (<0.05).

At salinity levels there is no significant differences between control and 2dS/m(<0.05). Treatments 4dS/m and 6dS/m supported similar yields, but their effects were significantly lower than those of the control and 2dS/m treatments.

Table 4.6 Yield components of seven rice varieties at four salinity levels

Treatment	Number panicles	Panicle length(cm)	100 grain weight (g)	seed Grain yield/pot
Variety	at harvest			

Sikamo	12	13.7	1.96	12.1
Gbewa J.85	12	10.06	1.94	7.5
Amankwatia	14	11.81	1.87	16.2
Nerica L19	11	17.96	2.96	10.8
IR841	10	10.84	1.84	10
Nerica/4	9	12.57	2.5	10.7
Tox 3377	7	12.14	2.44	3.6
LSD(0.05)	4.58	3.82	0.65	10.21
CV(%)	61.6	42.7	41.7	14.3
Salt levels(dS/m)				
0	17.25	21.71	3.98	16.5
2	20.5	24.42	3.99	22.8
4	3	4.01	0.78	1.1
6	1.57	0.75	0.11	0.2
LSD(0.05)	3.46	2.88	0.49	7.71
CV(%)	61.6	42.7	41.7	14.3

4.7 Number of days to booting and flowering

Varietal and salt concentration differences did not significantly ($p>0.05$) affect number of days to 50% booting and flowering (Table 4.7).

Table 4.7 Number of days to 50% booting and flowering of seven rice varieties at four salinity levels.

Treatment	Number of days to 50% booting	Number of days to 50% flowering
Variety Sikamo	53	60
Gbewa J.85	53	60
Amankwatia	53	60
Nerica L19	53	60
IR841	53	60
Nerica/4	50	57
Tox 3377	53	60

LSD(0.05)	NS	NS
CV(%)	0	0
Salt levels(dS/m)		
0	53	60
2	53	60
4	53	60
6	53	60
LSD(0.05)	NS	NS
CV(%)	0	0

4.8 Days to maturity and Root biomass

Days of maturity of the varieties are presented in the Table 4.8.

Variety Nerica/4 took the shortest days to mature and this was significantly ($p<0.05$) lower than all other varieties effects. All other treatment differences were not significant. Salt concentration did not affect days to maturity.

Both varieties and salt concentration did not affect root biomass ($p>0.05$) as shown in Table 4.8.

Table 4.8 Effects of variety and salt concentration of rice maturity and root biomass over two periods.

Treatment	Days to maturity	Root biomass(g)

Variety		
Sikamo	105	68
Gbewa J.85	105	76
Amankwatia	105	81
Nerica L19	105	82
IR841	105	82
Nerica/4	90.94	83
Tox 3377	104.06	60
LSD(0.05)	1.41	NS
CV(%)	1.9	43.1
Salt levels(dS/m)		
0	103	125
2	103	119
4	103	54
6	103	6
LSD(0.05)	NS	NS
CV(%)	1.9	43.1

CHAPTER FIVE

5.0 DISCUSSION

5.1 Soil composition

The results obtained from soil composition and chemical analysis showed significant reduction in soil pH, organic carbon, organic matter, calcium and magnesium and nitrogen, while an increase was observed in the Electrical conductivity (EC) and sodium concentrations from the initial soil sampled compared to the final soil sampled. This may be attributed to the application of sodium chloride in the case of soil, EC and exchangeable sodium and that of low nitrogen was caused by plant uptake and leaching. The decline of organic carbon and organic matter may be due to decomposition effect as observed at end of the experiment. According to Zepp *et al.* (2007) decomposition is the

process by which organic matter in (or on top of) the soil is converted into progressively smaller pieces and eventually inorganic compounds. With regards to the concentration of the elements in both samples nitrogen, calcium, potassium and magnesium concentrations were found to be generally very low as compared to optimum plant requirement for rice. Soils with organic carbon and nitrogen contents of

<2 and 0.1-0.2 respectively, are considered low (Landon, 1991).

5.2 Effect of salt concentration of growth of rice varieties.

The plant height was found to be significantly affected by salt concentration. The height of rice plant was observed to be reduced as salt concentration was increased from zero application to the application of salt at 6dS/m.

The rice plants tolerated salt concentration of 4dS/m beyond which the plants could not survive. The reduction of plant height at higher salt concentrations was related to the effect of salinity. This is in line with Yeo *et al*., (1990) who stated that the major inhibitory effect of salinity on plant growth and development has been attributed to osmotic inhibition of water availability as well as the toxic effect of salt ions responsible for salinization. Nutritional imbalance caused by such ions leads to reduction in photosynthetic efficiency and other physiological disorders. This is also in line with Akbar *et al.*(1972) who stated that earlier workers have reported reduction of plant height in rice under salt stress. Differential variation of tiller number under salt stress has also been reported. Rice plants are relatively susceptible to soil salinity as an abiotic stresses, and NaCl is a major salt that causes this problem (Flowers, 2004; Gao *et al*., 2007). Furthermore Neuman (1993), stated that when rice plants are exposed to high salinity

(NaCl>50 mM), they suffer a rapid and temporary drop in stomatal conductance and growth rate of rice.

The concentration of salt at different levels did not significantly affect the root biomass and days to 50% booting and flowering of the rice varieties tested. This is contrary to the findings of Rodriguez *et al.* (1997) who reported that rapid growth decline was observed at root level after stress imposition by NaCl

The effect of salt concentration on yield components such as tiller count, number of panicle, panicle length and 100 grain weight showed a declining trend with increase in salt concentration. The results obtained from this study is similar to that of Abdullah *et al.*, (2001) who stated that plant height, total number of tillers, panicle length, grain weight per panicle, 1000 seed weight and quality and quantity of grains decrease progressively with increase in salinity levels. This has indicated that at salt concentration above 4ds/m, the yield of rice is drastically reduced.

The higher concentration of salt in the solution may be facilited by the low concentration of calcium and magnesium in the soil as indicated above. According to Hanson *et al*., *(*1999) the three main problems caused by sodium-induce dispersion are reduced infiltration, reduce hydraulic conductivity, and surface crusting. Salts that contribute to salinity, such as calcium and magnesium do not have this effect because they are smaller and tend to cluster closer to clay particles. Calcium and magnesium will generally keep soil flocculated because they compete for the same spaces as sodium to bind to clay particles. Increased amounts of calcium and magnesium can reduce the amount of sodium-induce dispersion.

The effects of higher concentration of salt in this experiment could have been due to osmotic stress which may be the leading factor that caused significant reduction in yield component of the tested varieties. Wang and Han (2007), stated that osmotic stress causes dehydration of plant cells because of the lower osmotic potential generated by high salt concentration in soils. Ionic stress induced by excess accumulation of Na^+ disrupts cellular ion homeostasis and metabolism. High Na^+ concentration in soils can also inhibit the absorption of potassium ions (K^+), an essential nutrient, by the roots.

CHAPTER SIX

6.0 CONLUSSION AND RECOMMENDATIONS

6.1 Conclusions

The results of the study showed that salinity affected the growth of the varieties. Plant height and tiller production were significantly affected by soil salinity. Indeed, plants grown in the 6dS/m salt concentration could not survive. However root biomass was not affected by salinity. Grain yield and its component were also affected by salinity. Number of panicles, panicle length, mean seed weight and grain yield were all significantly influenced by salinity. In all these data, the control treatment and 2dS/m salt concentration produced similar effects, but their effects were significantly higher than the other salt concentration. The results indicate that the maximum salinity level to which the varieties used could tolerate was 2dS/m concentration.

6.2 Recommendations

It is recommended to make further research work on salinity levels on other rice varieties. The study recommend that the rice varieties studied these rice varieties should be produced at salt concentration of not more than 2dS/m for maximum growth and yield. Lastly, serious efforts must be employed to reduce or prevent soil salinisation because of its negative impact on crop growth and yield.

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Appendices

Appendix 1: Effect of salinity on varieties

Appendix 2: Salinity effect on rice varieties for their tolerance

Appendix 3: Rice varieties and their characteristics

	Gbewa jasmine	Nerica L 19	Amankwatia	Sikamo	Tox 3377	N/4	IR 841
Leaf blade attitude(early obersavation)	Erect	Erect	Erect	Erect	Erect	Erect	Erect
Plant height (cm)	130 intermediate	106 intermediate	130 intermediate	120 intermediate	125tall	115 intermediate	117 intermediate
Culm height (cm)	110 intermediate	74 shot	113 intermediate	91 short to intermediate	91 short to intermediate	85 short	83 short
Culm: underlying node color	Green	Light green	Green	Light green	Light green	Green	Light green
Flag leaf attitude late observation	Semi erect	Semi erect	Semi erect	Horizontal	Semi erect	Semi erect	Semi erect
Lemma color of appiculus	White	White	White	Red	White	Red	White
Panicle length (cm)	24	25	27	27	21	24	26
Panicle: attitude of main +axis	Semi upright	Semi upright	Slightly drooping	Slightly drooping	Semi upright	Semi upright	Semi upright
Panicle exsertion	well exserted	moderately exsetrd	well exserted	well exserted	well exserted	well exserted	just exserted

Panicle number	20	17	20	17		18	16
Panicle attitude of branching	semi-erect	semi-erect	Horizontal	Drooping	semi-erect	semi-erect	semi-erect
Panicle shattering	Very low <1%	Very low <1%	Low 3%	Very low <1%	moderate 15%	Very low <1%	Low 3%
Awn distribution	Awnless	Awnless	Awnless	Awnless	upper 3/4 only	Awnless	upper 3/4 only
Awn color					Whitish		Whitish
Lemma and paleapubersence	glabrous	Short hairs	Short hairs	Short hairs	Long hairs	Glabrous	Hairs on upper portion
Auricle color	Yellowish green	Yellowish green	Yellowish green	Yellowish green	Yellowish green	Whitish	Yellowish green
Antocynine coloration	Absent	Absent	Absent	Purple	Absent	Absent	Absent
Stigma color	White	White	White	Purple	White	White	White
Tiller number	21	18	22	17	17	20	17